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Internet of Things (IoT): Vision, Review, Drivers of IoT, Sensors Nodes, Communication Technologies and Architecture

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Abstract: *Now days most of the data is originated from people, those Exabyte of data traveling across Intranet is entered by human intervention, either using keyboards or pushing a button. So the current Internet is called Internet of People. It is time to change the way we put data on the Internet since we are using plenty of things around us and they can generate data which is useful. We need to empower the things around us to communicate with each other and react to the environment around it, take decisions without our intervention thereby improving the quality of our life. It requires multiple sensors to detect the event changes and a reliable network of things to interconnect them which in turn will, make them Internet enabled. Thus Intranet of Things is born. In this paper we discussed about vision of IoT, drivers of IoT and various sensors and technologies that are used in IoT.*

Keyword: *Internet; Internet of People (IoP); Internet of Things (IoT);*

1. INTRODUCTION

As per Wikipedia "The Internet of Things (IoT) refers to uniquely identifiable objects and their virtual representations in an Internet-like structure" [12]. This may give some vague idea of IoT but needs further discussion to understand what exactly IoT stands for.

Nowadays, the Internet has become the most important part of people's life. Billions of people around the world connected to each other with Internet by sending and receiving emails, using social networking applications, playing online games and many more things. This can be called the "Internet of People" [1]. The technologies like Sensor Networks and Radio-frequency identification (RFID) tags are evolving with rapid development in the field of Internet technologies. With a combination of these two technologies, i.e. the Internet and Sensor Networks leads to a new vision of direct machine to machine communication over the Internet. This can be called "Internet of Things".

It helps to create excellent network for controlling sensing and programming. IoT use to developed many products based on embedded technology and by the next few years billions of devices get connected with IoT. These devices provide health protection, create safer societies and better life style. The overall concept of IoT is based on sending and receiving the information through sensors and wireless network [17].

Applications of IoT include Consumer application, Transportation, Medical and healthcare sector, Infrastructure management, Energy management, Building and home automation, Environmental monitoring, Metropolitan scale deployments and Agriculture [12].

This paper is organize in following sections like literature survey, internet of people to internet of things, drivers of IoT, sensor nodes and communication technology.

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2. LITERATURE SURVEY

Vinton Cerf and Bob Khan are known as the father of Internet since they created Transmission Control

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Protocol (TCP)/Internet Protocol (IP) which was used in ARPANET in 1960s and 70s which later became Internet, as known today. When they switched on the "Internet" first time it crashed after displaying "lo" (login). From such a low beginning, Internet has grown today to be one of the basic needs for our survival. In its early days it was mainly used by scientists to exchange data using character terminals, and by the '80s it started expanding within US. Each machine was identified with an IP address. With the introduction of domain names in early '80s (DNS) most of the US corporations and Universities rushed to register their names which is known as "DNS Gold Rush"[2]. Internet slowly expanded to Europe, Australia and Asia by late '80s and early '90s. But it was the introduction of World Wide Web (WWW) in 1989 /90 by Tim Lee which facilities to host interlinked hypertext in the Internet. The creation of Mosaic browser by Mac Andreessen in 1993 to view those pages paved the way for the rapid growth of Internet. Users connect their computers from a Graphical user interface (GUI) based browser to a Web server using http protocol to access these static web pages. By mid 1990s Internet spread to Asia too.

By mid 90s webpages switched from hosting static pages to dynamic pages which revolutionized Internet to enable online money transactions. During this period we have seen the birth of eBay(1994) and Amazon (1995) heralding online retailing. In 1996 Sabeer Bhatia started Hotmail and we all rushed to create one free email account. Simultaneously there was another wave of search engines appeared in the DOT COM scene. Yahoo was launched in 1995 and many others. But the launch of Google in 1998 revolutionized the search engines pushed Yahoo search to oblivion [3]. In 2003 a couple of Estonian developers launched Skype (Skype + Peer) hosting VOIP calls using Internet. In 2004 Yahoo started Flickr, the photo sharing website which became a huge hit. Within one year (In 2005) YouTube was launched by 3 former Paypal employees on Valentine's Day. Rapidly Internet blossomed to spearhead the era of convergence, for sharing voice, data, photos and videos (Triple Play) [4].

So far we were using desktop computers to access Internet. We go to the device when we want to access Internet, In 2007 Apple introduced iPhone which revolutionized the way we access Internet. IPhone puts Internet in your pocket and you can access it any time anywhere. We entered the era of Internet of Mobile. The device goes with you. Later Android Phones and Windows Mobile Phones entered into the scene competing with Apple. Developers in each of these platforms were competing to bring applications for every need we can think of.

Apple store has approximately 1.5 million applications. As of today smart phones enable Internet access to the masses. In 2008 Facebook exploded with 100 million users and a year later Twitter crossed 50M tweets per day. Looking at the great success of Facebook and Twitter so many more social network were launched like Google+, LinkedIN, Pinterest, Fancy etc and people spent hours in posting every moment of their lives on these sites! [5]. with such a wide reach of Internet we are ready for the next revolution, Internet of Things.

3. INTERNET OF PEOPLE TO INTERNET OF THINGS

Most of the technologies related to IoT is not new. It was existing, people recognized it as separate entities. It is like the famous "blind-men and elephant" story. 6 blind men felt different parts of the elephant and described it in 6 different ways how it looks like. These are distinctly different. Then a 7th man came to the scene and said what you are seeing is IoT and it has all the features you mentioned. Who is this 7th man who recognized the sum total of these technologies is IoT? Kevin Ashton, a UK technologist coined the term "Internet of Things" in 1999 and the grant vision he had was to empower computers with their own means of gathering information [12].

Fig 1 Internet of things [15]

So far the data in the Internet is generated by people, it is time to empower the devices to generate data, feed to Internet, which will be stored in the cloud and subjected to detailed analysis using "Big Data" systems [1] resulting in some useful decisions/actions. In IoT things are connected to Internet at anytime, anywhere. In the age of IoT ordinary devices like lights and sensors become Internet enabled, environmentally aware, with the ability to interact with their surroundings. One should

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not confuse IoT with the related terms, M2M, Internet of Everything (IoE), Web of things (WoT), Industrial Internet etc. [6].

3.1 IoT Vision

IoT is going to generate tons of data. How is it going to help us? Let us look at philosophically how IoT is going to help mankind. If we look at the well-known DIKW Pyramid of learning, we can see that we need tons of data to be analyzed for a given context to get useful information. Meaningful Information leads to Knowledge and given insight and reflections to Knowledge we get Wisdom. Wisdom helps to make right decisions and help us to move forward.

So now you know how IoT can act as boon to mankind, it generates ton of data. In the era of Internet of Things home appliance will be talking to each other to help you out in your daily chores. Almost all of them will be Internet enabled either directly via your wireless broadband or indirectly using ZigBee or Bluetooth Smart connected to your smart phone or home gateway [7]. Your typical day may start listening to Alarm. Alarm time is not fixed like what we got used to, it will be automatically adjusted depending on the inputs from your daily schedule which itself is dynamic. Once the alarm goes the clock talks to bathroom heater to heat the water and heat the toilet seat if required. Once you are out of the rest room hot breakfast will be ready waiting for you. Your car will be heated or cooled few minutes before you walked towards the car parking. Car will inform you if any traffic hiccup on the way and adjust the route to office accordingly.

3.2 Internet of People vs Internet of Things

Following table gives an idea about the comparison of Internet of People as well as Internet of Things. Sentrollers are Sensors with built in controllers [4].

TABLE I INTERNET OF PEOPLE VS INTERNET OF THINGS

Internet of People	Internet of Things
Computers: Tablets, laptops, TVs, Game console etc.	Sentrollers: (Mote) Smart meters, thermostats, motions sensors, remoter controls etc
Content Sharing and distribution is main function	Sense controls is main function
High Data rate require	Long Battery Life require
Dynamic Roaming	Static (roaming for wearable)
GSM/ 3G/ LTE	Nuel (not yet) 3G/LTE
Wi-Fi (802.11)	Bluetooth Smart, ZigBee (IEEE 802.15.4) , Z-Wave

4. DRIVERS OF IOT

In the last section we have seen that many of the components of IoT is not new and some of them were existing for atleast a decade. Then what exactly happened to make IoT a house hold name. First of all a group technologies doing similar things brought under an umbrella by coining word "Internet of Things" and the subsequent analyst's prediction of huge markets potential and its associated hype gave the necessary push for IoT market. Following factors are the driving force for IoT [8]:

4.1 Microcontrollers: Availability of low cost and powerful microcontrollers, these power the sensor nodes (mote).

4.2 Sensor Advances: Availability of cheap and efficient sensors for every need (anything that can be sensed)

4.3 Widespread Wireless connectivity: Improved and reliable connectivity technologies and protocols ZigBee, Z-Wave, Bluetooth Smart, Wi-Fi, etc...

4.4 Cloud Computing: Latest developments in Cloud computing, providing remote storage and data sharing. Cloud computing make accessibility of data from anywhere, any device, any time a reality

4.5 Big Data: Latest developments in Analytics using BigData. This made it possible to analyses the huge chunk of data gathered by IoT devices and make some sense out of it and use it for decision making or controlling some actuator.

Fig 2 Smart phone applications [16]

4.6 Smart Phone Applications: Availability of tons of smart Phone apps in iOS / Android / Windows Mobile which made it possible to act as HUB / Gateway device for WSN (Wireless Sensor Network), at least for Home Automation IoT applications.

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IoT can be broadly classified into two categories, Industrial IOT and Consumer IoT. Home Automation is focus for Consumer IoT whereas Industrial IoT looks into applications like Smart Grid, Smart Building, Smart City, Connected cars, e-health, and the business benefits derived from employing IoT in manufacturing sector or even in various stage of a product Life Cycle.

As per the article by Michel E Porter and James Heppelman "Managing Internet of Things" published in Harvard Business Review Nov 2014 [14] "Smart connected products have 3 core elements, physical component, smart component and connectivity components. Physical component capabilities value amplify by smart components while connectivity amplifies the capabilities and value of the smart components and enable some of them to exist outside the physical product itself. The result is a virtuous cycle of value improvement."

Physical components comprise the product's mechanical and electrical parts [9]. In a car for example it includes the engine block, tires and the batteries. Smart components comprises the sensors, microprocessors, data storage, controls, software, and the embedded OS and Smart components include, the ECU, ABS and rain sensing windshields with automated wipers and the touch screen displays. Connectivity components comprise the antennae, ports, and protocols enabling wired or wireless connection with the product. Connectivity takes three forms [9].

- **One–to-One**: A product connects to the manufacturer, the user or another product using a port or other interface, for example when a car is hooked into the diagnostic machine.
- **One-to-Many**: A Central system is continuously or intermittently connected to many products and simultaneously. For example your set top box is connected to the manufacturer system that monitors performance and accomplishes remote service and firmware upgrades.
- **Many-to-Many**: Multiple products connect to many other types of products. An array of farm equipment is connected to one another, and to geo location data, to coordinate and optimize the farm system

5. SENSORS NODES

Sensor node is one of the essential building block of the IoT technology [4]. It is also known as Mote and is capable of performing

1. Gathering sensory information
2. Some processing
3. Communicating with other connected nodes in the network.

The components of a mote are

1. Microcontroller
2. Sensor/ sensors
3. Memory
4. Transceiver (Communication)
5. Power Source

6. COMMUNICATION TECHNOLOGIES

The sensors nodes need to be connected to the HUB, a dedicated hub or a smart phone which in turn will be running IP and connecting to Internet using Wi-Fi or 3G/ LTE. Since the sensor nodes are generally low power devices running on batteries, it cannot afford to have Wi-Fi connectivity which is very demanding on resources, power, CPU power and memory. So the resource constraint devices which will form the edge network in the IoT system will be communicating to the HUB using either one of the following protocols which is optimized for low power. All the communication technologies employed in low power devices look for a publisher/subscriber model communication techniques. Sensor node which has the data is the publisher and the hub which is interested in receiving the data is the subscriber. For example Bluetooth Smart uses advertiser/scanner model for communication. It helps the devices to be in sleep state normally to conserve energy and whenever it has data, wake up, send data and return to sleep.

Let us look at different methods of communication technologies employed in IoT [1, 10].

ZigBee is one of the most popular communication protocol for IoT devices used in Home Automation which works on 2.4 GHz or less popular sub GHz band. It uses IEEE 802.15.4 PHY and MAC layer like many other similar protocols meant for similar low power applications. (ex: Thread). It is specifically meant for low power devices and offers mesh connectivity unlike Bluetooth Smart with a maximum data rate of 250kbps, typically 100kbps. It is available in many flavors, ZigBee RF4CE which meant for replacing the legacy IR remotes in consumer equipment which is long overdue for replacement with its outdated one way communicating capabilities [11].

ZigBee Pro is meant of IoT devices and supports different profiles. Building automation, Health Care, Home Automation, Retail services, smart energy and telecom services. ZigBee IP uses IPv6/ 6LoWPAN stack instead of the traditional ZigBee stack for the

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network layer. In Nov 2014 ZigBee Alliance announced ZigBee 3.0 which is specifically focused on IoT and done away with different profiles for a unified application layer. It is very popular in Home Automation and it offers data rate around 40Kbps and operates in sub GHz frequencies. It offers mesh connectivity similar to ZigBee and is very popular in home automation applications since it is cheaper and need less power compared to ZigBee**.**

BLE (Bluetooth Low Energy) which is known by its trade name Bluetooth smart is a very recent entry (BLE 4.0 in 2010) in this field [12]. It is incompatible with the classic Bluetooth which you are familiar with its killer app, the wireless voice communication. Similar to ZigBee , BLE operates in 2.4Ghz ISM band and the data rate is typically 250kbps, faster than ZigBee. Bluetooth SIG (Special Interest Group) which manages Bluetooth standards revisedthe spec twice after its inception, latest being BLE 4.2 which promises IPv6/ 6LoWPAN direct support, an alternative to GAP (Generic Access Profile) and GATT (Generic Attribute Profile) services [12]. The data rate is increased from 250 kbps to 650kbps and the packet size is increased from 31bytes to 251 bytes maximum. It also features Industry standard security (FIPS) and privacy by hiding the device's public address. BLE is supported by popular smartphone OS. iOS and Android which gave great momentum for BLE to start in IoT World which was/is dominated by Z-Wave and ZigBee. Interestingly Apple gave it a great push for BLE by popularizing iBeacons.

Thread is a very recent entrant, originally from Nest Labs (Google). Thread is built on IEEE802.15.4 PHY and MAC layers runs 6LoWPAN stack over it. It offers mesh connectivity and can have up to 250 devices connected in a single PAN (Personal Area Network). The final specs will be out soon and you may find products supporting Thread protocol by July 2015.

ANT (Advanced and Adaptive Network Technology) is a WSN communication protocol and ANT+ is managed network which runs ANT protocol and ensures interoperability. ANT operates in 2.4GHz spectrum and divides it into 125 channels of 1MHz bandwidth. It is meant for ultralow power networking applications. ANT is ultra-lightweight protocol stack delivered as silicon solution. ANT+ mainly targets health and fitness devices and is suitable for battery powered devices with requirement of 3 or 5 years battery life. It is originally from Dynastream Innovations a Canadian company. ANT has two types of nodes, simple and central node and the central node will act as a master for the network.

ISA 100 (ISA100.11a) is designed for Industrial automation (IEC62734) and uses IEEE 802.15.4 PHY and MAC layers . It is supported by many Industrial Control / Automation companies, Yokogawa, Honeywell etc and supports Industry Process Automation. So it operates in 2.4GHz spectrum with 16 channels, the data rate is around 9.6Kbps. It supports 6LoWPAN in the network layer so it is ready for wider acceptance in the IoT industry adoption.

Wi-Fi is one of the most successful wireless protocols and is well understood available across many devices. Wi-Fi is employed in high performance wireless network and the latest standard IEEE 802.11AC supports upto 69 Gbps. Since Wi-Fi is not designed for low power devices it is employed many in HUBs to communicate to the Internet, act as a gateway between lower power protocols in the lower layers (ZiGBee, Z-Wave, BLE, etc..) to the IP World. WI-FI can even be employed in sensors nodes which have adequate CPU power and are not running on Battery power.

7. ARCHITECTURE OF IoT

There is no single consensus on architecture for IoT, which is agreed universally. Different architectures have been proposed by different researchers [13].

7.1 Three- and Five-Layer Architectures.

The most basic architecture is three-layer architecture [3–5] as shown in Figure 3. It was introduced in the early stages of research in this area. It has three layers, namely, the perception, network, and application layers [13].

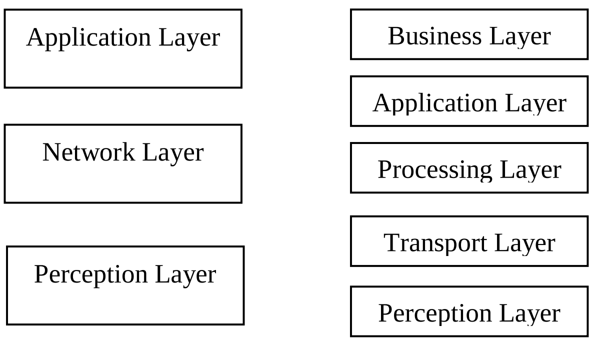

Fig 3 Architecture of IoT

(i) The perception layer, which uses sensors for gathering and sensing information about the external environment and it is the physical layer. It identifies other smart objects and senses some physical parameters from the environment.

(ii) The network layer is responsible for connecting to other smart things, network devices, and servers. Its features are also used for processing and transmitting sensor data.

(iii) To deliver application specific services to the user the application layer is responsible. It also helps to deployed the Internet of Things in various applications, for example, smart health smart cities, and smart homes.

The three-layer architecture gives the main idea of the Iot, but it is not fulfilling the requirement of research on Internet of Things because research concentrates on more finer aspects of the Internet of Things. That is why, we have many more layered architectures proposed in the literature. One is the five layer architecture, which additionally includes the processing and business layers [3–6]. The five layers are perception, transport, processing, application, and business layers (see Figure 3). The role of the perception and application layers is the same as the architecture with three layers. We outline the function of the remaining three layers.

(iv) To transfers the sensor data from the perception layer to the processing layer the transport layer is responsible and vice versa through networks such as, 3G, wireless LAN, RFID, NFC and Bluetooth.

(v) The processing layer is also known as the middleware layer. It stores, analyzes, and processes huge amounts of data that comes from the transport layer. It can provide and manage a set of services to the lower layers. It brings many technologies such as cloud computing, databases, and big data processing modules.

(vi) The whole Internet of Things system, including users' privacy, applications, profit and business models are manage by business layer.

Another architecture which is based on layers of processing in the human brain has proposed by Ning and Wang [7]. It is inspired by the intelligence and ability of human beings to think, feel, remember, make decisions, and react to the physical environment. It is constituted of three parts. First is the human brain, which is analogous to the processing and data management unit or the data center. Second is the spinal cord, which is analogous to the distributed network of data processing nodes and smart gateways. Third is the network of nerves, which corresponds to the networking components and sensors.

7. CONCLUSION

In this paper, we presented a survey of the current technologies used in the IoT domain. Currently, this field is in a very nascent stage. The technologies in the core infrastructure layers are showing signs of maturity. However, a lot more development needs to happen in the areas of Internet of Thing communication and applications technologies. This domain will definitely have impact on human life in inconceivable ways over the next many more years.

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