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Internet of Things (IoT): A Review of Literature

Dr. Kavitha Desai
Associate Professor, Dept of Management
Christ University,India,

Mahalakshmi S
Research Scholar, Dept of Management
University of Mysore, India,

Abstract

The Internet revolution has profoundly impacted our lives. Not only has it deeply changed the way businesses operate, but also the way we live. Today, we are witnessing a new technology and data-led transformation called Internet of Things (IoT) which is transforming almost every industry. It aims to unify everything in this world under one umbrella with which the things cannot just be controlled and monitored but the state of the thing could be known as well. In future Internet of Things transforms the real world objects into smart virtual objects allowing a seamless human-to machine and machine-to-machine communication. With this, present study addresses IoT concepts through methodical review of scholarly research papers, white papers and online databases. Besides this the research article focuses on definitions, chronology of IoT, pre-requisites for Internet of Things, provides an overview of IoT architectures, technologies, applications and the challenges faced in adopting it. The paper also revolves around the privacy and security aspect of Internet of Things which has rarely been discussed before. This paper helps in having a thorough understanding for beginners/researchers about the IoTconcepts.

Keywords- Internet of Things (IoT), seamless communication, smart virtual objects,privacy and security.

Introduction

Internet of Things is maturing and continues to be the state-of-the-art and most hyped concept in the IT world. Over the last decade the term Internet of Things (IoT) has attracted attention by projecting the vision of a global infrastructure of networked physical objects, enabling anytime, anyplace and

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anywhere connectivity [1]. Having said that with the power of advanced computing, new levels of connectivity, low-cost sensing and analytics allowed by the Internet, IoT is made possible and this interweaving of the digital world with the mechanical world brings a profound transformation to many facets of life [2]. It' combination of data access and data exchange that opens new prospects for IoT applications. Nearly half of Internet connections are already between or with things. While 2011 witnessed 15 billion things on the Web it is anticipated that by 2020, there will be over 30 billion connected things and this being enabled by Key technologies like embedded sensors, image recognition and NFC thereby making Internet of Things as Internet of Everything [3]. IoT is expected to offer classy connectivity that goes beyond machine-to-machine (M2M) communications [4]. Therefore IoTpromises to bring the real world and virtual world together. Cisco Internet Business Solution Group forecasts that 50 billion devices will be connected to Internet by 2020[5]. But with rapid advances in Internet technology, the connected device per person is also increasing. This research is conducted by considering the world population into account but considering the actual people connected to the Internet the number increases drastically.

The core components of IOT are [6]:

(a) **Hardware**: composed of sensors, actuators and embedded communication systems

(b) **Middleware**: on request storage mechanism and data analytical tools

(c) **Presentation:**visualization and interpretation tools which can be widely accessed across different platforms and applications

For the apprehension of a complete IoT vision an efficient, secure, scalable and market oriented computing and storage resourcing is a must [7].

Definition

IoT is an interconnection of exceptionally identifiable embedded computing devices within the existing Internet infrastructure, offering advanced connectivity of devices, systems, and services that goes beyond machine-to-machine communications and covers a variety of protocols, domains, and applications [8]"

ITU-T defines **Internet of things (IoT)** as a universal set-up for the information society, which enables interconnecting physical and virtual things based on current and future interoperable ICTs.

According to [9]IoT makes use of ICT to improvise the complex things like education, healthcare etc. more sensible, interactive and well organized.

Although there is no standard definition for Internet of Things an appropriate definition would be as stated below: "The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction."

Chronology of IoT

Accessed from URLs [10] dated on 18-Jan-18

The Internet of Things revolution was conceptualized way back in 1980s where the Members of the Carnegie-Mellon Computer Science department installed micro-switches in the Coke vending machine and connect them to the PDP-10 departmental computer so they could see on their computer terminals how many bottles were present in the machine and whether they were cold or not. Though the concept was applied the term "Internet of things" was coined only in the year1999.

1981: Steve Mann develops the first backpack-mounted "wearable personal computer-imaging system and lighting kit."

1991: Xerox PARC's Mark Weiser publishes "The Computer in the 21st Century" in Scientific American, using the term "ubiquitous computing" for the first time.

1999: The term Internet of Things was coined by Kevin Ashton of Auto-ID center at MIT and in the same year Electronic Product Code (EPC) was developed at Auto-ID center[20]

2000: LG announces the first of its kind Internet of refrigerators idea

2002: Chana Schoenberger and Bruce Upbinpublish "The Internet of Things" in Forbes where they insist on having a standardized way for computers to understand the real world and NY Times Magazine names IoT as one of the ideas of the year

2004: RFID was deployed on a massive scale in the defense and commercial world at US

2008: First ever European IoT conference is held and CISCO reported that the number of devices connected to the Internet exceeded the number of people on Earth thus paving way for the new era of Internet of Things

2011: New Internet protocol IPv6 was launched which can house 340,282,366,920,938,463,463,374,607,431,738,211,456(2^{128}) addresses

2012: Third international conference on Internet of Things (IoT2012) was held in Wuxi, China

2013: Computer scientists at MIT called it as "The year of internet of Things" **and Gartner forecasted that** IoT product and service suppliers would generate incremental revenue exceeding $300 billion, mostly in services, in 2020

2014: The IEEE World Forum on **Internet of Things 2014** was held at the Seoul Olympic Parktel Hotel in Seoul, Korea

2015: Forbes forecasts that Machine-to-machine (M2M) connections will grow from 5 billion at the beginning of this year to 27 billion by 2024

2016:2016 saw IoT begin to realize its potential. Its application in retail sector, power management, smart cities, health care and others started going deep roots

Architecture[11]

Standardization in the areas of architecture is more needed. Several researchers, authors and practitioners have proposed different architectures the uniformity is still missing. IEEE is working hard to overcome this issue by ensuring that the IPv6 packets can be routed across different network types [12]. Some of the IoT architectures are:

European FP7 Research Project: Interoperable IoT systems like retail, healthcare etc. are connected through internet with the interoperable technologies like RFID, ZigBee, Bluetooth, etc.

ITU Architecture: As recommended by the International Telecommunication Union (ITU), the architecture of Internet of Things is similar to the Open Systems Interconnection (OSI) reference model used in computer networks that consists of Sensing Layer, Access Layer, Network Layer, data Layer and Application Layers.

IoT Forum Architecture: According to the IoT Forum the Internet of Things Architecture is categorized into three types namely the applications, processors and transmission.

Qian Xiaocong, Zhang Jidong Architecture: According to this architecture three layers namely the perception layer, transportation layer and application layer needed for IoT.

IoTTechnologies

Radio Frequency Identification (RFID) [13]: It was the RFID application that gave rise to the concept of Internet of Things. Radio Frequency Identification (RFID) is a system that transmits the identity of an object wirelessly using radio waves. RFID comprises of a tag, an antenna, a reader, software and a server. It is low-priced, effective and secured thus making it reliable [14].

Internet Protocol (IP) Internet Protocol (IP) is the prime network protocol across the network. The two versions of Internet Protocol (IP) in use are: IPv4 and IPv6 as stated in Bicknell, IPv6 Internet Broken, and Verizon Route Prefix Length Policy 2009. The protocol provides for 4.3 billion IPv4 addresses while the IPv6 will significantly augment the availability to 85,000 trillion addresses. This supports around for 2128 addresses.

Electronic Product Code (EPC) Electronic Product Code (EPC) is a 64 bit or 98 bit code electronically recorded on an RFID tag. EPC code can store information about the type of EPC, unique serial number of product, its specifications, manufacturer information etc.[Wikipedia, "EPC Global", 2010] Electronic Product Code (EPC) technology, which is used for sharing RFID information

Barcode: Barcode is just a different way of encoding numbers and letters by using combination of bars and spaces of varying width. Bar codes are optical machine-readable labels attached to items that record information related to the item. Barcodes are designed to be machine-readable. Usually laser scanners and cameras are used to read them.

Wi-Fi: Wireless Fidelity (Wi-Fi) is a networking technology that allows computers and other devices to communicate over a wireless signal. The integration of Wi-Fi into almost all electronic gadgets has accelerated the adoption of Wi-Fi to the point where it is nearly a default in these devices [15].

Bluetooth: is an inexpensive wireless technology, short-range radio technology. This Piconet (communication channel for Bluetooth) is capable of connecting 2 - 8 devices at a time within the range of 30 feet for data sharing.

ZigBee is one of the protocols developed for enhancing the features of wireless sensor networks. It's a low cost, low data rate, relatively short transmission range flexible protocol design. It is a low

power wireless network protocol based on the IEEE 802.15.4 standard [16]. ZigBee has range of around 10-100 meters and a bandwidth of 2.4 GHz.

Near Field Communication: is a set of short-range wireless technology at 13.56 MHz, typically requiring a distance of 10 cm or less. NFC is complementary to Bluetooth and 802.11 at a distance of up to 20 cm but much slower than that of Bluetooth. Since, NFC has a shorter range it reduces the likelihood of unwanted interception.

Actuators An actuator is something that converts energy into motion, which means actuators drive motions into mechanical systems. Actuators can create a linear motion, rotary motion or oscillatory motion. Cover short distances, typically up to 30 feet and generally communicate at less than 1 Mbps

Wireless Sensor Networks (WSN) A WSN is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations.

Artificial Intelligence (AI) refers to any device that perceives its environment and takes actions that maximize its chance of success at some goal. It is characterized by an embedded, Context Aware, personalized and adaptive system [17].

IoT Applications [18]

- **Home automation:** Home automation is building automation system for homes. It involves the control and automation of lighting, heating, ventilation, air conditioning, and security as well as home appliances. Smart Home ranks one in IoT applications as on all measured channels.
- **Smart gadgets:** Wearables remain are smart electronic devices (electronic device with microcontrollers) that can be worn on the body as implant or accessories. Apple watch2 and Fitbit are creating waves in the wearable technology and are called tech game changers of 2017 [19].
- **Smart City:** Smart City solutions promise to alleviate real problems of people living in cities these days. IoT solutions in the area of Smart City solve traffic congestion problems, reduce noise and pollution and help make cities cleaner and safer.
- **Smart Grid:** Smart grids refers to the electric grid which is a network of transmission lines, substations, transformers that deliver electricity from the power plant to your home or business.This automates the distribution system and reduces power pilferage. It uses information about the behaviors of electricity suppliers and consumers in an automated fashion to improve the efficiency, reliability, and economics of electricity.

- **Industrial Internet of Things (IIoT):** IIoT is the use of Internet of Things technologies in manufacturing.It incorporates machine learning, big data, using sensor data, machine-to-machine (M2M) communication and automation technologies that have existed in industrial settings for years. IoT holds great potential for quality control, sustainable and green practices, supply chain traceability and overall supply chain efficiency.
- **Smart Car:** Connected cars consists of Navigation systems, which will enable drivers to determine not just the fastest route but also the most fuel-efficient and Vehicle management systems, which will provide detailed information about the car's performance. Price Water Coopers predict a bright future for connected cars by 2020.
- **Connected Healthcare**: Connected healthcare management and delivery by using technology to provide healthcare services remotely.
- **Smart retail:** Retail industry is slowly transforming from an un-organized sector to an organized one by incorporating technology. Smart retailing is evolving and proving to be a promising
- **Smart supply chain:** Radio frequency identification (RFID) is the technology that uses an RFID tag on objects or people, so that they can be identified, tracked and managed automatically using IoT technology.Supply chains have already been reaping benefits from IoT.
- **Smart farming:** Growing concerns about farming like climate change, limited arable land, and costs/availability of fossil fuels is reducing the productivity. The remoteness of farming operations and the large number of livestock that could be monitored the Internet of Things could revolutionize the way farmers work.

Security in IoT

IoT security that once was ignored, has now become an issue that needs more attention. With the advent of IPv6 and the wide deployment of Wi-Fi networks, IoT is growing at a dangerously fast pace, and researchers estimate that by 2020, the number of active wireless connected devices will exceed 40 billion. As the Internet of Things (IoT) connects innumerable everyday devices, previously closed systems are opened up to remote access and control. More connected devices mean more attack vectors and more possibilities for hackers to target us. The greater the volume of sensitive data we transfer over the IoT, the greater the risk of data and identity theft, device manipulation, data falsification, IP theft and even server manipulation. The rising security concern will be an inevitable disaster if it's not addressed properly.

Compliances ensure that organizations are abiding by both industry regulations and government legislation. While compliance bodies like PCI DSS, The Payment Card Industry Data Security Standard monitors information security standard for organizations handle branded credit cards,(HIPPA) Health Insurance Portability and Accountability provides privacy standards to protect

patients' medical records and other health information provided to health plans, doctors, hospitals and other health care and The Sarbanes-Oxley (SOX) protects shareholders and the general public from accounting errors and fraudulent practices in the enterprise. Lack of strict and efficient compliance body is a big loophole w.r.t IoT security.

Challenges for IoT

1. Standards: Standardization in the areas of architecture, technology and internet protocols is needed. IEEE is working to ensure that the IPv6 packets can be routed across different network types.
2. Powerful sensors: For Internet of Things to reach its full potential self-sustaining sensors must be developed where, the sensors generate electricity from environmental elements like heat, friction, movement etc.
3. Security: Privacy and security issues are inevitable, arising from the facts that objects on the IoT transmit information via public data networks, information gathered is often transmitted to third parties. Privacy and security considerations have been of minimal concern in the design of IoT devices and absence of compliance/ Regulatory body furtheradds to it.

Conclusion

IoT is making our lives simpler, more comfortable and thereby giving a better standard of life. It has touched almost every aspect of the business right from day-to-day task of manufacturing, tocomplex task like mining. Although there are many challenges and barriers in adopting this technology, the pros outweigh the cons. Implementing universally accepted standards, a compliance/ regulatory body, proposing a generic architecture, emphasizing on standard Internet protocols and opting for vendor specific technologyIoT can be made more realistic. Security is another big challenge and having a compliance body could be the solution for most of the privacy and security concerns. With all these IoT is still growing at an exponential pace and promising to deliver better results in days to come.

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