Survey: Internet of Things

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Abstract - **Internet of Things is a paradigm where everyday objects can be equipped with identifying, sensing, networking and processing capabilities that allow them to communicate with one another and with other devices and services over the Internet to accomplish some objective. This paper is a survey on Internet of Things (IoT) which is believed to be the next evolution of Internet. It bridges the cyber and the physical worlds. Ultimately, IoT devices will be ubiquitous, context-aware and will enable ambient intelligence. This article reports on the current state of research on the Internet of Things by examining the literature, identifying current trends, describing challenges that threaten IoT diffusion, presenting open research questions and future directions and compiling a comprehensive reference list to assist researchers. Then, there is an example of IoT in a smart city.**

Keywords: Internet of Things, IoT, Survey, Machine to machine, *Ubiquitous, Ambient, Internet.*

I. INTRODUCTION

THE Internet of Things (IoT) is a novel paradigm that is rapidly gaining ground in the scenario of modern wireless telecommunications. Basic idea of this concept is pervasive presence around us of a variety of things or objects – such as Radio-Frequency IDentification (RFID) tags, sensors, actuators, mobile phones, etc. – which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals [1]. Anyone who says that the Internet has fundamentally changed society may be right, but at the same time, the greatest transformation actually still lies ahead of us. Several new technologies are now converging in a way that means the Internet is on the brink of a substantial expansion as objects large and small get connected and assume their own web identity.

From the Internet of computers, when servers and personal computers were connected to a global network, and the Internet of mobile telephones, when it was the turn of phones and other mobile units, the next phase of development is the Internet of things, when more or less anything will be connected and managed in the virtual world [2]. This revolution will be the Net's largest enlargement ever and will have sweeping effects on every industry — and all aspects of our lives.

In 2003, the number of things connected to the internet was greater than the people living on earth. Within 2020, the number of things connected to the internet will be about 50 billion. According to the GSMA, this amounts to $1.3 trillion revenue opportunities for mobile network operators alone spanning vertical segments such as health, automotive, utilities and consumer electronics. Internet of Things is an integrated part of future internet and could be defined as 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 intelligence interfaces and are seamlessly integrated into the information network.

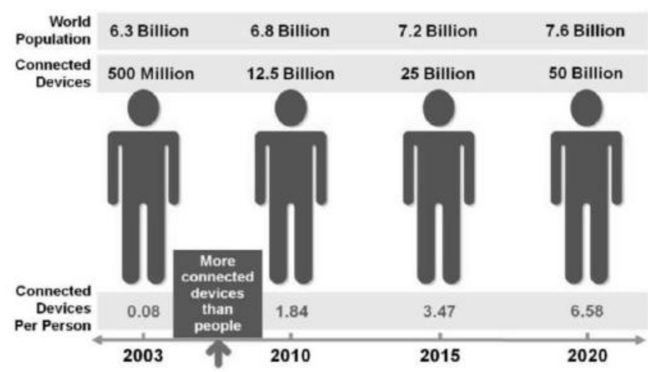

Figure 1. Internet Usage and Population Statistics.

II. THE IOT HISTORY

IoT Definition: Internet has become more prevalent in our lives in a shorter time period than any other technology in the history. It revolutionized the way people communicate. Currently, the Internet involves the process of connecting machines, equipment, software, and things in our surroundings [11]. This connection will be through the use of the unique Internet protocol address that permits things for communicating to each other without human intervention. This new scenario is called IoT. The term IoT is formalized by MIT Auto-ID center at [3]. Till now there is no accepted or standard definition for IoT [11].

"Things are active participants in business, information and social processes where they are enabled to interact and communicate among themselves and with the environment by exchanging data and information sensed about the environment, while reacting autonomously to the real/physical world events and influencing it by running processes that trigger actions and create services with or without direct human intervention." — Cluster of European research projects on the Internet of Things.

"The Internet of Things represents an evolution in which objects are capable of interacting with other objects. Hospitals can monitor and regulate pacemakers long distance, factories can automatically address production line issues and hotels can adjust temperature and lighting according to a guest's preferences, to name just a few examples." – IBM.

History: The Internet of Things (IoT) is the network of physical objects, devices, vehicles, buildings and other items which are embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data [4]. IoT allows objects to be sensed and controlled remotely across existing network infrastructure, creating opportunities for more-direct integration between the physical world and computer-based systems, and resulting in improved efficiency, accuracy and economic benefit. When IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical systems, which also encompasses technologies such as smart grids, smart homes, intelligent transportation and smart cities. Each thing is uniquely identifiable through its embedded computing system but is able to interoperate within the existing Internet infrastructure.

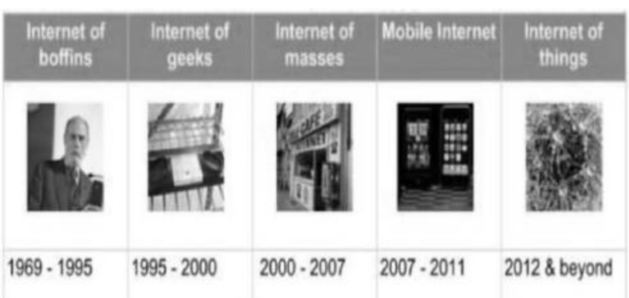

Figure 2. IoT history.

British entrepreneur Kevin Ashton first coined the term in 1999 while working at Auto-ID Labs (originally called Auto-ID centers - referring to a global network of Radio-frequency identification (RFID) connected objects). Typically, IoT is expected to offer advanced connectivity of devices, systems, and services that goes beyond machine-to-machine communications (M2M) and covers a variety of protocols, domains, and applications [5]. The interconnection of these embedded devices (including smart objects), is expected to usher in automation in nearly all fields, while also enabling advanced applications like a Smart Grid, and expanding to the areas such as smart cities.

III. IOT ARCHITECTURE

Implementation of IoT is based on an architecture consisting of several layers: from the field data acquisition layer at the bottom to the application layer at the top. The layered architecture is to be designed in a way that can meet the requirements of various industries, enterprises, societies, institutes, governments etc. Figure 3 presents a generic layered architecture for IoT [6]. The layered architecture has two distinct divisions with an Internet layer in between to serve the purpose of a common media for communication. The two lower layers contribute to data capturing while the two layers at the top are responsible for data utilization in applications.

The 5-Layer Architecture: The first layer is called business. The purpose of this layer is to define the IoT applications charge and management. Also, it is responsible about the user's privacy and all research related to IoT applications [7]. The second layer is called application. The target of this layer is determining the types of applications, which will be used in the IoT.

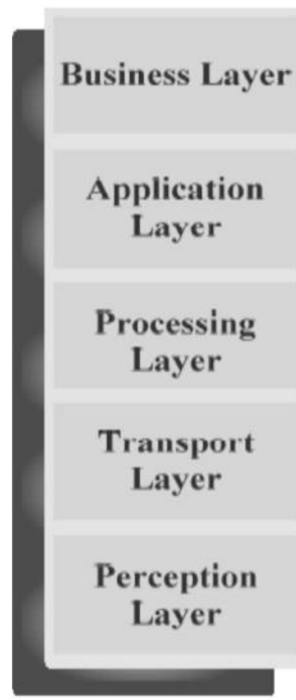

Figure 3 IoT architecture.

The third layer is called processing. Its responsibility is to handle the information gathered by perception layer. The handling process contains two main topics; storing and analyzing [11]. The target of this layer is extremely hard due to the huge gathered information about system things. So, it uses some techniques such as database software, cloud computing, ubiquitous computing, and intelligent processing in information processing and storing. The fourth layer is called transport. It seems like the network layer in the 3-layer architecture [8]. It transmits and receives the information from the perception layer to the processing layer and via versa. It contains many technologies such as infrared, Wi-Fi and Bluetooth. Also, the target of this layer is to address each thing in the system using IPV6. The fifth layer is called perception. The target of this layer is to define the physical meaning of each thing in the IoT system such as locations and temperatures. It also gathers the information about each object in the system and transforms this data to signals. In addition, it contains the technologies that are used in the IoT such as the RFID and the GPRS [9].

IV. TECHNOLOGIES

In general, three types of technologies enable IoT.

RFID and near-field communication: In the 2000s, RFID was the dominant technology. Later, NFC became dominant. NFC has become common in smart phones during the early 2010s, with uses such as reading NFC tags or for access to public transportation.

Optical tags and quick response codes: This is used for low cost tagging. Phone camera decodes QR code using image-processing techniques [10]. In reality, QR advertisement campaigns gives less turnout as users need to have another application to read QR codes.

3. *Bluetooth low energy*: This is relatively new technology. All newly releasing smart phones have BLE hardware in them. Tags based on BLE can signal their presence at a power budget that enables them to operate for up to one year on a lithium coin cell battery.

RFID : Radio-frequency identification (RFID) is the wireless use of electromagnetic fields to transfer data, for purposes of automatically identifying and tracking tags attached to objects [11]. The tags contain electronically stored information. Some tags are powered by electromagnetic induction from magnetic fields produced near the reader. Some types collect energy from the interrogating radio waves and act as a passive transponder. Other types have a local power source such as a battery and may operate at hundreds of meters from the reader. Unlike a barcode, the tag does not necessarily need to be within line of sight of the reader and may be embedded in the tracked object. RFID is one method for Automatic Identification and Data Capture (AIDC).

RFID tags are used in many industries, for example, an RFID tag attached to a can be tracked through warehouses; and implanting RFID microchips in livestock and pets allows positive identification of animals.

Since RFID tags can be attached to cash, clothing, and possessions, or implanted in animals and people, the possibility of reading personally-linked information without consent has raised serious privacy concerns. These concerns resulted in standard specifications development addressing privacy and security issues. ISO/IEC 18000 and ISO/IEC 29167 use on-chip cryptography methods for untraceability, tag and reader authentication, and over-the-air privacy. ISO/IEC 20248 specifies a digital signature data structure for RFID and barcodes providing data, source and read method authenticity. This work is done within ISO/IEC JTC 1/SC 31 Automatic identification and data capture techniques [12].

Sensors: Many IoT devices have sensors that can register changes in temperature, light, pressure, sound and motion. They are your eyes and ears to what's going on the world. These sensors are part of a device category called a micro electromechanical system (MEMS) and are manufactured in much the same way microprocessors are manufactured, through a lithography process [11]. These sensors can be paired with an application-specific integrated circuit or an ASIC. This is a circuit with a limited degree of programming capability and is hardwired to do something specific. It can also be paired with microprocessor and will likely be attached to a wireless radio for communications.

For example, you are away on vacation and the house is empty. A moisture sensor detects water on the basement floor. That sensor finding is processed by an app, which has received another report from a temperature sensor that detects the flow of water in the main water pipe. (When water automobile during production can be used to track its progress through the assembly line; RFID-tagged pharmaceuticals flows, it takes away heat and lowers the temperature). That both sensors are detecting anomalies is cause for concern. A high rate of flowing water may signal a burst pipe, triggering an automated valve shutoff; a slight water flow might be a running toilet, and the water on the basement floor by routine leakage from a heavy rain [13]. In either case, you get a machine-generated message describing the findings.

IPv6: The original idea of the Auto-ID Center is based on RFID-tags and unique identification through the Electronic Product Code however this has evolved into objects having an IP address or URI [11].

An alternative view, from the world of the Semantic Web focuses instead on making all things (not just those electronic, smart, or RFID-enabled) addressable by the existing naming protocols, such as URI. The objects themselves do not converse, but they may now be referred to by other agents, such as powerful centralized servers acting for their human owners.

The next generation of Internet applications using Internet Protocol Version 6 (IPv6) would be able to communicate with devices attached to virtually all human-made objects because of the extremely large address space of the IPv6 protocol [14]. This system would therefore be able to scale to the large numbers of objects envisaged.

A combination of these ideas can be found in the current GS1/EPC global EPC Information Services (EPCIS) specifications. This system is being used to identify objects in industries ranging from aerospace to fast moving consumer products and transportation logistics [11].

V. APPLICATIONS OF IOT

Potentialities offered by IoT make it possible to develop numerous applications based on it, of which only a few applications are currently deployed. In future, there will be intelligent applications for smart homes and offices, smart transportation systems, smart hospitals, smart enterprises and factories [15]. A few important applications of IoT are briefly discussed.

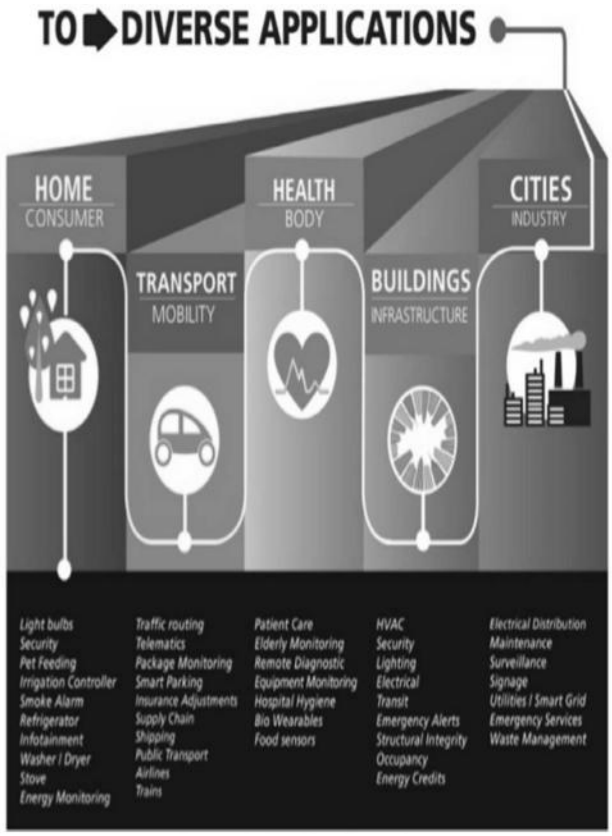

Figure 4. Applications of IoT.

Healthcare: IoT is proposed to improve the quality of human life by automating some of the basic tasks that humans must perform. In that sense, monitoring and decision making can be moved from the human side to the machine side. One of the main applications of IoT in healthcare is in assisted living scenarios. Sensors can be placed on health monitoring equipment used by patients. The information collected by these sensors is made available on the Internet to doctors, family members and other interested parties in order to improve treatment and responsiveness [16]. Additionally, IoT devices can be used to monitor a patient's current medicines and evaluate the risk of new medications in terms of allergic reactions and adverse interactions.

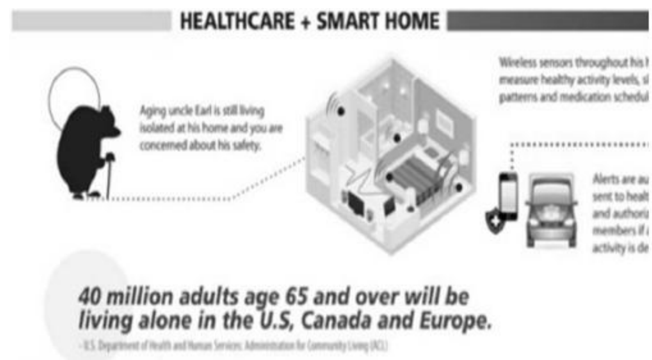

Figure 5. Health care.

Smart environments domain: Smart water supply: Smart cities must monitor water supply to ensure that there is adequate access for resident and business need. Wireless Sensor Networks provide the technology for cities to monitor their water piping systems more accurately and discover their greatest water loss risks. Cities that are addressing water leakage problem with sensor technology are producing high savings from their investment. Tokyo, for example, has calculated they save $170 million each year by detecting water leakage problems early (LIBELIUM, 2013). The system can report pipe flow measurement data regularly, as well as send automatic alerts if water use is outside of an estimated normal range. This allows a smart city to determine the location of leaking pipes and prioritize repairs based on the amount of water loss that could be prevented.

Figure 6. Smart home.

Smart homes and offices: We are surrounded by various electronic gadgets around us such as microwave ovens, refrigerators, heaters, air conditioners, fan and lights. Actuators and sensors can be installed in these devices in order to utilize the energy sufficiently and also to add more comfort in life.

These sensors can measure the outside temperature and even can determine the occupants inside the rooms and thereby control the amount of heating, cooling and flow of light etc. Doing all these can help us to minimize the cost and increase energy saving.

Improved gyms: The gymnasium experience can be enhanced by involving new technologies like a separate exercise profile which can be installed on machines and each person can be identified from his identification id alone and thereby, concerned profile will get activated.

Food sustainability: Food that we eat has to go through various stages before they arrive in refrigerators. They are bound in a strict food cycle: production, harvesting, transportation and distribution. With the use of appropriate sensors, we can prevent the food from climatic damages by keeping a good eye on temperature, humidity, light, heat etc. Sensors can measure these variations precisely and notify the concerned person. Monitoring helps in prevention of possible degradations.

Transportation and logistic domain:
Smart parking: The new Smart Parking sensors buried in parking spaces detect arrival and departure of vehicles. Smart parking provides extensive parking management solutions which helps motorists save time and fuel (LIBELIUM, 2013). A significant contribution to congestion arises from motorists searching for accessible parking spaces. Providing accurate information about parking spaces helps traffic flow better, and this will also allow the deployment of application to book parking spaces directly from the vehicle [17]. This will help to reduce CO_2 emissions and minimize traffic jams.

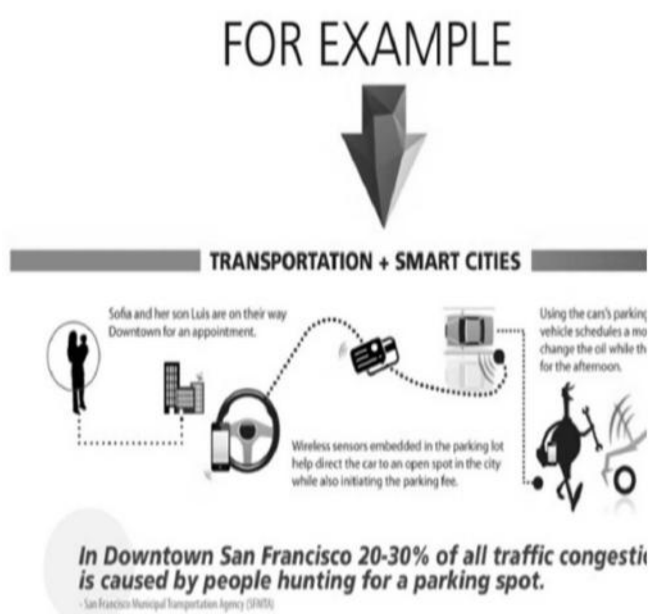

Fig 8: Transportation issues [13].

3D Assisted driving: Vehicles like cars, buses and trains along with the roads and rails equipped with sensors may provide valuable information to the driver to provide better navigation and safety. With the use of assisted driving, we will be able to find the right track with prior information about traffic jams and incidents. In an Enterprise context, information about the vehicle transporting goods together with information about the type and status of the goods can integrate to provide valuable information about the delivery time, delivery delays and faults.

Figure 9. Auto driving [13].

Augmented maps: Tourist augmented maps with tags allow NFC-equipped phones to browse the information about the places and quickly connect it to the web services providing information about hotels, restaurants, monuments, theater and the local attractions. This can be done by hovering your mobile phone over the tag within its reading range so that the additional information about the marker can be displayed on the screen.

Logistics: Implementing IoT in Retail chain monitoring has many advantages: RFID and NFC can be used to monitor almost every link of supply chain, ranging from commodity details, raw material purchasing, production, transportation, and storage, sale of product and after sales services. With the help of IoT, we will track the inventory in the warehouse so that stock can be refilled at appropriate time for continuous sale and this will reduce the waiting time of customer which results in customer satisfaction and increased sales [17].

VI. DISADVANTAGES AND CHALLENGES

Disadvantages of IoT:
Privacy: IoT is going to add a lot to our lives, it's probably going to take our privacy in payment, whether you want it to or not.

Concept of being offline, of being unavailable, or simply being alone, will recede.We are standing on the brink of a post-privacy society. After implementation of IoT, we may well be living in the last era of privacy.

Complexity: Any failure or bugs in the software or hardware will have serious consequences. Power failure can cause a lot of inconvenience. Development needs to be easy for all developers, not just to experts.

Change in human behavior: As a society we're addicted to tech in a way that no generation ever has been before. When we live in a world in which there are countless sensors and smart objects around us, all the time; when the clothes we wear, even things inside our bodies, are smart and connected then change in behavior is obvious. Human will be like robot but with blood.

Environmental impact: A concern regarding IoT technologies pertains to the environmental impacts of the manufacture, use, and eventual disposal of all these semiconductor-rich devices. Electronic components are often simply incinerated or dumped in regular landfills, thereby polluting soil, groundwater, surface water, and air.

Lesser employment of mental staff: The unskilled workers and helpers may end up losing their jobs in the effect of automation of daily activities. This can lead to unemployment issues in the society. This is a problem with the advent of any technology and can be overcome with education.

Challenges of IoT: Connectivity: Variety of wired and wireless connectivity standards are required to enable different application needs.

Power is critical: Many IoT applications need to run for years over batteries and reduce the overall energy consumption.

IOT is complex**:** IoT application development needs to be easy for all developers, not just to experts.

Government interest: If Government allows then only set up of IoT in a particular country is possible. Government allows only when they get profit from this new technology. Also depends very much upon the economy and revenues of the country.

Compatibility**:** As devices from different manufacturers will be interconnected; the issue of compatibility in tagging and monitoring crops up. Though this disadvantage may drop off if all the manufacturers agree to a common standard, even after that, technical issues will persist [18]. Today, we have Bluetooth-enabled devices and compatibility problems exist even in this technology! Compatibility issues may result in people buying appliances from a certain manufacturer, leading to its monopoly in the market

VII. CONCLUSION

Internet has drastically changed the way we live. IoT has the potential to add a new dimension to this process by enabling communication between smart objects. IoT should be considered as a part of future internet as everything is going to be connected in a network so that objects can interact with each other, but still there are lots of issues which are to be solved to make this a reality. Lot of research is required in this field, once implemented successfully; the quality of life is improved because of the reduction of the effort made by humans on unimportant things.

In this paper, we presented the technologies and applications that can be used to make Internet of Things a reality. After that, we state some good examples where Internet of Things is of great use, and at last we discuss some open issues which are still to be solved before the wide acceptance of this technology.

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