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The Internet of Things: The Reality of Tomorrow

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Abstract:
The Internet of Things (IoT) is a vision which aims at creating a highly interconnected and intelligent environment. The development of sensor networks and wireless communications are gateways to the emerging smart world which is an imminent future possibility. Presented here is an exhaustive summary of the revolutionary technology of the Internet of Things. We have discussed and analyzed its various aspects right from the technologies which form its basis to the challenges that this technology faces for its effective implementation in today's world. We have also discussed one of the models of the architecture called the three-layer architecture of the IoT that attempts to demystify the functioning of this technology. Also reviewed are various applications that are an outcome of this revolution.

Keywords: *Internet of Things, RFID, Sensors, Three-Layer Architecture, Security and Privacy, Standardization, Socio-Ethical Considerations*

1. Introduction

Man is a social animal. The need for communication has given rise to a plethora of inventions. One of the major breakthroughs was the invention of the internet. From using sign language and handwritten letters, we have reached the highly interconnected social media platforms for communication and it has all been possible because of the internet. But, the internet is highly dependent on humans for all the information. The chief problem in such an arrangement is that human beings are not very accurate sources of data collection especially the data related to the physical world that we live in. Interaction with the physical world is the next evolutionary step in the process of information exchange. It is with this idea that the concept of the Internet of Things (IoT) was born.

The Internet of Things is a revolutionary technology that is aimed at making the world more interconnected than it has ever been. It represents the future of computing and communications and its success depends on the development of a number of important fields ranging from sensor networks to nanotechnology. According to the International Telecommunication Union report in 2005, virtually every physical thing in our surrounding can also become a computer connected to the internet. [1] This idea forms the basis of the Internet of Things. In order to connect the things in our physical environment to large databases and networks, the first requirement is that all things must have a unique identification. This process of item identification should be simple and cost-effective. This enables collection and processing of information about the things that are to be connected on a network. The development of RFID and sensor networks plays a crucial role in achieving this aim. In order to make an interactive system, it is not just important to collect static data about things but it is also important that these sensors detect any changes that are related to the interconnected things. Furthermore, embedded intelligence in the things would enhance the efficiency of the system through their information processing capabilities. Lastly, the development in the field of nanotechnology would enable smaller things to connect to the network and thus make the system more compact. Together, all these technologies create a network of interconnected things that we now know as the Internet of Things.

2. Evolution

The need for interconnection between two computers gave rise to the internet. With the internet, the data that was once difficult to communicate to far off places could be communicated with ease. Every computer connected to the internet could talk to each other and participate in data exchange. Until now, internet has been a means to unite information and people. With the inception of the Internet of Things, the internet has been transformed into a tool that can connect things in our environment to other things and humans.

The concept of Internet of Things emerged through a research conducted in the field of RFID and sensor networks at the Auto-ID Centre of the Massachusetts Institute of Technology. [2] The term Internet of Things was coined by Kevin Ashton, the Executive Director of the Auto-ID Centre at MIT. [3] There are seven academic research centers under the Auto-ID Centre located across four continents that were chosen by the Auto-ID Center to design the architecture of the IoT.
The connection of objects to the internet is being accepted across all sectors. Factors like ubiquitous connectivity and the availability of billions of IP addresses with IPv6 have been the contributing factor in the evolution of the Internet of Things. It is forecasted that the number of devices connected to the internet would surpass 25 billion in 2020 from 10 billion in 2014. [4] The "Internet of PCs" would eventually evolve to the "Internet of Things" which would be an exponentially larger network of interconnected devices and human beings.

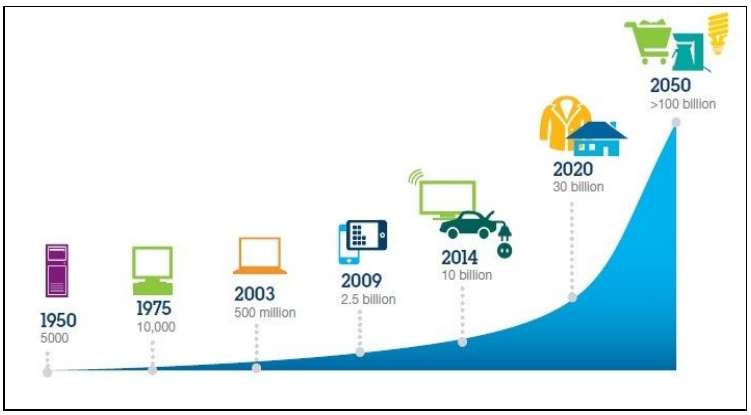

Figure 1: Rise in the number of devices connected to the internet from 1950 to 2050

3. Enabling Technologies
The development of the Internet of Things is dependent on the development of many technologies. There are four important technical innovations that have helped in bringing the Internet of Things to the foreground.

3.1 Radio-Frequency Identification (RFID)
RFID is used to automatically identify people, objects, and animals using short range radio technology to communicate digital information between a stationary location (reader) and a movable object (tag). [5] An RFID system comprises two components – an RFID reader and an RFID tag. [6]
The RFID reader is the transmitter in the system. The reader generates the signal that drives the antenna which creates a radio wave. For this purpose, the reader uses an external power source. The radio wave created by the reader is received by the RFID tag which in turn reflects some of the energy it received based on the identity of the tag. During this process, the RFID reader also acts as a radio receiver and detects and decodes the reflected signal in order to identify the tag. The process is depicted in the Figure 2.

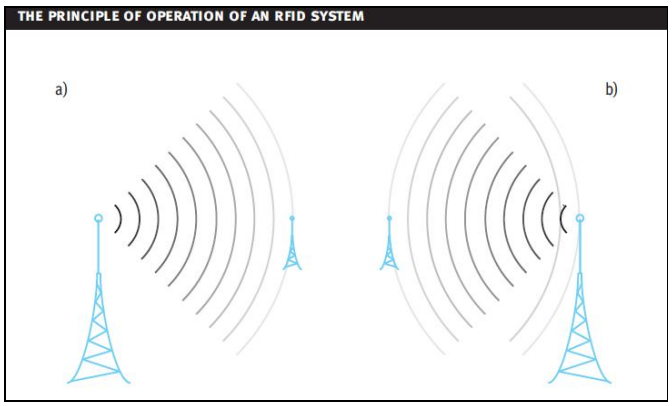

Figure 2: The principle of operation of an RFID system a) The RFID reader (left) initially transmits a radio wave, which is used to power the RFID tag (right). b) The tag selectively reflects energy back to the reader, which is now acting as a receiver, in order to communicate its identity. [6]

A major benefit of the RFID technology as compared to the bar codes is that RFID does not require line of sight to read the tag. It also has a longer range than the normal bar code reader and it can also store more data than bar codes. Another benefit of the RFID technology is that the RFID reader can simultaneously communicate with multiple tags. [5]
For the Internet of Things to be a possible theory, it is important that each and every device that is to be the part of the larger interconnected network must have a unique ID. Because of its various benefits, the RFID technology can be used as an efficient

means of device identification in the Internet of Things. RFID and sensors when combined together with mobile phones can create an environment where in the status of the interconnected objects can be continuously determined and monitored. [7]
Rapid advances in the technology of radio-frequency identification have promised smaller and cheaper RFID tags. [8] This advancement is the harbinger to the revolution that is the Internet of Things.

3.2 Sensor Technologies
The connection of devices and things on the internet requires them to have their unique identification which is provided by the RFID tags. But the RFID tags provide static data. To enumerate any changes that take place in or on the device, we need a wide network of sensor technologies which can sense the change and report the change accordingly. Sensors are ubiquitous and can be deployed anywhere because they are small and can be embedded easily in the devices. The main advantage of the sensors is that they can anticipate human needs. [9] Sensors are intelligent and when used in a network, they can not only provide reports about the external environment but they can also take appropriate action without human intervention.
When a sensor forms part of a sensor network, its intelligence increases exponentially. This sensor which is a part of a sensor network is also known as a sensor node and various sensor nodes in a network can be connected to each other in two ways: wire line and wireless. While wire line communication is more secure and reliable, laying cable and relocating them at a later date is a costly and time consuming affair. Because of these factors, wireless sensor networks are being used extensively.
As we have already seen, the RFID tags are used to identify an object and track its location. A sensor on the other hand, is an intelligence device which can sense the changes in the physical device to which it is connected and also take appropriate action minimizing human intervention. Together these technologies can remove the boundaries between the physical objects and the networked world. Thus, an RFID sensor tag can not only provide identification and location tracking of the device, but it can also sense the change in the device, report the change and also take appropriate action. This elimination of human intervention provides the things with an ability to think for them. These things, also called as smart things, form the building blocks of the IoT architecture.

3.3 Addressing Schemes
The Internet Protocol is a basic requirement that provides an addressing scheme for any data transfer on the web. This protocol provides an identification and location system for computers on networks and routes traffic across the internet. The current IPv4 protocol has a problem of address exhaustion i.e. it could not anticipate the sheer number of devices that would be connected to the internet in the future. Therefore, there is an exponential transition to the new addressing scheme called IPv6. IPv6 provides 2^{128} address which is approximately equal to 3.4×10^{38} addresses. This huge availability of addresses sufficiently meets the requirements of present and future communicating devices. The encryption and authentication options in IPv6 provide confidentiality and integrity of the packets to be transferred. Furthermore, IPv6 can also be extended to meet the future requirements if any. [10]
A compressed version of the IPv6 called 6LoWPAN (Low-power, Wireless Personal Area Networks) [11] have been developed to make high power consumption IPv6 compatible with constrained devices like sensors and microcontrollers. Moreover, an application layer protocol like the CoAP (Constrained Application Protocol) enables these small devices to communicate easily over the internet. [12]

3.4 Nanotechnology
Nanotechnology is the engineering of material on a molecular scale limiting their size between 1-100nm. Nanotechnology brings new solutions to the sensor actuator layer, network layer and application layer by creating new kind of sensors and actuators, high bandwidth and energy efficient communication channels and high performance application platforms. [13] Nanotechnology facilitates IoT development by sensing, manipulating and connecting things in nano-scale. This enables the entire IoT network to be a compact and low power consuming network.

4. Architecture of Internet of Things
The study of the architecture of the Internet of Things is of chief importance. The rapid development of the idea of the Internet of Things across the globe has given rise to very high expectations. If these expectations are to be met, a clear picture of the IoT architecture is imperative. There are many different IoT architectures such as ITU, EPC Global, UID architecture (Ubiquitous Identification), web service oriented architecture etc. But these architectures provide a hazy picture. This paper attempts to provide the basic model of the IoT architecture as proposed by China Communication Standards Association (CCSA). [14]
The architecture proposed by CCSA is three-layer architecture.

- Perception Layer
- Network and Processing Layer
- Application Layer

4.1 Perception Layer
The Perception Layer is the bottom layer of the three layer architecture. This layer is an object-object network which consists of a variety of sensors including RFID technology. This RFID and sensor technology provides a unique identification to every device connected on the network and also provides the device with the ability to detect changes in its state and take appropriate measures.

4.2 Network and Processing Layer

The data collected in the Perception Layer needs transmission. This is where the Network and Processing Layer is formed. This layer is a bidirectional layer that consists of various wired and wireless technologies that provide an exhaustive framework for data transmission from one place to another. Various data transport technologies include GPS (Global Positioning System), GPRS (General Packet Radio Service), the Internet and so on. This layer forms an interface between the bottom Perception Layer which is a hardware layer and the top Application Layer. It performs critical functions like device management and information management and also takes care of data filtering, data aggregation, semantic analysis, access control, and information discovery.

4.3 Application Layer

The data that is collected and transmitted needs to be processed at the receiving end. This is where the Application Layer materializes. This is the top most layer of the three layer architecture. This layer is responsible for delivery of various applications to different users in the IoT. These applications are found in various industries like agriculture and breeding, manufacturing, retail, healthcare, logistics, environment, aviation etc.

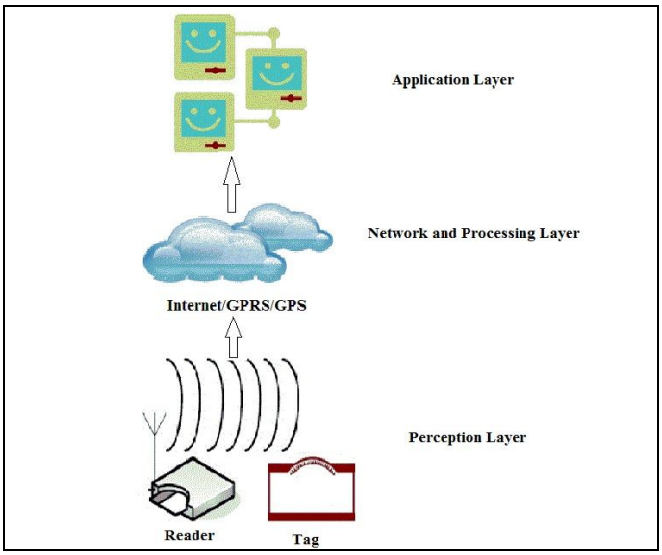

Figure 3: Three-Layer Architecture of Internet of Things

5. Applications

The Internet of Things has the potential to pervade each and every sphere of human life in the near future. It is clear that this revolutionary technological innovation has uncountable applications. Some of the applications of the IoT like Smart Grid, Smart Industries, Smart Logistics, Smart Agriculture, e-Finance, Smart Healthcare, Smart Housing, Environment Protection and Energy Saving, and Public Safety have already found their way into the market. This paper briefly discusses some of them:

5.1 Smart Healthcare

For patients whose physiological status needs to be monitored closely, IoT can offer excellent solutions. The patient monitoring system consists of sensors which collect comprehensive information about the status of the patient. The information from the sensors is sent to the cloud where it can be processed. This processed information is further sent wirelessly to the doctors or caregivers for further analysis and review. This kind of non-invasive monitoring provides continuous care effectively at low cost. The system is also a boon to patients who are located remotely and have no continuous access to healthcare. IoT can also offer solutions for early intervention and prevention of various kinds of diseases. A heart rate monitor for example, can send periodical data of a heart patient to his doctor and his immediate family. This data can be analyzed and used for timely diagnosis and treatment.

5.2 Transportation

In the field of transportation, IoT offers wide ranging solutions. One of the major solutions is an efficient traffic management system. An example of a traffic management system is a system which employs unique identification of all the vehicles on the road made possible by RFID technology. The location of these vehicles is obtained using GPS and then this data is sent to the cloud through GPRS where it can be processed and analyzed. The solutions are then sent to the users on their mobile phones. The IoT technology can be used to manage luggage at airports by providing automatic tracking, sorting and increased security.

5.3 Agriculture and Breeding

Animals can be traced effectively using the IoT technology. This helps in knowing the number of animals in a farm and whether they are vaccinated or not. This information is used to manage outbreak of contagious diseases, official identification of animals, manage subsidies to farms etc. With the advent of IoT, the farmers can deliver crops directly to the consumers thus making food cheaper and unadulterated. Thus, IoT has the potential to revolutionize the agriculture industry by providing livestock and crop management solutions.

6. Challenges

While it is true that Internet of Things has the potential to change the world forever, its benefits can only be harnessed once it overcomes various challenges. The challenges to the IoT technology are many and this is not only because of the nature of the technologies that are employed in the Internet of Things but also because of their large scale deployment. Some of the major challenges that plague the development of this technology into a truly large scale revolution are:

6.1 Security and Privacy

Security is a major source of concern when large interconnected networks are employed. The system can be attacked in many ways like intercepting personal information, disabling the network, sending erroneous data etc. Viruses, Worms and Trojans are already the bane of connectivity in today's world. RFID is the most vulnerable to such attacks as with RFID, people can be tracked easily and continuously. Solutions to these problems can be provided by development of cryptography. Encryption offers security against outsider attacks by providing data confidentiality while message authentication codes provide data integrity and authenticity. [14] Data sent across devices goes through the cloud and thus security in the cloud is another important area that needs attention.

RFID tags together with the mobile communication technology poses serious privacy concerns. These sensors can track users' movements, habits and preferences and keep them in their record for a very long time. This data collected can be used in a positive manner, say for example, in individualistic advertising or in a negative manner, say for example, for defamation and thus digital forgetting can also be a key area of research to address the concern of privacy.

6.2 Standardization and Harmonization

A large scale service like the Internet of Things needs appropriate set of standards to govern it. The Internet of Things is made up of many manufacturers, multiple industries and has a wide ranging applications and requirements. All the commercially successful technologies like TCP/IP or IMT-2000 have undergone standardization because without standards it is impossible to achieve efficiency and mass market penetration. The RFID technology was initially standardized by the Auto-ID Centre and is now being standardized by EPC Global. [1] Other forums like ISO and ITU are also being called upon for harmonization. Wireless Sensor Networks have been standardized by ZigBee Alliance. Standardization in the field of robotics and nanotechnology are more fragmented because there are no common definitions and many regulating bodies. If the IoT has to become a truly ubiquitous technology in the near future, it is important that standardization and harmonization of the enabling technologies be carried out.

6.3 Socio-Ethical Considerations

Technological innovations have always had a huge impact on the society. The IoT would make a lot of activities convenient which would have a positive impact on the quality of our lives. But, it is highly doubtful whether the society is ready for the level of integration that this new technology provides. The biggest fear is that a growing atmosphere of surveillance is being fostered by these new technologies. This environment of surveillance can instill distrust and fear in human beings which would adversely affect healthy social interaction and impede creativity and overall human development. When each human would be provided with an identification tag, it would lead to a conformist and uniform society where individuality and self expression would be challenged. Furthermore, it can also create a divide between have and have-nots of the society. It is possible that with such all-encompassing interconnection in our lives, content may give way to form. This has been seen in the case where more people now prefer to text each other than call each other. Last but not the least the concept of individualistic advertising may pose a serious threat to universal equality because there would not be any standard which defines what information should be available to whom. Thus a pervasive technology like the Internet of Things must conquer all these challenges before it can develop further.

Apart from the above, there are various other challenges that this technology must overcome. For example, there is no standard architecture for IoT which can be common to all the application domains. Secondly, a generalized framework is needed to meet the demands of different sensing technologies which can effectively analyze the data and produce tangible results. Furthermore, the quality of service should be guaranteed in each application domain which can be possible by the development of dynamic scheduling and resource allocation algorithms. It is also imperative to be able to extract relevant data from a gigantic pool of data that would be collected by the bottom Perception Layer in the IoT architecture. For this purpose, it is important that research be conducted in the areas of artificial intelligence and machine learning.

7. Conclusion

According to new research from International Data Corporation (IDC), a transformation is underway that will see the worldwide market for IoT solutions grow from $1.9 trillion in 2013 to $7.1 trillion in 2020. [15] Due to the advances in the enabling technologies for the Internet of Things and their seamless incorporation in our day-to-day lives, the vision of a truly interconnected world has now become possible.

The Internet of Things works on a three-layer architecture. The bottom layer or the Perception Layer consists of sensor networks that collect data from the devices. The sensors are also able to detect changes and take appropriate action minimizing human intervention. This collected data is then transported over wired or wireless networks which form the second layer of the architecture. The development of the IPv6 protocol has made it possible to connect a large number of devices on the internet. The application layer forms the third layer of the architecture. It is here that the user receives the analyzed and processed data as per their requirement. The Internet of Things has made possible the proliferation of wide-ranging applications like Smart Transportation, Smart Healthcare, Smart Grid, Agriculture and Breeding etc. But, for a truly pervasive technology which is the vision of the Internet of Things ideology, there are various challenges which need to be conquered. These are security, privacy concerns, standardization, and socio-ethical implications. However, these challenges can be subjugated by directional research and

development, and appropriate government support. There is thus no doubt that the Internet of Things would be a tangible reality in the future.

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