Communication of Multifarious Devices through Internet of Things and their Organization

Sharat Sharma S, B R Prasad Babu

Abstract- **The Internet is an always changing and ever evolving entity. The broadband connectivity has become cheaper and ubiquitous while the devices are becoming smaller and powerful. These kind of powerful devices are getting connected via Internet which leads to a paradigm, the Internet of Things. The Internet of Things allows the interaction of heterogeneous devices through internet to achieve a common goal. The objective of the Internet of Things is to expand the Internet by including physical objects that have the ability to provide smarter services. The Internet of Things benefits various application domains ranging from energy efficiency to logistics, from grocery shopping to health care. There are a few challenges since this paradigm can be subjected to disasters; outages and other adverse conditions. Hence the devices must be resilient. The Internet of Things is under the agenda of research of several European and Asian countries. This paper provides a survey of the enabling technologies and the organization of the Internet of Things.**

Index Terms- **Internet, Internet of Things, Self Organization, Sensors, Smart devices**

I. INTRODUCTION

As the technologies are evolving, our society is advancing towards an *always connected* paradigm. We use a wide variety of gadgets in our daily life. These include mobile phones, sensors, measuring devices, laptops, tablets and many others. In the near future these devices will interact with each other through Internet. These interactions will be carried out to achieve a common goal. The devices being referred to as things, the ecosystem is called as the Internet of Things (IoT). To simplify this, IoT is connecting anything at anytime from any place through Internet. Figure 1 shows the dimension of the IoT.

Since this paradigm is heterogeneous, the integration of the devices and their services is a problem. Each device in the Internet of Things is independent. The IoT may be part of many independently existing systems and the devices of different systems in IoT may interact with each other [1] as shown in Figure 2.

The figure 2 shows the ecosystem of the IoT. The ecosystem may consist of different environments in which devices are deployed and connected to the Internet. Each device of these environments can interact with the devices deployed in other environments. A few examples of the interactions are

1) The temperature and humidity sensors adopted in home can interact with the heart monitoring devices implanted
   inside the human body which is connected to the Internet provides the real time logs to the cardiologist for remote health monitoring.

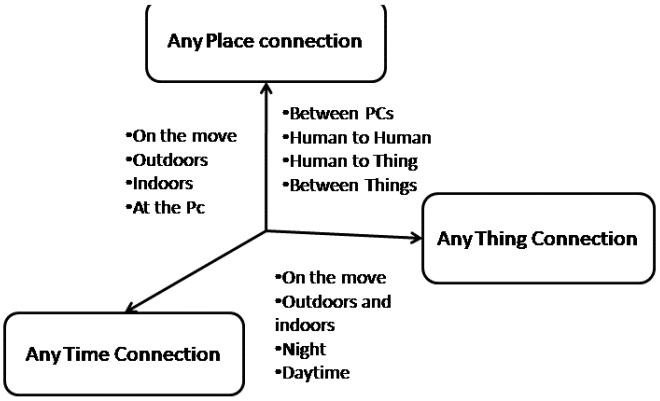

Figure 1: The Dimensions of Internet of Things

2) Solar panels have energy monitoring sensors which can communicate with the smart grid operator to maximize the utilization of green energy resources.
3) A network of sensors set up throughout a vehicle can interact with its surroundings to provide valuable feedback on local roads, weather and traffic conditions to the car driver, enabling adaptive drive systems to respond accordingly.
4) The interactions among the devices must be standardized. Understanding the need for data from these devices during the times of disasters and cyber or physical attacks is equally important. During these times the communication systems or the energy resources provided may fail thereby do not allow realizing the potential and the benefits of IoT. Thus there is a need to setup a robust communication network through self organization.

The vision of the IoT is that the objects which are uniquely identified, accessible to the network, whose position and status can be known become the part of Internet where intelligence and services are added to this expanded Internet which has an impact on the social, personal and professional environments. The concept of IoT is nothing but combining the physical objects to create a digital world.

The self organization process and its benefits are explained in the later sections of this paper. The remainder of this paper presents an overview of Internet of Things, its evolution, its application and potential benefits. Section 2 presents the reason for evolution of IoT. Section 3 presents the Implementation methodology. Section 4 covers the self organization technique used to provide a robust communication system. The applications and case studies are presented in the following sections. Finally the conclusion ties the threads presented in the paper together.

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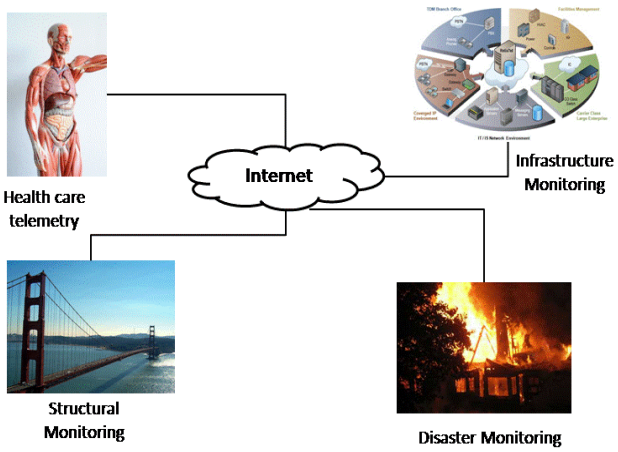

Figure 2: The Eco System of Internet of Things

II. THE EVOLUTION

The internet was originally started as internet of Computers. The global network with services, says World Wide Web, was built on top of the original platform. The Internet then gradually changed to the Internet of People. This led to the creation of concepts like Social Web where the content is created and consumed by millions of connected people. The best example for a social web is Facebook which has about 500 million subscribers across the globe. It is evident that the Internet of present day has taken a long leap from the primitive Internet of Computers.

The advance in the technology is a rapid process. This is expanding the boundaries of the Internet. The expensive broadband and internet connectivity are getting cheaper day by day everywhere. The devices are becoming smaller while their processing power and storage capacity is rapidly increasing. The PCs are being replaced by smart phones and tablets. These devices are also fitted with sensors and actuators which can make the devices to sense, act and compute and thus become a successful part of the Internet. The devices are also being fitted with tags such as Radio Frequency Identification (RFID), Quick Response Code (QR Codes), Global Positioning System (GPS) and so on to make them more intelligent. [2] Thus the Internet now has taken a further step which is been coined as Internet of Things.

The Internet connectivity began to proliferate in enterprise and customer markets in 1990s.Gradually the Internet began to become a part of many enterprises due to the improvements in the network performances. However, the devices connected through internet still required human intervention and monitoring to manage applications and interfaces. To make things simple and avoid human interactions a new technology called Internet of Things was adapted wherein the smart devices equipped with sensors and actuators communicate with each other to form an intelligent network.

The Internet of Things is one of the most important and powerful creations of human history. This has a strong impact on the education, business, science, communication, government and so on. By 2020, it is expected that about 50 billion heterogeneous devices will be connected to each other via Internet. [3]

The Figure 3 gives the overview of the components of the Internet of Things. The things have tags. The scanners can identify and retrieve the location information of the things. Networked things with scanners and actuators are smaller which can communicate status and events to a higher level service from a local network. Thus smart things can sense activity and link it to the IoT. The frameworks and middleware which enables the application and service deployment receives the data from the smart things. Most often these reside in the cloud. They are responsible for giving better services since they provide the capability to add intelligence to the data received from the local environment.

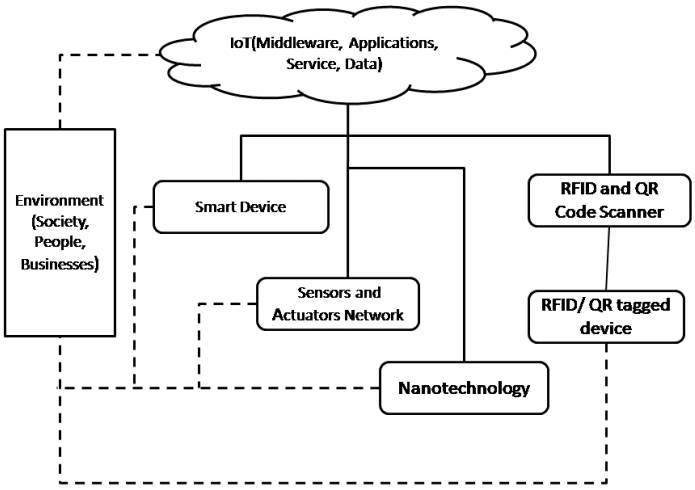

Figure 3: Components of internet of Things

After the intelligent processing of the data, the services like decision making and actions could be create more smartly. The IoT represents the next generation of internet in which smart devices themselves can sense, gather, analyze and process information which can be turned into knowledge and ultimately wisdom.

III. DESIGN

When the things have to be embedded with the networking capabilities, certain architectural decisions are to be made which guarantees the scalability, security, future proof and viability of the IoT for businesses and the end users. The best approach towards the architecture of IoT is The Internet Protocol (IP). Although this is not a 100% perfect architectural model, the researchers are expected to enhance the protocol suite. The IP is chosen due to certain reasons. Devices can be deployed onto the internet on a very large scale. All types of traffic including critical traffic like voice and video can be handled in both centralized and distributed deployment models. IP runs on most of the industry standard network links available and hence interoperable. [4]

The IoT architecture can be analyzed as a four layered model comprising of the layers as shown in the Figure 4. The four layers are Sense and Identification Layer, Network construction Layer, Management Layer and Integrated Application Layer which are used for information generation, information transmission, information processing and information application respectively.

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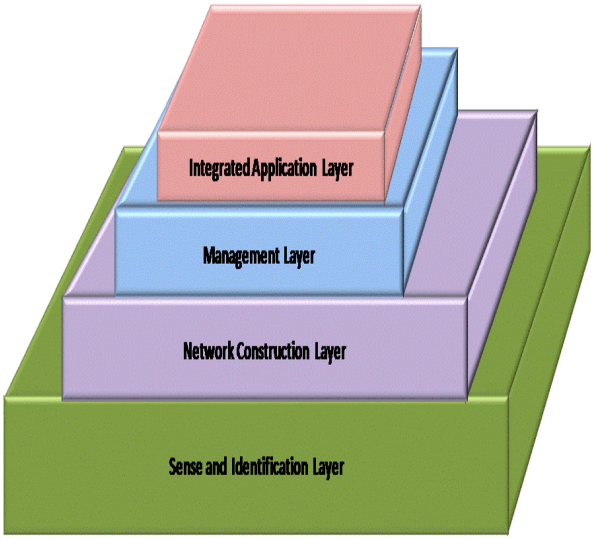

Figure 4: The Four Layer Model for Internet of Things

The Sense and Identification layer comprises of the smart devices equipped with sensors, actuators and tags like RFID, GPS, NFC etc. The main functionality of this layer is to sense the activities and to indentify the information resulting from the activity. This is the lowest level of the four layered model. Next to the Sense and Identification layer, there is a layer which comprises of wide variety of transmission protocols including WWMAN, WMAN, WPAN, WLAN etc. The purpose of this layer is to transmit the information sensed by the sensors for further processing over the Internet.

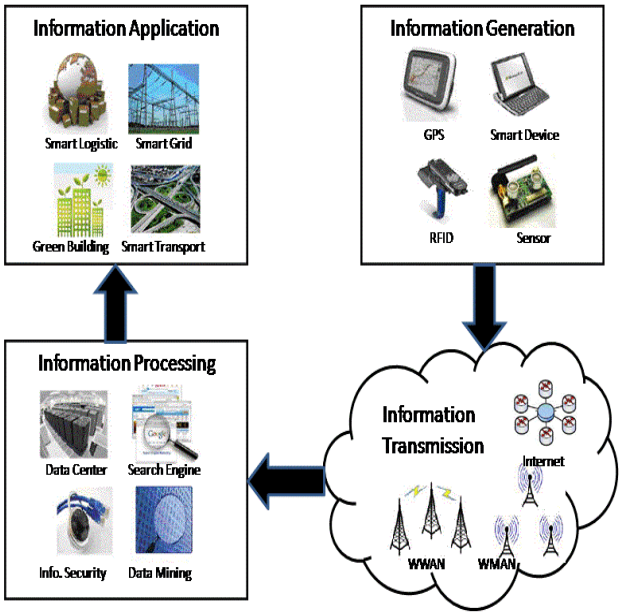

Figure 5: Description of Four Layered Model

The Management Layer is responsible for information processing and finally the Integrated Application Layer exploits the wide range of applications that is provided by the IoT. These applications include Environment Monitoring, Smart Transport and so on. The detailed structure of the four layered model is given in Figure 5.

IV. FRAMEWORK

The IoT is a technology which is achieved by integrating several other technologies. These underlying technologies which contribute to the IoT are called Enabling Technologies of the IoT. The State of the Art of these Enabling Technologies is as shown in the Figure 6.

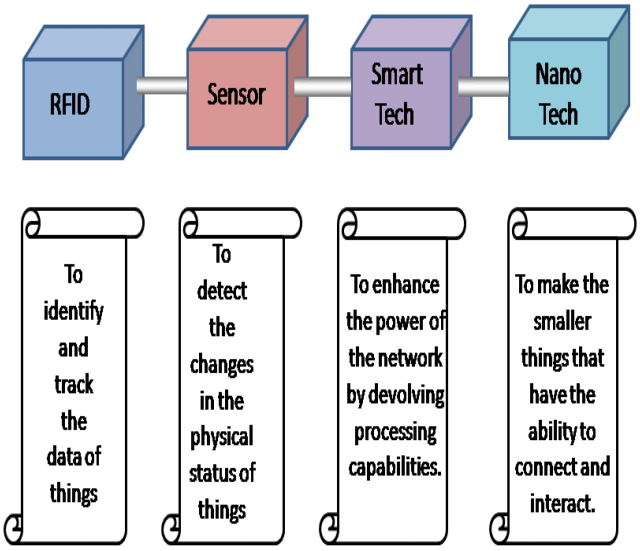

Figure 6: State of the Art of Internet of Things

Mainly four technologies are discussed here. The Radio Frequency Identification (RFID) is used to identify and track the data of things like the location information. Sensors are used to collect and process the data to detect the changes in physical status of things. The Smart Technology enhances the power of the network by devolving processing capabilities to different parts of the network. The Nano Technology makes the things having the ability to connect and interact smaller.

The IoT framework is based on an Event Driven Architecture (EDA). The EDA is a software architecture which is mainly based on the real time flows. This architecture promotes producing, detecting, consuming and reacting to the events [5]. Since the IoT is mainly based on the sensing, identification, transmission and the processing of events, the Event driven Architecture can be applied.

The architecture of the IoT is as shown in the Figure 7. The architecture can be divided into three layers namely the Physical layer, The Event Driven Framework and the Applications layer. The Physical layer contains the smart devices, things and sensors which produces and detects the event. To record the changes in the environment, it is essential to be able to detect the changes in the physical status of the thing. The wireless sensor technology enables the things to respond to changes in their physical environment and thus play a vital role in bridging the gap between the physical and the virtual worlds. The Event driven framework consumes the events and reacts to the events. The top level Applications layer has the applications which have resulted from the lower level layers.

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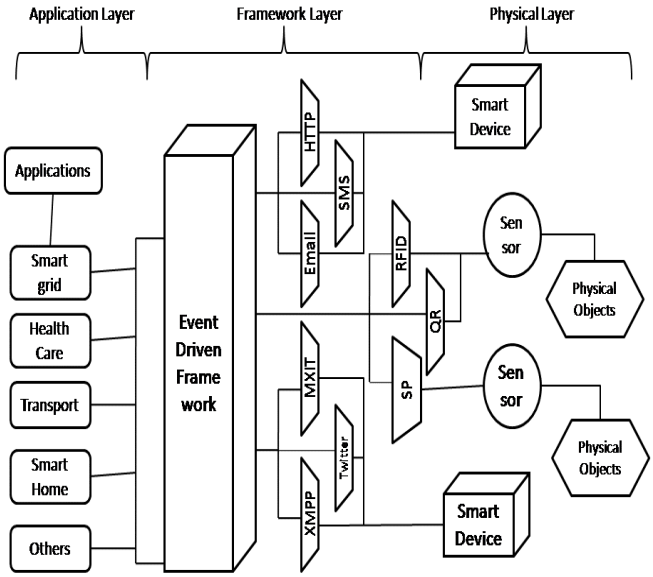

Figure 7: The Architecture of Internet of Things

V. SELF ORGANIZATION IN IoT

The devices which are envisioned in the IoT paradigm form a part of heterogeneous network. The things are heterogeneous not only in the computation capability point of view but also with respect to the network and communication methodology used to interconnect with the other devices on the network. In order to handle these heterogeneous devices, their self organization is very essential. The Self Organization can be achieved using five key components [6]. The components are discussed below.

a) *Discovering the Neighbors*: The IoT is deployed in networks which are generally hierarchical. That is, the sensor network setup within a building report the data to a nearby sink and the sink then reports the data to the building's sensor network gateway. It is similar to a group of slave devices communicating recursively with the master device [7]. The sink must be aware of the presence of the downstream devices and collect data from them and forward them to upstream devices. This is not possible in case if one or more devices fail. So, the peers must be aware of the operational status of the devices in the IoT paradigm. In case of failure or an event that triggers self organization, the peers can seek connection and can cooperate with the distressed device to support its communications.

b) *Access Control*: When one of the network nodes is accessing a channel, no other nodes of the network must be able to access the same channel. It is the responsibility of the medium access control to ensure that a channel that is accessed by one of the nodes is reserved only for that device. The access control can be done using two methods. First by polling method that is by allowing a device to use the channel for a specified schedule [8]. Other way is random access where the channel is accessed randomly. The devices check if the medium is being accessed by other devices, if no then the device makes use of the channel. The medium access control is one of the important perspectives in the self organization of IoT.

c) *Clustering:* The discovery of neighbors or the nearby peers is alone not sufficient for coordination and self organization. Many applications require multi hop communications to reach the internet or network service because of the limitations of access control and increased propagation distance. The upstream devices have the capability to haul more traffic than the downstream network connected devices. Hence to provide more scalability in self organization, the nodes are organized into local groups called clusters. Each cluster has a cluster head. The cluster head can communicate with other devices in the cluster via one hop or multi hop. Further the cluster heads are connected in a mesh topology so that they can communicate with data collectors and thus achieve scalability.

d) *Recovery Management:* The devices may fail during disasters, outages or even during normal operations. Once the device fails the connections and services supported by the device dies. Since there is clustering in the network, self organization has more advantages [9]. The cluster head maintains the global knowledge and hence the other nodes need not maintain the global knowledge. Thus it reduces on board memory. Since the clusters are interconnected through a mesh topology, the node failures can be repaired by routing the traffic via other nodes in the cluster. The cluster heads can also perform statistical operations on the data from the cluster's devices.

e) *Optimizing Energy Consumption:* All the sensing devices are powered by energy lines. In case if the energy lines fail, the self organized network has to depend on the battery power. In this circumstance optimizing energy consumption becomes necessary. If the energy is not managed properly the devices might start to fail due to lack of energy. In wireless sensor networking community, the energy management has been studied with an aim to optimize energy for various constraints [10]. Light weight operating devices have been designed to conserve energy. The energy consumption also depends on the selection of cluster head since it is the node which consumes maximum energy.

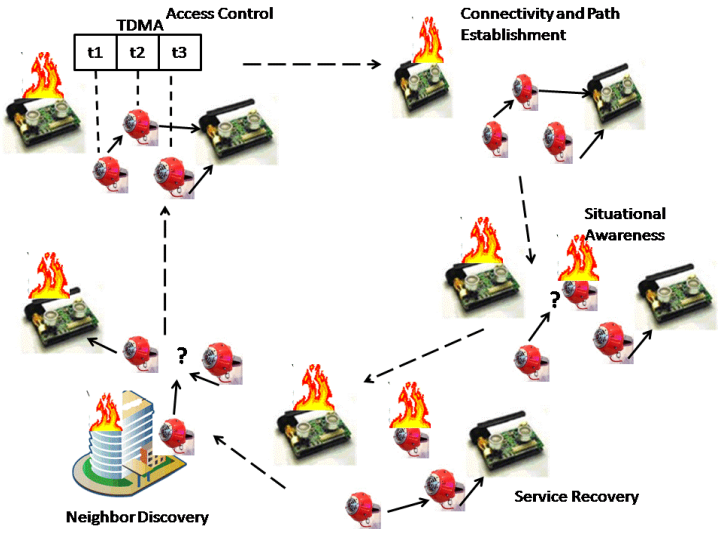

Figure 8: The Self Organization in Internet of Things

The Figure 8 illustrates the self organization in the IoT. When adversarial conditions trigger the self organization process, the devices in the network which are closely monitoring their environment, discover their neighbors,

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connect with them, cooperate for medium access, monitor their faults, do fault recovery and re- establish the service. Hence the network is self organized.

VI. APPLICATIONS of IoT

As the usage of IoT is getting more, it is has potential for economical and social impacts. IoT is being implemented in numerous fields ranging from logistics, transport telemetry, health monitoring, disaster monitoring, critical infrastructure management, structural management, smart environment, defense and even agriculture. Today's IoT is a collection of loose and desperate purpose built networks. For example, a car may have separate networks for engine control and to maintain safety measures. Similarly a smart home may have different networks for temperature monitoring, telephone, security etc. As the IoT evolves, all the networks may be again interconnected to form a network of networks [11].

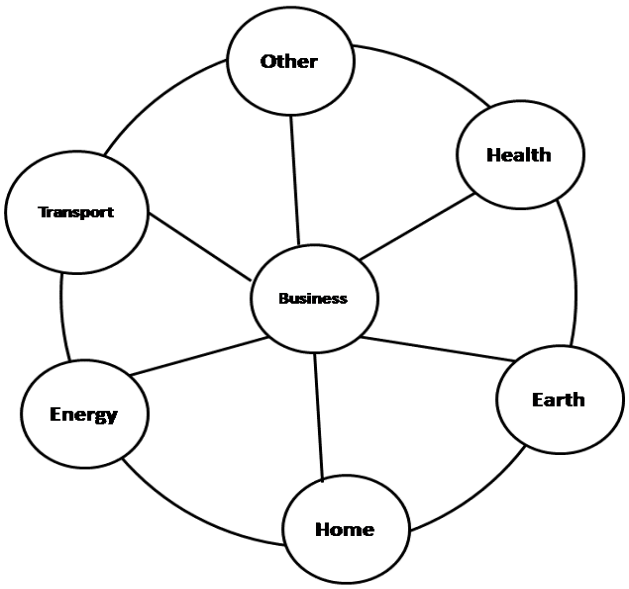

Figure 9: IoT as Network of Networks

The IoT helps in the dynamic control of industry and daily life. Since everything will be connected to a network, people can lead a sophisticated life without the need of controlling everything manually. By the virtue of environmental monitoring using IoT, a better understanding between the humans and nature can be achieved. The IoT forms an intellectual entity by connecting human society to the physical objects thus creating a smart environment.

A) *Application Scenarios*: There are many instances in which IoT is applicable. Here are a few scenarios of the application of IoT [12].
   1) *The Shopping Scenario*: A lady enters a store for shopping. While entering through the door, the scanners scan the tag on her clothes. They notify her where similar kind of clothes can be purchased at a cheaper price. When she is walking through the racks, the items introduce themselves to her including their manufacturing date and price. When she takes out one of the shelf, the reader notifies the staff to put a new one in its place. When the lady is checking out, the microchip on her credit card will communicate with the checkout reader and makes smart payment.
   2) *The Health Care Scenario:* To monitor the brain condition of a patient, a biodegradable micro chip can be implanted in his brain cavity. The sensors in the micro chip sense the variations in the brain pressure. The external RF readers supply power to the sensors and other electronics equipped in the biodegradable material. Whenever there is a variation in the brain pressure, the sensors notify the RF readers and in turn the RF readers can notify the medical expert.
   3) *The Transportation Scenario:* A car is set up with a network of sensors which can interact with the local environment and provide feedback on the road condition, weather and traffic conditions to the driver so that he can adapt himself to the driving condition. If the car is in automatic driving mode, the automatic braking system and speed control may be activated. Condition and event detection sensors may also adjust the air bags and the seat belt pre tensioning for the comfort of the driver as well as the passengers. A set of mood detection and facial indicators can determine the driver's behavior as well as conditions like fatigue or drunken state and alarm the warning system or directly take control of the vehicle to ensure the safety of the driver.

B) *Challenges in IoT:* Any advance in the technology cannot be achieved easily. There may be a number of hurdles and challenges that have to be faced before advancing. IoT is no exception. There are a few challenges that are to be faced [13]. They are
   1) *Architectural Challenge:* IoT involves a wide range of technologies. Various smart devices like sensors, actuators, smart phones, tablets etc are connected in the same network. Also, the devices like mobiles and tablets make the network more decentralized which forms a barrier for the simplified design of architecture of IoT.
   2) *Technological Challenge:* Different applications and environments need different networking technologies. Since the Iot is an integration of different type of technologies, each technology has to be treated separately and reliability must be maintained. Providing security is also a barrier because the communication involves thousands of devices with a wide range of communication mechanisms.
   3) *Expensive Hardware:* Since inter device communication leads to smart systems with high degree of intelligence, all the hardware in IoT must have the ability to communicate with each other. Any hardware must have the two properties which are; the device must consume less power in sleep mode and must be of low cost. Since IoT terminals are never kept in sleeping mode, the power consumption is always high. Traditionally it is observed

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that low cost devices give low performance. To achieve high performance, the IoT hardware is always expensive.

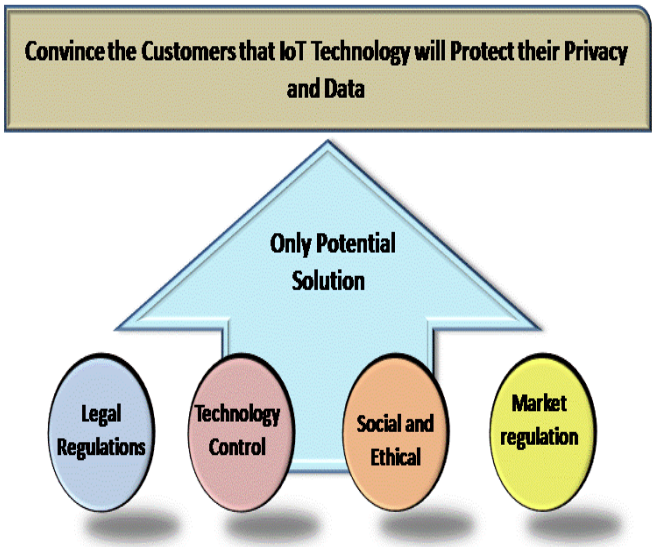

Figure 10: Potential Challenges of IoT

4) *Privacy Challenge:* In comparison to other networks, the IoT requires more security because it contains personal information of the individuals using it. The nodes involved in the network are also very large which forms a major setback in providing security. Researches are being carried out to design a low cost, low latency encryption algorithm for IoT.
5) *Standardization Challenge:* Standardization is very necessary for all the end users to equally access and uses the network. The main drawback of IoT is that it does not have proper standards. Technological standards in most areas still remain fragmented.
6) *Marketing Challenge:* Unlike mature applications, the business model and the application scenarios cannot be modeled into business- technology alignment in IoT since there are too many possibilities and uncertainties in this technology. Though small scale applications are profitable in some industries, large scale applications are not salable yet.

VII. CONCLUSION

This paper introduces the evolution of the Internet through various phases from Internet of Computers to the Internet of Things. It also describes the advancement in technology of internet which was once used only for the communication between two persons is now being used for the communication between two devices. This paper also provides an overview of the design and architecture of the Internet of Things. The key components for the Self Organization of the network are also briefed. The applications with a few application scenarios are mentioned. The challenges of IoT are quoted.

The IoT is an ever growing technology. Many popular Universities like the Stanford University, Cambridge University and Chemnitz University of Technology are carrying out research on IoT. Multi National electronic and networking giants like Nokia, SAP, IBM, Google, Ambient, Siemens, SUN, Cisco and GE are providing aid to research in this field.

The Internet of Things Services all aspects of the future internet. The world is just at the beginning of an interesting journey. The day is not far when the whole world gets connected to the internet. The journey may be difficult but the future is very bright.

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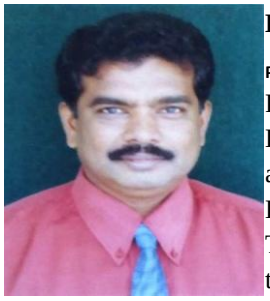

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