Internet of Smart Things

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Abstract

The 'Things' in 'Internet of Things' is 'Everything' and 'Anything' we are capable to imagine or fantasize. Internet of things is basically an extension of Internet into physical realm by means of things or embedded devices having unique identification number. A unique identifier is absolutely possible with IPv6, through which it is possible to have literally infinite number of unique identifiers. Technology is always growing and in modern times it is growing at hefty pace. Technological advances made internet easily available in the form of fixed and mobile broadband service at reasonable cost. Availability and affordability of internet coupled with embedded technologies, growth in the field of data mining and RFID technologies have led to development of devices capable of transmitting data without any human help. Although technologies such as 3D printing indicates the inception of Internet of things but significant amount of work is yet to be done in order to truly allow everything to act as things in the Internet of Things. This paper provides current status, architecture and components on which Internet of things will be based, barriers in front of Internet of things and possible smart application of 'Internet of Things'.

Keywords: RFID, Cloud, Sensors, Protocols, Data Mining

I. INTRODUCTION

World Wide Web was found in 1989. First Smartphone was launched in 1994 and with the advent of iPhone in 2007, in came a revolution with the promise to change the way mobile phones were used. There were almost as many mobile phones as the Population of earth in 2013 where as number of connected devices already crossed the population of earth around 2008-2009.

Fig. 1: Internet of Things

The evolution of 'World Wide Web' to as it is popularly known today 'The Internet' and growth of mobile technologies is the reason why number of connected devices is forecasted to be around 50 Billion by the year 2020. Proliferation of connected devices from 500 Million in 2003 to 25 Billion in 2015 along with growth of internet is itself sufficient to corroborate that world is not only expanding rapidly but galloping. Internet of things is poised to evolve as next big thing!

"When wireless is perfectly applied the whole earth will be converted into a huge brain, which in fact it is, all things being particles of a real and rhythmic whole.....and the instruments through which we shall be able to do this will be amazingly simple compared with our present telephone. A man will be able to carry one in his vest pocket", a quote by Nikola Tesla. It is a proof that although the term Internet of things was coined in1999 but Internet of things became a vision in 1926 only. Internet of things is still more or less a vision, a vision to change the future, a future full of smart thing, a future which has the potential to change everything of course including Homo-Sapiens too. The potential impact which Internet of things can produce is something beyond our current imagination. Before exploring potential smart objects or things, first let's consider the current scenario and architecture on which internet can evolve as Internet of things.

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Fig. 2: Map of Smart Things

II. PREVAILING SCENARIO

Wearable gadgets like Google Glass, smart watches, and smart foot wears are enough to substantiate that Internet of things is not a gimmick and sooner or later Internet of things will emerge and for that to happen Internet would act as catalyst. The World demonstrated by science fiction movies might be a reality. The physical things such as towns, hospitals, airplanes, vehicles may soon transform into smart hospitals, smart cities, smart airplanes, smart vehicles etc. However, some of these are very close to being a reality or already a reality, for instance Google has already manufactured a smart car i.e. a driverless car, an smart syringe is on its way which will automatically dispose needles as soon as they are used. As modern internet transform into Internet of things, which has been stagnant for a while then the mundane tasks and things of our daily lives will be taken care of by things themselves.

Fig. 3: Modern Smart Gadgets

III. TRANSFORMATION OF INTERNET AS INTERNET OF THINGS

A. History of Internet Devices:

- In 1832, an electromagnetic telegraph was created by Baron Schilling in Russia, and in 1833, Carl Friedrich Gauss and Wilhelm Weber invented their-own code to communicate over a distance of 1200 m within Gottingen, Germany.
- In 1844, Samuel Morse sends the first Morse-Code public telegraph message "What hath God wrought?" from Washington, D.C. to Baltimore.
- In 1990, John Romkey created the first Internet ‘device’, a toaster that could be turned on and off over the Internet. The toaster was connected to a computer with TCP/IP networking. It then used an information base (SNMP MIB) to turn the power on.
- In 1993, The Trojan Room coffee pot was inverted, which became inspiration for the world's first webcam. The coffee pot was located in the corridor just outside the so-called ‘Trojan Room’ within the old Computer Laboratory of the University

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of Cambridge. The webcam was created to help people working in other parts of the building to avoid pointless trips to the coffee pot.

- In 1998 in Touch was developed. It was a project to explore new forms of interpersonal communication through touch. Force-feedback technology is employed to create the illusion that people, separated by distance, are interacting with a shared physical object. The "shared" object provides a haptic link between geographically distributed users, opening up a channel for physical expression over distance.
- In 2005, the Nabaztag (Now a part of Aldebaran Robotics) was originally manufactured by the company Violet and created by Rafi Haladjian and Olivier Mével. The little WiFi enabled rabbit was able to alert and speak to you about stock market reports, news headlines, alarm clock, RSS-Feeds, etc as well as connect to each other.
- In 2008, a group of companies launched the IPSO Alliance to promote the use of Internet Protocol (IP) in networks of "smart objects" and to enable the Internet of Things.
- It was Tim Berners Lee who brought this HTML, URL together and created the World Wide Web. On 6 August 1991, the World Wide Web went live to the world. The WWW project merges the techniques of information retrieval and hypertext to make an easy but powerful global information system.

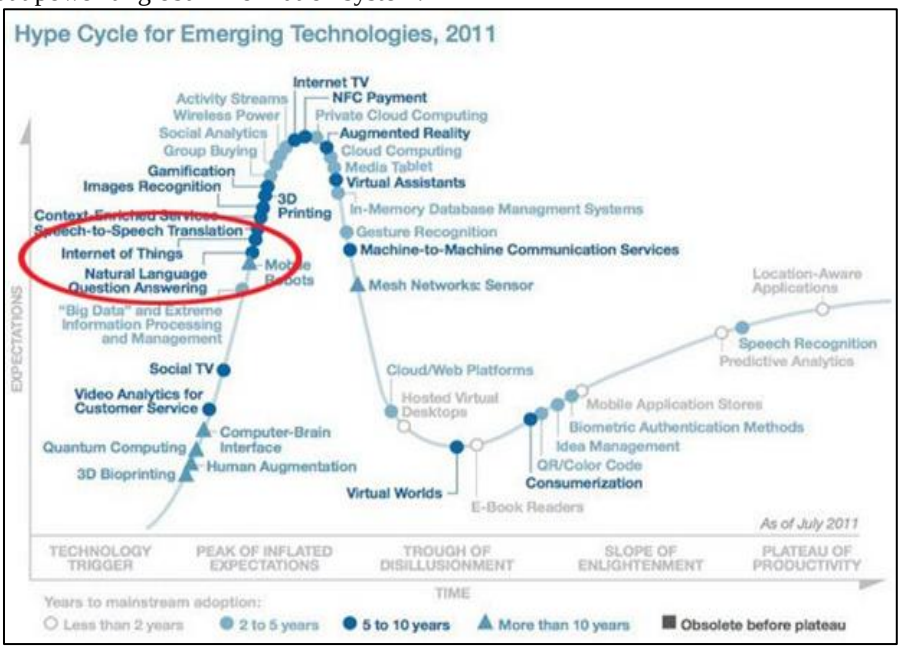

Fig. 4: Hype Cycle for Emerging Technologies

IV. ARCHITECTURE OF INTERNET OF THINGS

A. Layers of Architecture:

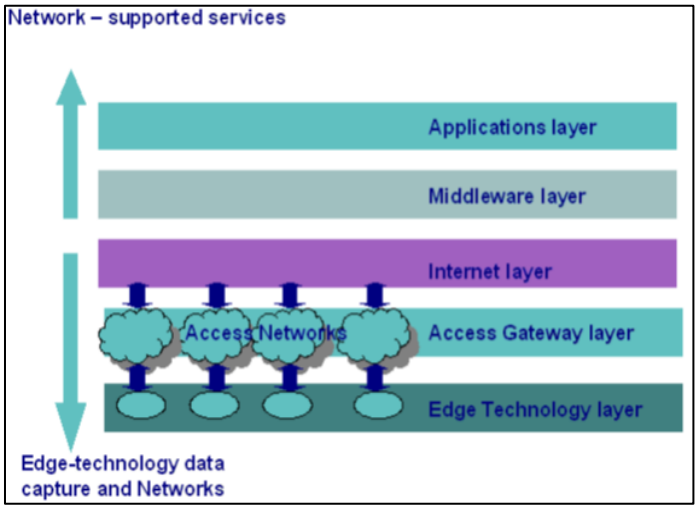

Fig. 5: Layered Architecture Model

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Multi-layered architecture is a way in which Internet of things implementation will be based on. It is designed in such a way so as to fulfill the requirements of every type of user and organization. Edge layer consists of sensor networks, embedded systems, RFID tags and readers or other soft sensors in different forms. These entities are the primary data sensors deployed in the field. First stage of data handling happens at Access gateway layer. It takes care of message routing, publishing and subscribing. Middleware layer acts as an interface between the hardware layer at the bottom and the application layer at the top. It is responsible for critical functions such as device management and information management. Application layer at the top of the stack is responsible for delivery of various applications to different users in Internet of things.

B. Components of Internet of Things:

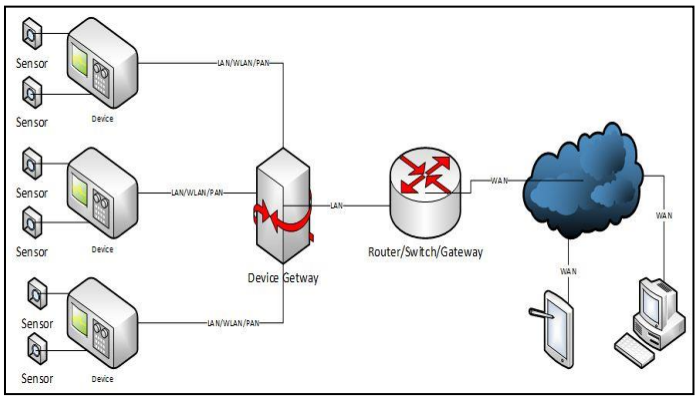

Fig. 6: Components of Internet of Things

1) Communication:

Humans evolve because they communicate. This principle of sharing information and building on discoveries will be a key factor in growth of Internet of things too. Internet of things dramatically increases the amount of data available for us to process. This, coupled with the Internet's ability to communicate this data, will enable people to advance even further. These can be classified under edge technology layer.

a) Near Field Communication (NFC):

It is a short-range, low power wireless link evolved from Radio Frequency Identification technology that can transfer small amount of data between two devices held very close.

b) Frequency Identification (RFID):

A radio-frequency identification system uses tags, or labels attached to the objects to be identified. RFID technology is a major breakthrough in the embedded communication paradigm which enables design of microchips for wireless data communication. They help in automatic identification of anything they are attached to acting as an electronic barcode. RFIDs too can be classifies as Active or Passive.

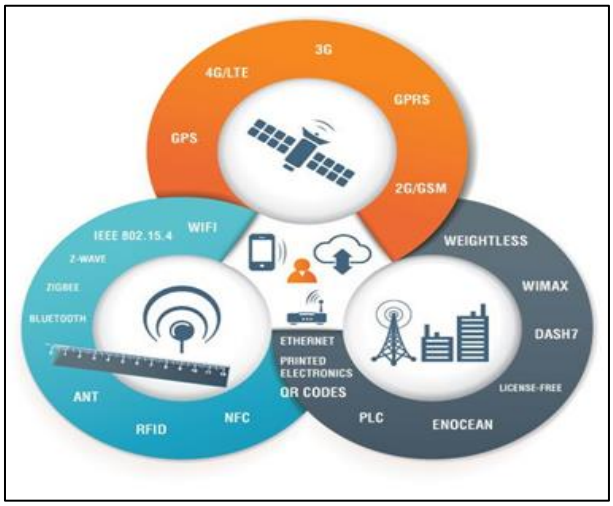

Fig. 7: Communication Technologies

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c) Wi-Fi:

It is a popular wireless technology which uses radio waves to provide high speed internet and network connections.

d) Bluetooth:

A Bluetooth is a wireless protocol for communication in the form of exchanging data over short distances from fixed and mobile devices by creating personal area networks.

2) Backbone:

a) IPv6:

"Internet Protocol version 6 (IPv6) is the most recent revision of the Internet Protocol. With the increasing internet connected devices the need for more IP address also growing as every device on the Internet must be assigned an IP address in order to communicate. But, Unfortunately IPv4 has a limit. Thus IPv6 was introduced which uses a 128-bit address, allowing 2128, or approximately 3.4×1038 addresses."

b) UDP:

"The User Datagram Protocol (UDP) is one of the core members of the Internet protocol suite (the set of network protocols used for the Internet). It uses a connectionless transmission model. In UDP messages sent are referred as 'datagrams'."

c) TCP:

"The Transmission Control Protocol (TCP) is intended for use as a highly reliable host-to-host protocol between hosts in packet-switched computer communication networks, and in interconnected systems of such networks."

d) 6LoWPAN:

"6LoWPAN is an acronym of IPv6 over Low power Wireless Personal Area Networks. The 6LoWPAN group has defined encapsulation and header compression mechanisms that allow IPv6 packets to be sent to and received from over IEEE 802.15.4 based networks."

3) Hardware:

a) Device Gateway:

Device Gateway is the aggregation device for an Internet of things deployment and typically has significant computing and networking capability. This can be categorized as Access gateway layer. In some configurations, the Gateway may also connect directly to Sensor, in such cases gateway also acts as a device. Functions:

1) Accumulating data from multiple devices
2) Routing data between devices.
3) Providing enhanced security.
4) Provides additional computing ability.

b) Router/Switch/Gateway:

It is also a part of internet layer. This component serves as the Gatekeeper between the in-premise networks. Apart from routing and switching, it's another purpose is to partition the network into two parts:

1) Secure/trusted network
2) In-secure/un-trusted network.

c) Sensor:

A sensor detects or measures a physical property and the converts it into some kind of electronic representation. Sensors may be passive or active – with the difference being the amount of intelligence embedded in the sensor.The physical interface between the Sensor and Device can take on a number of different forms. Just a few of these are:I2C, RS-232/485, SPI, Analog, and Dallas One-Wire. According to a study we will be surrounded by about 5000 sensors by 2035.

d) Wireless SoC (system on Chip):

Manufactures like Gainspan, Wiznet, Nordic Semiconductor, TI and others are creating self-contained, RF-certified module solutions that have TCP, UDP and IP on chip. Prototyping boards and platforms from the Arduino to the Raspberry Pi to the new Beagle Bone Black, there are a large number of community DIY and prototyping platforms available that are making it possible to create your own Internet of Things project.

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4) Protocols:

a) LAN/WLAN/PAN:

This component represents the network in a geographically small area (typically a building) and is the glue which allows Devices and Device Gateways to communicate. There are a number of protocol choices and each has its own pros and cons. For distance and speed (at the expense of power consumption), some variant of Wi-Fi (IEEE 802.11 a/b/g/n/ac) is appropriate. For lower range and speed but with lower power consumption (useful for battery powered devices), Bluetooth Low Energy makes sense. Thus, choice depends upon usage.

b) CoAP:

"Constrained Application Protocol (CoAP) is a software protocol intended to be used in very simple electronics devices that allows them to communicate interactively over the Internet. It is particularly targeted for small low power sensors, switches, valves and similar components that need to be controlled or supervised remotely, through standard Internet networks. CoAP is designed to easily translate to HTTP for simplified integration with the web.

c) REST ful HTTP:

"Representational State Transfer (REST) is a style of software architecture for distributed systems such as the World Wide Web. REST has emerged as a predominant web API design model."

d) MQTT:

"Message Queue Telemetry Transport (MQTT) is an open message protocol for M2M communications that enables the transfer of telemetry-style data in the form of messages from pervasive devices, along high latency or constrained networks, to a server or small message broker."

e) XMPP:

"The Extensible Messaging and Presence Protocol (XMPP) is an open technology for real-time communication, which powers a wide range of applications including instant messaging, presence, multi-party chat, voice and video calls, collaboration, lightweight middleware, content syndication, and generalized routing of XML data."

5) Software:

a) Riot OS:

"RIOT OS is an operating system for Internet of Things (Internet of things) devices. It is based on a microkernel and designed for energy efficiency, hardware independent development, a high degree of modularity."Features:

1) Support for 6LoWPAN, IPv6, RPL, TCP, and UDP
2) Built for maximum energy-efficiency and low resource requirements:
3) Min RAM (~ 1.5kB) and Min ROM (~ 5kB)
4) Ability to operate on several platforms (Embedded devices and common PCs)
5) Standard programming in C or C++ and can run both 16 and 32-bit platforms.

6) Data Brokers / Cloud Platforms:

a) Cloud:

Cloud a term used to describe some processing or computing capacity which is hosted by a third party. If the Cloud is private, then the hosting service is performed by the same organization using the service. Cloud will play a crucial part if Internet of things has to be realized because data is increasing day by day and as per a current approximation there exists an Exabyte of data which will be infinitesimally in comparison of data 20 years from now.

b) ThingWorx:

"The ThingWorx platform provides a complete application design, runtime, and intelligence environment - allowing organizations to rapidly create M2M applications and innovative solutions that unleash the value found at the intersection of people, systems, and intelligent connected Things."

c) EVRYTHNG:

The EVRYTHNG Engine provides high scale, industrial technology to create and serve millions of Active Digital Identities™ for a company's products and other objects. These unique online profiles create a persistent, unique digital presence for any physical object on the Web. Think of a Facebook for Things™ where individual objects, just like people on social networks, have their own unique digital profiles that enable communications, apps and services."

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d) Sense:

"Open Sense an open platform for all those who want to imagine, prototype and test new Devices, Installations, Scenarios, Applications for this globally interconnected and immersive world. Designers, developers, tinkerers, students, hobbyists, R&D departments, artists, self-quantifiers, dataviz maniacs, whatever your skills are, we tried to make Open.Sen.se easy to use and yet powerful for you. Needless to say Open Sense is free.'

7) Machine Learning:

a) Grok Engine:

"Grok is having a high level of automation in analyzing streaming data, the ability to learn continuously from data, and the ability to drive action from the output of Grok's data models. These three unique capabilities help in overcoming with bottleneck problems. "

V. CHALLENGES STOPPING OBJECTS FROM BEING SMART

Emerging technologies such as NFC, Real-Time localization, and embedded sensors along with internet is helping in transformation of everyday objects into smart object. This trend won't stop as either more effective technology continues to emerge or current technology gets better. Smart objects will be the stepping stone over which internet of things will be built thus, the term internet of smart things.

Contemporary Smart Objects or things work separately, though it is still having a profound impact on our society but to achieve the ultimate target of creating a community full of smart things or a smart community indeed inter communication between these are a must. Although there has been a lot of research in this direction but still there are few stumbling blocks ceasing Internet of things to reach where it's destined to.

Fig. 8: Interconnected Technologies

A. The Bottleneck Problem:

Yes, Data Mining is a big barrier in front of Internet of things. A fact, there is an Exabyte of data; now considering the future events this will increase substantially. Reason behind this substantial increase of data would be presence of too many sensors and too many devices. Mark Weiser once wrote in an article that, "The most profound technologies are those that disappear. They weave themselves into fabric of everyday life until they are indistinct from it". As per predictions by 2032 number of sensors should be anything around 3000 to 5000.It is beyond our current imagination for us to imagine mammoth amount of data. There are 4 phases in data life cycle: Acquisition, Architecture, Analysis and Archival. Now, apart from Analysis problems present in rest of the data cycle have been more or less solved, thus, leaving Analysis of data i.e. nothing but Data Mining.

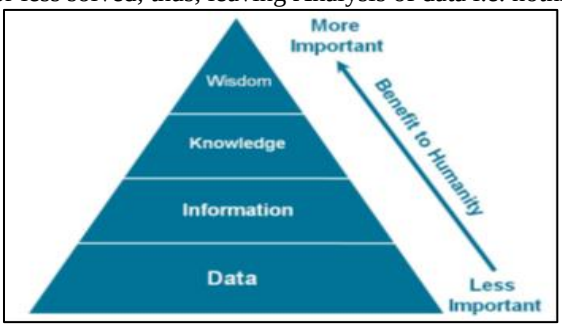

Fig. 9

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Internet of things dramatically increases the amount of data available for us to process. The more data that is created, the more knowledge and wisdom people can obtain. This, along with the Internet's ability to communicate this data, will eventually benefit humanity. Microsoft's Azure Machine, Azure Intelligent Systems Service (ISS) and HDInsight along with few others could be our way of this bottleneck.

B. Too many Things:

Although this is very sure that path to Internet of Things will be guided by Smart Objects only but how many devices are too many?

According to Mark Weiser Devices need to be indistinct-able, now people should not feel that there are actually smart objects, they need to merge with life style behave as if they were ordinary not something flashy. Moreover no one would like to wear 20-30 wearable's.

VI. TOO MUCH DATA

Where exactly enormous amount of data will be stored? Although memory is getting cheaper and hard disks are getting bigger in terms of storage, there are data warehouses yet possibly a data-ocean is required to store huge amount of data, keeping in mind there will approx 50 Billion devices as soon as 2020. So, now imagine data by 2030 or 2035. Also, the type of data is not an issue now but with growth of smart objects separate infrastructure for these of data has to be developed.

VII. STANDARDIZATION

Lack of protocols and standards could hinder the growth of Internet of things. It is not only essential to fully harness the potential of smart objects but also to be able to communicate with across all platforms as obviously all the smart things won't be based on same platform and auto-communication between things via Internet is the essence of Internet of things.

VIII. CONSUMER PRIVACY

With so many sensors around a consumer, how does Internet of things guarantees privacy? If vision of Internet of things is to be accomplished then consumer privacy has to an integral part it or it cannot sustain, a consumer won't buy the product developed lacking privacy.

IX. DATA BURDEN ON SERVERS & DATA CENTER NETWORKS

Existing servers and data center wide area networks are built to handle the current use of technology; the bandwidths are built for moderate data handling unlike in future where to handle incoming data both servers and WANs need to be upgraded and this needs to happen soon as without Data center and serves Internet of things cannot survive or even if it does won't be able to fulfill tasks it was built for.

X. THE REVISED IP

Revision in Internet Protocol was done as IPv4 won't be able to manage demand of IP address in the near future. So IPv6 was introduce which is very capable of handling approx. 3.4×1038 addresses number of IP addresses. While IPv6 is the future, its global roll out is yet to happen and IPv6 is a necessity because each smart thing needs have unique identifier.

XI. SECURITY OF THINGS

This is the ultimate issue and biggest threat in transforming 'Internet of Nothing' to 'Internet of Things'. Here are some security threats which Internet of Things needs to overcome to transform our future into a smart future.

A. Context Based Security:

This is not exactly a threat with respect to privacy but more with respect to changes in context of a smart object brought due to implementation of security frameworks.

For Instance, security framework requires that before data is exchanged with another thing, data needs to be encrypted in a certain way. Now if this encryption affects data quality smart object won't be able to provide smart service.

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B. Reliability

For Internet of Things to succeed gaining trust of consumer is a must. Lack of reliability is menace to consumer. To demonstrate this, consider if somebody could gain access to a heart patient's pacemaker, imagine the possible consequences.
In hospitals, Intense Care Unit has equipments like dialyzer, defalcators etc. and unauthorized control over these life saving equipments could turn life-saving devices into life-demolishing devices. There could be several other instances of this like unethical access to a Google Car could destroy lives of innocent.

C. Unauthorized Access of Essential Data & Documents

Cyber-attacks are one of key issues which we are facing currently and it will be an important security threat with Internet of things as well. After all automatic communication of things makes Internet of things a hot prospect so, security while communication needs to be addressed with utmost importance.

D. Identification

Internet of things sensors should be able to do proper identification of authorized individuals and things are important if Internet of things is to be called as Internet of Secure Things. Identification should be accurately checked irrespective of the surroundings, this is the building block for ensuring legitimacy and reliability.

E. Anonymity of User Data

Data present in data centers should be anonymous to any other person accept the person himself or the recipient for which data is intended for.

XII. SMART APPLICATIONS

A world of Internet of Things rests on the shoulder of smarts objects.

A. Smarter Body

This is a personal application of Internet of things, in which there are sensors connected to body in the form of wearable's. Although there are wearable's like smart watch which can help with monitor Heart Rate, Blood Pressure etc. But few more applications are possible like:

Infant Monitor: It is aimed at keeping in health status at check by providing real time Information like pulse rate, temperature and many other details to parents.

Smart Pill Box: It is aimed at providing information like name of medicine, precautions, side-effects, composition etc. to patients and doctors.

Personal Doctor: It could continuously monitor activity level of body and based on detection of symptoms provide an advance warning of what could happen in near future and thus safe guarding lives.

B. Smarter Home:

1) This is another personal use of Internet of things. Homes are already smart with surveillance, and CCTVs. But then definitely other things such as Smart Electricity Management can be done by detecting any human activity in the room. This is possible by Heat Map.
2) Sensors can be installed to sense if there is a gas leak, water leakage or any other incidents which could lead to disasters.
3) Already we can control lights with our smart phones, in future gestures could switch on/off the lights.
4) Controlling Home remotely, like pre heat oven, control room temperature either by switching on Air conditions or heaters. Smart thermostats could be used to do this. Appliances could signal to user in case something is faulty within their system.

C. Smarter Town:

This is an application which would ease lives of people as well as workers in the town.
1) Street Lights:
Sensors in street lights could detect the presence of light in the surroundings and then providing lights as per the requirement. Especially when it's raining, dark clouds reduce visibility and as of now street lights are not lit up in that scenario.

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2) Waste Management:
A smart dustbin could classify waste into organic into inorganic substance so as to make decomposition is easy. In Current scenario waste is dumped to decompose without any separation and harmful gases are released in atmosphere.
3) Pollution Sensor:
Sensors could check impurities in air and if pollution level increases beyond a threshold value, it would communicate with officials and also suggest the cause, so that pollution could be mitigated taking necessary action.
Smart City Map: City Maps could be installed at several places within the city. It would help tourist and even citizens with information they need in real time. For instance, it could show the route of the destination by guiding through the video.

D. Smarter Enterprise:

A crucial application would be an industrial one. Industries are already automated accept things like quality check and some critical tasks are done by human. But, Internet of things could be game changer for industries:

Safety of Workers: If at all industries require humans to do some work, sensors present in the industry could continuously check for harmful gas leaks like NO2, Co etc. and protect employee's lives.
Maintenance: Continuous monitoring of machines to check if any machine needs repair work, this could avoid any potential disaster or delay in work.

Monitoring: Monitoring could be used in retail stores to know which products are the best sellers by putting sensors on products themselves. It will be an easy way to keep a check.Monitoring could also be done in the case of new buildings; they could be used to do quality checks.

E. Farming:

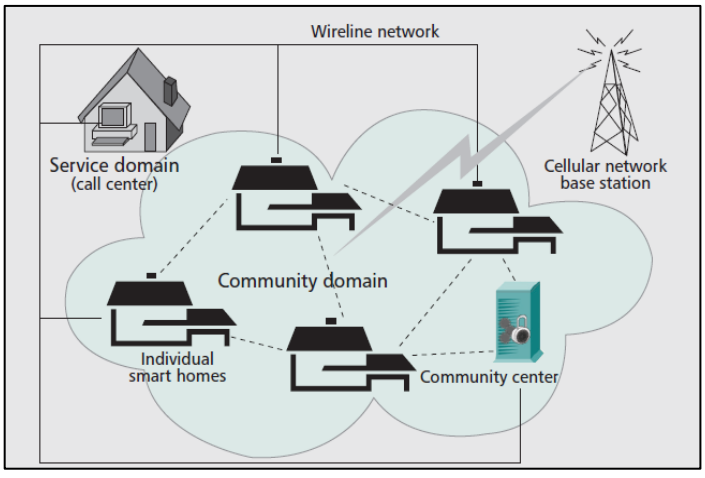
This could change fortunes of farmers. Not only they can keep a check on pests and track status of plants to avoid destructions of plants due to drought.

F. Smart Environment Protection:

Already mentioned pollution checker, along with it sensor to check water levels, oxygen levels etc.

G. Smart Community:

Finally a smarter community, of course it will include all the above but here is a snapshot of smart community architecture. Smart Cities, hospitals, prisons and many more combine to form a smart community which is the ultimate goal of Internet of Things.



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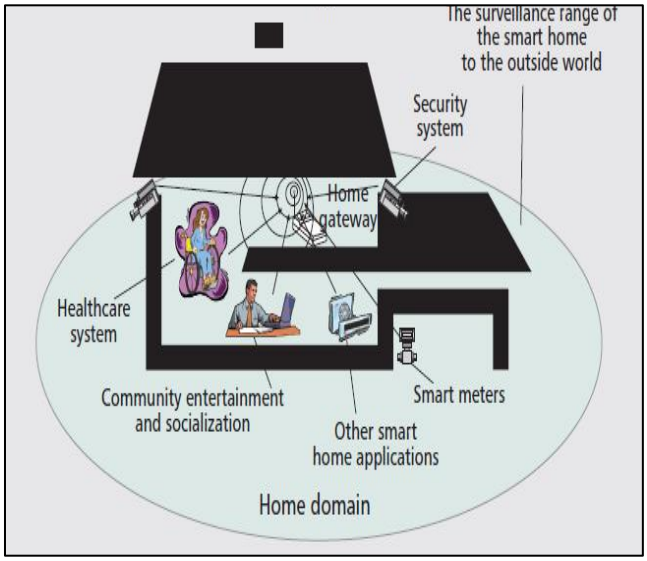

Fig 10: Smart Community Architecture: Community Service & Home Domains Respectively

XIII. Related Work in Smart Objects

1) Bruce coined the term 'spime to describe a new category of space-time objects that are aware of their surroundings and can memorize real-world events
2) Julian Bleeker advocated a similar notion of 'blogjects'(objects that blog) in his "Manifesto for Networked Objects." This more visionary work has been met by a growing body of technol¬ogy- and business-focused research on RFID, smart objects, and smart products.
3) Friedemann Mattern formulated in a similar way: "Smart objects might be able to not only to communicate with people and other smart objects, but also to discover where they are, which other objects are in the vicinity, and what has happened to them in the past."

XIV. Conclusion

With Internet of things set to be the next big Thing, possibilities are infinite; Internet of things has the potential to transform thinking into reality. Thus, in this sense limitation is within our mind. With this being said, still there are hurdles, which Internet of things needs to overcome in order to become the force of future, a force which will be a leap from internet of virtual things to internet of real physical things. Internet of things is still in early stages of research, but important thing is that 'things' have started, and with each day passing there is an increment in research work on Internet of things. Numerous independent groups have started their approach in this direction such as upgrade of IPv4, introduction of Open Sense, Grok Learning, 6LoWPAN, introduction of smart gears, getting new patents for data management products. Internet of things must survive challenges and become an integral part of our future, Internet of things should be developed with the motto that it is greatest gift for every specie in the planet.

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