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Internet of Things (IoT): A Literature Review

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Abstract - *Internet, a revolutionary invention, is always transforming into some new kind of hardware and software making it unavoidable for anyone. The form of communication that we see now is either human-human or human-device, but the Internet of Things (IoT) promises a great future for the internet where the type of communication is machine-machine (M2M).. The future is In-ternet of Things, which will transform the real world objects into intelligent virtual objects. The IoT aims to unify everything in our world under a common infrastructure, giving us not only con-trol of things around us, but also keeping us informed of the state of the things. In Light of this, present study addresses IoT concepts through systematic review of scholarly research papers, corporate white papers, professional discussions with experts and online databases. Moreover this research article focuses on definitions, geneses, basic requirements, characteristics and aliases of Internet of Things. The main objective of this paper is to provide an overview of Internet of Things, architectures, and vital technologies and their usages in our daily life. However, this manuscript will give good comprehension for the new researchers, who want to do research in this field of Internet of Things (Technological GOD) and facilitate knowledge accumulation in effi-ciently.*

Key Words: Internet of Things, IoT, RFID, IPv6, EPC, Barcode, Wi-Fi, Bluetooth, ZigBee, Sensors

1.INTRODUCTION

"The With the continuous advancements in technology a potential innovation, IoT is coming down the road which is burgeoning as an ubiquitous global computing network where everyone and everything will be connected to the Internet [1]. IoT is continually evolving and is a hot research topic where opportunities are infinite. Imaginations are boundless which have put it on the verge of reshaping the current form of internet into a modified and integrated version. The number of devices availing internet services is increasing every day and having all of them connected by wire or wireless will put a powerful source of information at our finger tips. The concept of enabling interaction between intelligent machinesis a cutting-edge technology but the technologies composing the IoT are not something new for us[2]. IoT,as you can guess by its name, is the approach of converging data obtained from different kinds of things to any virtual platform on existing Internet infrastructure[3].

The concept of IoT dates back to 1982 when a modified coke machine was connected to the Internet which was able to report the drinks contained and that whether the drinks were cold [4]. Later, in 1991, a contemporary vision of IoT in the form of ubiquitous computing was first given by Mark Weiser [5]. However in 1999, Bill Joy gave a clue about Device to Device communication in his taxonomy of internet[6] .In the very same year, Kevin Ashton proposed the term "Internet of Things" to describe a system of interconnected devices [7]. The basic idea of IoT is to allow autonomous exchange of useful information between invisibly embedded different uniquely identifiable real world devices around us, fueled by the leading technologies like Radio-Frequency IDentification (RFID) and Wireless Sensor Networks (WSNs) [2] which are sensed by the sensor devices and further processed for decision making, on the basis of which an automated action is performed [1]. The ability to code and track objects has allowed companies to become more efficient, speed up processes, reduce error, prevent theft, and incorporate complex and flexible organizational systems through IoT [8]. The IoT is a technological revolution that represents the future of computing and communications, and its development depends on dynamic technical innovation in a number of important fields, from wireless sensors to nanotechnology. They are going tag the each object for identifying, automating, monitoring and controlling.

2. Internet of Things

The Internet of Things is a novel paradigm shift in IT arena. The phrase "Internet of Things" which is also shortly well-known as IoT is coined from the two words i.e. the first word is "Internet" and the second word is "Things". The Internet is a global system of interconnected computer networks that use the standard Internet protocol suite (TCP/IP) to serve billions of users worldwide. It is a network of networks that consists of millions of private, public, academic, business, and government networks, of local to global scope, that are linked by a broad array of electronic, wireless and optical networking technologies [9]. Today more than 100 countries are linked into exchanges of data, news and opinions through Internet. According to Internet World Statistics, as of December 31, 2011 there was an estimated 2, 267, 233, 742 Internet users worldwide (Accessed data dated on 06/06/2013: from the Universal Resource Location http://www.webopedia.com/TERM/I/Internet.html). This signifies 32.7% of the world's total population is using

Internet. Even Internet is going into space through Cis-co's Internet Routing in Space (IRIS) program in the coming fourth years (Accessed on 10/05/2012: (http://www.cisco.com/web/strategy/government/space-routing. html). While coming to the Things that can be any object or person which can be distinguishable by the real world. Everyday objects include not only elec-tronic devices we encounter and use daily and technologically advanced products such as equipment and gadgets, but "things" that we do not do normally think of as electronic at all—such as food, clothing; and furniture; ma-terials, parts and equipment, merchandise and specialized items; landmarks, monuments and works of art and all the miscellany of commerce, culture and sophistication [10]. That means here things can be both living things like person, animals—cow, calf, dog, pigeons, rabbit etc., plants—mango tree, jasmine, banyan and so on and non-living things like chair, fridge, tube light, curtain, plate etc. any home appliances or industry apparatus. So at this point, things are real objects in this physical or material world.

2.1. Definitions

There is no unique definition available for Internet of Things that is acceptable by the world community of users. In fact, there are many different groups including academicians, researchers, practitioners, innovators, develo-pers and corporate people that have defined the term, although its initial use has been attributed to Kevin Ashton, an expert on digital innovation. What all of the definitions have in common is the idea that the first version of the Internet was about data created by people, while the next version is about data created by things. The best definition for the Internet of Things would be:

"An open and comprehensive network of intelligent objects that have the capacity to auto -organize, share information, data and resources, reacting and acting in face of situations and changes in the environment"

2.2. Vision

In 2005, ITU reported about a ubiquitous networking era in which all the networks are interconnected and everything from tires to attires will be a part of this huge network [11]. Imagine yourself doing an internet search for your watch you lost somewhere in your house. So this is the main vision of IoT, an environment where things are able to talk and their data can be processed to perform desired tasks through machine learning [12]. A practical implementation of IoT is demonstrated by a soon-to-be released Twine, a compact and low-power hardware working together with real-time web software to make this vision a reality [13]. However different people and organizations have their own different visions for the IoT [14]. An article published in Network World revealed IoT strategies of top IT vendors, they carried out some interviews from the key IT vendors. As of HP's vision, they see a world where people are always connected to their content. Cisco believes in the industrial automation and convergence of operational technology. Intel is focused on empowering billions of existing devices with intelligence. Microsoft does not consider IoT as any futuristic technology; they believe that it already exists in today's powerful devices and that the devices just need to be connected for a large amount of information which could be helpful. While, IBM has a vision of a Smarter Planetbyremotelycontrollingthedevicesviasecuredservers[15]. Despite of having different visions, they all agree about a network of interconnected devices therefore more developments within the coming decades are expected to be seen including that of a new converged information society [16].

2.3. Requirements

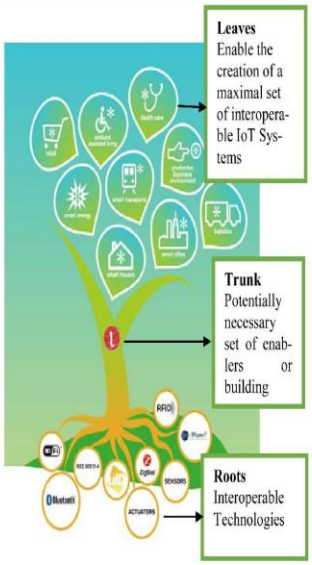
For successful implementation of Internet of Things (IoT), the prerequisites are (a) Dynamic resource demand (b) Real time needs (c) Exponential growth of demand (d) Availability of applications (e) Data protection and user privacy (f) Efficient power consumptions of applications (g) Execution of the applications near to end users (h) Access to an open and inter operable cloud system.
According to another author, there are three components, which required for seamless Internet of Things (IoT) computing (a) Hardware—composed of sensors, actuators, IP cameras, CCTV and embedded communication hardware (b) Middleware—on demand storage and computing tools for data analytics with cloud and Big Data Analytics (c) Presentation—easy to understand visualization and interpretation tools that can be designed for the different applications.

3. Architectures

One of the main problems with the IoT is that it is so vast and such a broad concept that there is no proposed, uniform architecture. In order for the idea of IoT to work, it must consist of an assortment of sensor, network, communications and computing technologies, amongst others [17]. Here, some of IoT architectures or models are given by several researchers, authors and practitioners.

3.1. European FP7 Research Project

This is to be used as a blueprint for IoT concrete architecture design; (2) Model: Architectural Reference Model (ARM); (3) Developed By: Project partners of the European FP7 Research Project IoT-A; (4) Derived From: Business considerations, application-based requirements and current technologies.



3.2. ITU Architecture

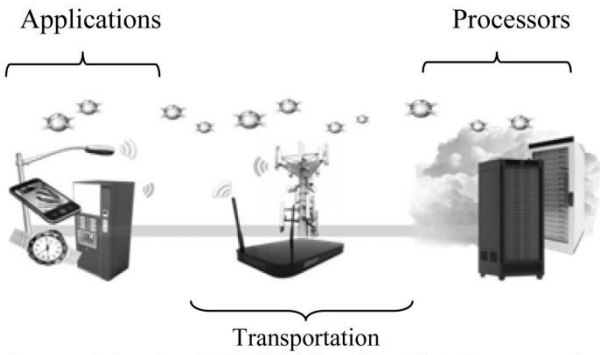
According to the recommendations of the International Telecommunication Union (ITU), the network, Archi-tecture of Internet of Things consists of

(a) The Sensing Layer
(b) The Access Layer
(c) The Network Layer
(d) The Middleware Layer
(e) The Application Layers

These are like the Open Systems Interconnection (OSI) reference model in network and data communication.

3.3. IoT Forum Architecture

The IoT Forum says that the Internet of Things Architecture is basically categorized into 3 types including Ap-plications, Processors and Transpiration.



Accessed dated on 2/09/2014 from http://iotaforum.com/.

3.4. Xu Cheng, Minghui Zhang, Fuquan Sun Architecture

A six-layered architecture was also proposed based on the network hierarchical structure [18]. So generally it's divided into six layers as shown in the Fig. 2. The six layers of IoT are described below:

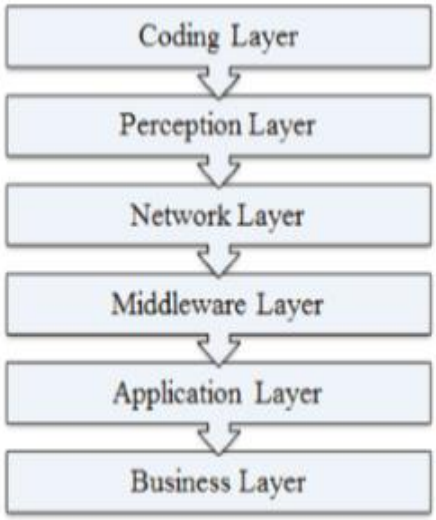


Fig. 3. Six-Layered Architecture of IoT

3.4.1.Coding Layer

Coding layer is the foundation of IoT which provides identification to the objects of interest. In this layer, each object is assigned a unique ID which makes it easy to discern the objects [18].

3.4.2.Perception Layer

This is the device layer of IoT which gives a physical meaning to each object.It consists of data sensors in different forms like RFID tags, IR sensors or other sensor networks [19] which could sense the temperature, humidity, speed and location etc of the objects. This layer gathers the useful information of the objects from the sensor devices linked with them and converts the information into digital signals which is then passed onto the Network Layer for further action.

3.4.3.Network Layer

The purpose of this layer is receive the useful information in the form of digital signals from the Perception Layer and transmit it to the processing systems in the Middleware Layer through the transmission mediums like WiFi,Bluetooth,WiMaX,Zigbee,GSM,3G etc with protocols like IPv4, IPv6, MQTT, DDS etc [20].

3.4.4.Middlware Layer

This layer processes the information received from the sensor devices [2]. It includes the technologies like Cloud computing, Ubiquitous computing which ensures a direct access to the database to store all the necessary information in it.Using some Intelligent Processing Equipment, the information is processed and a fully automated action is taken based on the processed results of the information.

3.4.5.Application Layer

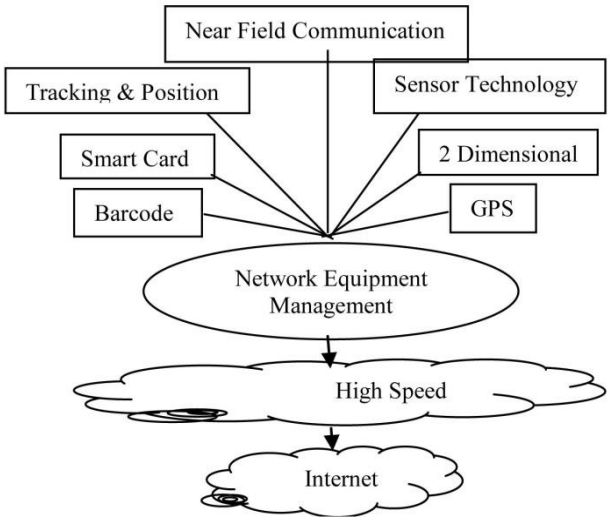
This layer realizes the applications of IoT for all kinds of industry, based on the processed data. Because applications promote the development of IoT so this layer is very helpful in the large scale development of IoT network [21]. The IoT related applications could be smart homes, smart transportation, smart planet etc.

3.4.6.Business Layer

This layer manages the applications and services of IoT and is responsible for all the research related to IoT. It generates different business models for effective business strategies [1].

3.5. Kun Han, Shurong Liu, Dacheng Zhang and Ying Han's (2012)'s Architecture

In "Initially Researches for the Development of SSME under the Background of IoT", the model is



4. Technologies

The Internet of Things [22] was initially inspired by members of the RFID community, who referred to the possibility of discovering information about a tagged object by browsing an internet address or database entry that corresponds to a particular RFID or Near Field Communication [23] technologies. In the research paper "Research and application on the smart home based on component technologies and Internet of Things", the included key technologies of IoT are RFID, the sensor technology, nano technology and intelligence embedded technology. Among them, RFID is the foundation and networking core of the construction of Internet of Things [24]. The Internet of Things (IoT) enabled users to bring physical objects into the sphere of cyber world. This was made possible by different tagging technologies like NFC, RFID and 2D barcode which allowed physical objects to be identified and referred over the internet [25]. IoT, which is integrated with Sensor Technology and Radio Frequency Technology, is the ubiquitous network based on the omnipresent hardware resources of Inter-net, is the Internet contents objects together. It is also a new wave of IT industry since the application of compu-ting fields, communication network and global roaming technology had been applied. It involves in addition to sophisticated technologies of computer and communication network outside, still including many new support-ing technologies of Internet of Things, such as collecting Information Technology, Remote Communication Technology, Remote Information Transmission Technology, Sea Measures Information Intelligence Analyzes and Controlling Technology etc. [26].

4.1. Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) is a system that transmits the identity of an object or person wirelessly using radio waves in the form of a serial number [27]. First use of RFID device was happened in 2nd world war in Brittan and it is used for Identify of Friend or Foe in 1948. Later RFID technology is founded at Auto-ID center in MIT in the year 1999. RFID technology plays an important role in IoT for solving identification issues of objects around us in a cost effective manner [28]. The technology is classified into three categories based on the method of power supply provision in Tags: Active RFID, Passive RFID and Semi Passive RFID. The main components of RFID are tag, reader, antenna, access controller, software and server. It is more reliable, efficient, secured, inexpensive and accurate. RFID has an extensive range of wireless applications such as distribution, tracing, patient monitoring, military apps etc. [29].

4.2. Internet Protocol (IP)

Internet Protocol (IP) is the primary network protocol used on the Internet, developed in 1970s. IP is the prin-cipal communications protocol in the Internet protocol suite for relaying datagrams across network boundaries. The two versions of Internet Protocol (IP) are in use: IPv4 and IPv6. Each version defines an IP address diffe-rently. Because of its prevalence, the generic term IP address typically still refers to the addresses defined by IPv4. There are five classes of

available IP ranges in IPv4: Class A, Class B, Class C, Class D and Class E, while only A, B, and C are commonly used. The actual protocol provides for 4.3 billion IPv4 addresses while the IPv6 will significantly augment the availability to 85,000 trillion addresses [30]. IPv6 is the 21st century In-ternet Protocol. This supports around for 2^{128} addresses.

4.3. Electronic Product Code (EPC)

Electronic Product Code (EPC) is a 64 bit or 98 bit code electronically recorded on an RFID tag and intended to design an improvement in the EPC barcode system. EPC code can store information about the type of EPC, unique serial number of product, its specifications, manufacturer information etc. EPC was developed by Auto-ID centre in MIT in 1999. EPCglobal Organisation [Wikipedia, "EPCglobal", 2010] which is responsible for standardization of Electronic Product Code (EPC) technology, created EPCglobal Network [Wikipedia, "EPCglobal Network", 2010] for sharing RFID information. It has four components namely Object Naming Service (ONS), EPC Discovery Service (EPCDS), EPC Information Services (EPCIS) and EPC Security Ser-vices (EPCSS).

4.4. Barcode

Barcode is just a different way of encoding numbers and letters by using combination of bars and spaces of va-rying width. Behind Bars [31] serves its original intent to be descriptive but is not critical. In The Bar Code Book, Palmer (1995) acknowledges that there are alternative methods of data entry techniques. Quick Response (QR) Codes the trademark for a type of matrix barcode first designed for the automotive industry in Japan. Bar codes are optical machine-readable labels attached to items that record information related to the item. Recently, the QR Code system has become popular outside the automotive industry due to its fast readability and greater storage capacity compared to standard. There are 3 types of barcodes of Alpha Numeric, Numeric and 2 Dimen-sional. Barcodes are designed to be machine readable. Usually they are read by laser scanners, they can also be read using a cameras.

4.5. Wireless Fidelity (Wi-Fi)

Wireless Fidelity (Wi- Fi) is a networking technology that allows computers and other devices to communicate over a wireless signal. Vic Hayes has been named as father of Wireless Fidelity. The precursor to Wi-Fi was in-vented in 1991 by NCR Corporation in Nieuwege in the Netherland. The first wireless products were brought on the market under the name WaveLAN with speeds of 1 Mbps to 2 Mbps. Today, there are nearly pervasive Wi-Fi that delivers the high speed Wireless Local Area Network (WLAN) connectivity to millions of offices, homes, and public locations such as hotels, cafes, and airports. The integration of Wi- Fi into notebooks, hand-helds and Consumer Electronics (CE) devices has accelerated the adoption of Wi-Fi to the point where it is nearly a default in these devices [32]. Technology contains any type of WLAN product support any of the IEEE 802.11 together with dual-band, 802.11a, 802.11b, 802.11g and 802.11n. Nowadays entire cities are becoming Wi-Fi corridors through wireless APs.

4.6 Bluetooth

Bluetooth wireless technology is an inexpensive, short-range radio technology that eliminates the need for pro-prietary cabling between devices such as notebook PCs, handheld PCs, PDAs, cameras, and printers and effec-tive range of 10 - 100 meters. And generally communicate at less than 1 Mbps and Bluetooth uses specifi- cation of IEEE 802.15.1 standard. At first in 1994 Ericson Mobile Communication company started project named "Bluetooth". It is used for creation of Personal Area Networks (PAN). A set of Bluetooth devices sharing a common channel for communication is called Piconet. This Piconet is capable of 2 - 8 devices at a time for data sharing, and that data may be text, picture, video and sound. The Bluetooth Special Interest Group comprises more than 1000 companies with Intel, Cisco, HP, Aruba, Intel, Ericson, IBM, Motorola and Toshiba.

4.7. ZigBee

ZigBee is one of the protocols developed for enhancing the features of wireless sensor networks. ZigBee tech-nology is created by the ZigBee Alliance which is founded in the year 2001. Characteristics of ZigBee are low cost, low data rate, relatively short transmission range, scalability, reliability, flexible protocol design. It is a low power wireless network protocol based on the IEEE 802.15.4 standard [33]. ZigBee has range of around 100 meters and a bandwidth of 250 kbps and the topologies that it works are star, cluster tree and mesh. It is widely used in home automation, digital agriculture, industrial controls, medical monitoring &power systems.

4.8. Near Filed Communication (NFC)

Near Field Communication (NFC) is a set of short-range wireless technology at 13.56 MHz, typically requiring a distance of 4 cm. NFC technology makes life easier and more convenient for consumers around the world by making it simpler to make transactions, exchange digital content, and connect electronic devices with a touch. Allows intuitive initialization of wireless networks and NFC is complementary to Bluetooth and 802.11 with their long distance capabilities at a distance circa up to 10 cm. It also works in dirty environment, does not re-quire line of sight, easy and simple connection method. It is first developed by

Philips and Sony companies. Da-ta exchange rate now days approximately 424 kbps. Power consumption during data reading in NFC is under 15ma.

4.10. Wireless Sensor Networks (WSN)

A WSN is a wireless network consisting of spatially distributed autonomous devices using sensors to coopera-tively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations (Wikipedia). Formed by hundreds or thousands of motes that communicate with each other and pass data along from one to another. A wireless sensor network is an important element in IoT paradigm. Sensor nodes may not have global ID because of the large amount of overhead and large number of sensors. WSN based on IoT has received remarkable attention in many areas, such as military, homeland secu-rity, healthcare, precision agriculture monitoring, manufacturing, habitat monitoring, forest fire and flood detec-tion and so on [34]. Sensors mounted to a patient's body are monitoring the responses to the medication, so that doctors can measure the effects of the medicines [35].

4.11. Artificial Intelligence (AI)

Artificial Intelligence refers to electronic environments that are sensitive and responsive to the presence of people. In an ambient intelligence world, devices work in concert to support people in carrying out their every- day life activities in easy, natural way using Information and Intelligence that is hidden in the network con-nected devices. It is characterized by the following systems of characteristics (1) Embedded: Many Net- worked devices are integrated in to the environment (2) Context Aware: These devices can recognize you and your situ-ational context (3) Personalized: They can be tailored to your needs (4) Adaptive: They can change in response to you (5) Anticipatory: They can anticipate your desires without conscious mediation.

5. Conclusions

IoT has been gradually bringing a sea of technological changes in our daily lives, which in turn helps to making our life simpler and more comfortable, though various technologies and applications. There is innumerable use-fulness of IoT applications into all the domains including medical, manufacturing, industrial, transportation, education, governance, mining, habitat etc. Though IoT has abundant benefits, there are some flaws in the IoT governance and implementation level. The key observations in the literature are that (1) There is no standard de-finition in worldwide (2) Universal standardizations are required in architectural level (3) Technologies are va-rying from vendor-vendor, so needs to be interoperable (4) For better global governance, we need to build stan-dard protocols. Let us hope future better IoT.

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