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A Survey on Internet of Things

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Abstract— Internet has made a significant impact on our economy and society. With the advances in information and communication technologies, Internet of Things (IoT) has emerged as one of the most powerful communication paradigms of the 21st century representing the trend of future networking and is leading the wave of the IT industry revolution. Advancement in technology related to data collection, such as embedded devices and RIFD technology had led to increase in number of devices that are connected to the net and transmit the data continuously. The continuation of this trend is poised to evolve as an "Internet of Things" where the web will provide a medium for objects to become interactive. IoT makes internet more pervasive by extending the concept of internet to accommodate each and every object existing in this world or likely to exist in the coming future. These objects continuously generate information about the physical world, communicate with other objects and the seamless interactions among them lead to many different applications such as home automation, smart grid, smart city, traffic management, etc. This paper addresses different perspectives, challenges, applications and current world wide activities related to IoT.

Keywords— Internet of Things, IoT

I. INTRODUCTION

Kevin Ashton first coined the term Internet of Things in 1999 [1].The Internet of Things (IoT) is a concept reflecting a connected set of anyone, anything, anytime, anyplace, any service, and any network. To date, the vast majority of internet connections worldwide are devices which are used directly by humans e.g. computers and mobile handsets [2]. IoT is an extension and expansion of Internet-based network, in which the communication from human and human is expanded to human and things or things and things [3].

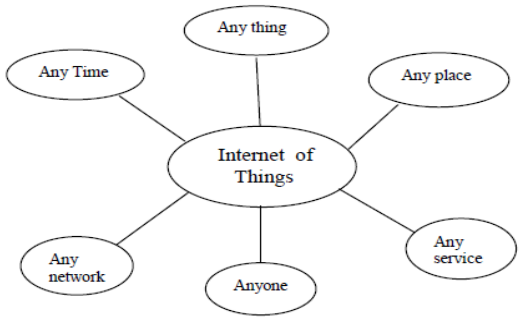

Fig.1: Internet of Things

The word *thing* here indicates actually the *thing's information* and the *Internet* here is actually the *Internet application*. The semantic meaning of *Internet of things* is "the Internet relating to information of things", and the "relating to" in it means "thing's information flows rationally and orderly on the Internet, so as to being shared on a global scale"[4].

Internet of Things is bringing the physical world and information world together. The basic concept of IoT is autonomous and secure exchange of data between real world devices and applications.

IoT comprises of objects, sensor devices, communication infrastructure, computational and processing unit, decision making and action invoking system. Object specific information is communicated by the sensors to computational and processing unit, the result of which is then passed to the decision making and action invoking system for determining the automated action accordingly. Hence Things in the IOT will not only be devices with sensing capabilities but also provide action capabilities. e.g. it can be a big animal with a chip, a sensor embedded motor vehicle that alerts the driver when the gear rod is not properly working or any other natural or manmade object having an IP address and capable of transferring data over a network [2,5,6].

As on date number of things connected to the internet exceeds human population. In the near future, the number of

connected devices will be tens or hundreds of times larger than the number of connected people. Internet of things is actually the internet of product information. The product information flows on Internet for the information sharing on a global scale [7].

The Internet of Things is a technology revolution that represents the future of computing and communications and will contribute in creating a better world for human beings, where objects around us know what we like, what we want, what we need and act accordingly without explicit instructions [2,8].

Rest of the paper is organized as follows Section II contains perspectives on IoT, applications of IoT are mentioned in Section III, in Section IV we have addressed challenges in IoT field, in section V we discuss current activities in IoT space, Section VI is the conclusion.

II. PERSPECTIVES

A] CHINA:
China started research in IoT field in 1999 and identified IoT as a new engine for economic growth. The government of China released its twelfth Five-Year Plan clearly defining goal and objectives for IoT development. China has invested around RMB 500 million into IoT related fields for supporting the development of IoT, 2/3rd of the funds is allocated for R&D and applications [3].

B] INDIA:
India has recently formulated a draft IoT policy to leverage India's strength as a leader in the global service industry and to create IoT ecosystem in the country. India is planning to create an IoT industry of USD 15billion by 2020 which is expected to have a share of 5-6% of global IoT industry. The Indian Government has allocated Rs.7060 crores in the current budget to develop 100 smart cities in the country. To transform India into digitally empowered society and a knowledge economy the Government has launched Digital India program which is expected to provide the required impetus for development of the IoT industry in the country. Table 2 shows possible IoT application fields in India.

C] Customers and Companies:
Information is a powerful value-creation tool: It offers customers the ability to make more informed decisions, and it offers companies the opportunity to differentiate themselves from competitors. The information or data generated from sensors have the potential to change the relationships between customers and companies. Companies will better anticipate customer needs and serve them effectively, on the other hand, customers will get better products and services at a lower total cost [10].

III. APPLICATIONS

Internet of Things will impact a number of application domains. The applications are categorized into four different domains: (1) Personal and Home; (2) Enterprise; (3) Utilities; and (4) Mobile [1,6].

1. Healthcare Applications:
Glucose level sensing, Monitoring of various parameters such as ECG, Blood Pressure , Oxygen saturation , Body temperature , monitoring medicine intake etc. [11,12,13,14,15].

2. Agriculture Applications:
Intelligent farming system, Fertilizer and pest control mechanism that can initiate actions by responding to specific local conditions [4].

3. Home appliances:
Smart Refrigerator: It measures how much of each product is left and then orders it online.

Other applications include prediction of natural disaster, smart cities, Smart Security, Intelligent transportation education management in academic campus [16,17,18, 19,20].

Table1: Internet of Things application domains

Domain	Applicable to	Applications
Personal & Home	Individual or home. [Information gathered by sensors is used by individuals who own the network]	Control of Home appliances e.g. Air Conditioner, Washing Machine, Refrigerator. Personal Body Area Network
Enterprise	Community. [Information gathered by sensors is used for service optimization and resource management].	Environmental Monitoring, Smart Transport
Utilities	National or Regional Scale	Smart Grid, Smart Metering, Water network monitoring
Mobile	-	Efficient Logistics management

Current Applications in use:

1] Disney World Magic Band:
By investing 1 billion dollar Disney launched a wearable magic band consisting of RFID which is given to the visitors to be used while check in their rooms and into attractions. This way Disney gathers data of park use.

2] Wemo Switch Smart Plug:
This is a smart plug that plugs into a regular socket, accepts the power cord from any device and is used to turn it ON or OFF on set schedule or just by touching on your smart phone. Another model called "Insight Switch" measures energy consumed by devices.

3] Philips Hue Smart Bulbs:
These bulbs can change to any colour you choose, can be turned ON & OFF on a schedule or from your smart phone. They can be synced with music for an awesome sound and light party.

4] August Smart Lock:
This is a smart lock that locks and unlocks automatically thereby making you free from carrying keys. An optional keypad is provided to set a code to open the door in case you forget to carry your phone with you. You can grant keys from your smart phone to your friends, relatives or maid and have them expire when you no longer want to give them access.

5] Petnet Smart Pet Feeder:
With this smart feeder you can monitor and control your pet's food consumption even if you are away from home. It even sets delivery of pet food when it is about to finish.

IV. CHALLENGES

The IoT is changing the shape of the Internet and offering enormous economic benefits but it also faces many key challenges which are listed below.

1] Unique Addressing:
Billions of devices will be connected providing different services. Hence to assign unique address to all these objects/sensors an efficient system is required. Currently we are facing shortage of IP addresses as we are using Internet Protocol version4 which has a capacity of only 4 billion public addresses i.e. less than one public IP address per living human on earth. To overcome this, we need to implement Internet Protocol version6 which is based on addressing scheme of 2^{128} bits consisting of 2^{64} bits for network address and 2^{64} for host address enabling almost unlimited number of addresses [6,21,22].

2] Standardization:
Manufacturers provide devices using their own technologies and services that may not be accessible by others. Hence to provide better interoperability for all objects and sensor devices standardization of IoT is necessary.

3] Safety and security of objects:
It is important to prevent the intruder which may cause physical damage to the objects that are spread over some geographical area or may change their position [23].

4] Data confidentiality and encryption:
A number of IoT devices are battery driven and are using low-power CPUs operating on low clock rates. Hence the sensor devices which transfer data to the processing unit over the transmission system should have faster and less energy consuming encryption mechanism to guarantee the data integrity at the processing unit [24].

5] Network security:
Wired or wireless transmission network is used to send the data from sensor devices. Data from large number of sensor devices should be handled properly by the transmission system without causing any data loss due to network congestion, proper security measures must be ensured for the transmitted data and it should be prevented from external interference or monitoring [25].

6] Greening of IoT:
Rapid growth of Internet connected edge-devices, increase in data rates, number of Internet-enabled services are causing the network energy consumption to increase at very high rate. Thus green technologies need to be adopted to make energy efficient network devices.

7] Data storage investments:
As IoT develops the amount of data created will be huge. To store the huge amount of data that will be generated by the millions of devices connected to the internet large storages will be needed with energy and power resources [6].

8] Low Power Sensor design:
Once the sensors are deployed in the field it is almost impossible to replace their batteries. Therefore, designing low power sensors or sensors which do not require a battery change over the lifetime is a challenge e.g. If a sensor is deployed on an animal for tracking purposes, the battery of the sensor should not get discharged before the animal dies[26].

V. CURRENT ACTIVITIES IN THE IOT SPACE

Activities under Internet of Things are getting momentum around the world as industry, academia and various governments worldwide have undertaken numerous initiatives [27,28].

[A]IBM's *Smarter Planet* initiative is a corporate vision driven by 3 I's: instrumentation, interconnection and intelligence that is intended to help systems, societies,

industries, processes to become more efficient, productive, intelligent, reliable, responsive and resilient so as to make Earth a smarter planet.

[B]Microsoft's *Eye-On-Earth* implemented in European countries is a vision based on the concept of " sharing is everything " gathers and shares environmental data online helping not only researchers to keep a track on air and water quality but also policymakers for planning distribution of resources.

[C] Through the *Central Nervous System for the Earth* project HP is deploying tiny intelligent sensors in billions or trillions everywhere on earth to sense the motion and vibrations or to collect the real time seismic data worldwide which will be transmitted at very high speed alerting the people about earthquake or tsunami seconds before they feel the vibrations hence making living on planet safer.

[D]The *Cluster of European Research Projects on the Internet of Things* (CERP-IoT) has brought together European research projects to define and promote a common vision of IoT.

[E] The *MIT Auto-ID Laboratory* is a research network of academic laboratories from seven renowned universities of the world has launched recently *Cloud of Things* programme to connect physical world objects with the cloud.

Table2: Main IoT Applications Fields in India [9,29,30]

FIELD	TYPICAL APPLICATIONS
SMART CITY	Smart Metering, Smart parking , Smart Health, traffic management, Smart building, Wi-Fi Internet access & Surveillance, Solid Waste Management, Smart Lighting Development of tools that enable accessibility for persons with disabilities.
SMART WATER	Real-time detection of leakages and factory wastes in rivers , Monitoring the tap water quality in all government owned education institutes and public places, Monitoring of water level variations in rivers, dams and reservoirs,
SMART ENVIRONMENT	Controlling generation of toxic gases and CO2 emissions from factories, vehicles.
SMART HEALTH	monitoring various vital parameters of patients, Early detection of diseases and life-threatening problems and their preventive warnings in the hospitals as well as at remote patient location.
SMART AGRICULTURE	Soil moisture monitoring, developing online update mechanism for farmers. Unmanned tools development for insecticides and pest control spray. Online temperature monitoring of storage areas.
SMART SAFETY	Wearable safety devices for physically disabled, women, child, old people. Smart devices for patients suffering through dementia to prevent them from getting lost.
SMART SUPPLY CHAIN & LOGISTICS	Universal ambulance service at any place. E-commerce purchases.
SMART MANUFACTURING / INDUSTRIAL IOT	Preventive and in-time maintenance for equipments optimal utilization of resources through process improvement in manufacturing monitoring of operations, warning/alerts for deviation/damages.

VI. CONCLUSION AND FUTURE SCOPE

The Internet of Things is a revolution, currently under progress, will change the way people work, think and live life. The idea to connect everything and anything and anytime is appealing and will transform human-human form of communication into human-device and device –device communication. The dynamic nature of IoT and the scale on which it will be functional is hard to imagine and hence to overcome the challenges will be a huge responsibility. Low power sensor design, network security, designing encryption algorithms are some of the challenging fields open to the researchers. Proper coordination among academia, industry and governments will boost the progress of Internet of Things.

In this paper we introduced the emerging future form of Internet called "Internet of Things", described current and possible future applications, addressed key challenges associated with the IoT and finally discussed some active international projects in the field of IoT.

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Vinayak Bairagi has completed PhD degree in Engineering from Pune University. He has teaching experience of 12 years and research experience of 8 years. He has filed 9 patents and 5 copyrights in technical field. He has published more than 58 papers, of which 26 papers are in International journals of which 12 papers in SCI Indexed journals, with five Springer journal publications along with One in The_IET journal publication. He is a reviewer for nine scientific journals including IEEE Transactions, The-IET Journal, and Springer Journals. He is the P.I. for UoP-BUCD research grant. He has received "Maniratna" Best Teacher Award for Excellent academic Performance (2013). He is recognized PhD Guide in Electronics engineering of SavitribaiPhule Pune University.

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