Internet Of Things – The Inevitable Future of the Consumers and a peek of its transformation into Mobile Cloud of Things

Deekshith Sandesari

Department Of Computer Science, The University Of Akron

E-mail: ds168@zips.uakron.edu

Abstract

The Internet of Things (IoT) is an emerging M2M (Machine 2 Machine) related technology that enables physical objects, or devices to connect to the Internet. Given such an arrangement consumers can communicate with the things and manage them remotely. With billions of devices connected to the Internet, huge amounts of data being generated, with the need for mobility and real-time processing; this paper presents the need to integrate evolving communication technology such as Mobile cloud computing with consumer IoT that gives rise to a new term known as Mobile Cloud of Things. Moreover this paper aims to evaluate the possibilities of this integration by discussing its challenges to enhance the adoption of consumer IoT.

***Keywords** – Internet of Things (IoT), consumer IoT, wearables, Mobile cloud computing (MCC), Mobile Cloud of Things (MCoT).*

1. Introduction

Internet of Things is considered as the next generations Internet. It is a network with intelligence that connects all things to the Internet for the purpose of exchanging information and communicating by means of sensors. It is an extension and expansion of

Internet-based network, which expands the communication from human and human to human and things or things and things [1]. IoT connectivity transforms the current state of the world to a new smart world by using existing resources and technologies.

Since devices are able to perceive data and transmit the information through Internet, consumers are trying to adopt the technology to their daily use, such as wearable technology, smart homes and smart appliances. While the consumer adoption of IoT is still in its infancy but it is inevitable for the consumers in near future. This paper is organized as follows: Initially this paper describes the adoption of IoT Technology by consumers, evolution of IoT and wearable market. After that the paper describes the role of mobile devices in IoT, the need to integrate IoT with mobile cloud computing. Finally this paper addresses the issues and concerns in integrating new technologies such as mobile cloud computing with IoT termed as Mobile Cloud of Things.

2. Consumers as integral part of IoT

We as consumers envision the world around we live in to be smart. We expect the things we use not only to be intelligent and responsive but also should be able to anticipate our needs. Many of these consumer desires can be fulfilled by emerging Machine-to-Machine and related technologies [3].

IOT is one such emerging technology that fulfills such human desires at a large scale. A recent study by ABI Research states that there are more than 10 billion wirelessly connected devices in the market today and over 30 billion devices are expected by 2020 [4]. For example, nowadays we have smart home technologies, smart sensors and wearable but this is just the beginning and there is more yet to come. Consumers will be able to manage personal health, energy, food, security, entertainment, shopping and even socialize with the help of things with sensors connected to the Internet. In future one of these things may help to monitor individual's health status and predict medical problems; another may help in managing the financial resources like payments using biometrics. Devices like smart fridges help in ordering the groceries and food. We can say that IOT makes the world a better place to live in where consumers will often be the integral parts

of the IoT system. Consequently, in the future, the IoT will evolve at large scale and will affect each and every aspect of all our lives.

3. The Evolution of IoT

Initially, only things that are electronic and non-electronic served the purpose of consumers. Self contained things like thermometers serve as an example. Later, things were connected but there was no direct connection of these things to the Internet. For example, sensors devices were connected to display devices to transfer and display the information. After that, we are being evident of evolution of device being connected to the Internet. Initially only PC devices were connected to the Internet but these days each and every smart device such as phones, tablets are connected to the Internet.

In this decade, the Internet connectivity is expanding to things [3]. Things talk to each other and Internet. Things now refer to electronic/non-electronic devices that have some kind of access to the Internet. Adding connectivity to the Internet adds intelligence to these things, which also improves the efficiency and reduces the operation costs. In total, IoT represents intelligent end-to-end systems that enable smart solutions and covers a diverse range of technologies such as communications, networking, sensing, information processing, computing, and intelligent control technologies [5].

4. Wearables as first generation IoT for Consumers

With the invention of products such as Google glass, smart watches consumer market has captured the attention of wearables. Wearables are smart products with wireless connectivity and independent processing capability that are worn on user body for enhancing user experience [6].
According to a new market report published by Transparency Market Research, "Wearable Technology Market—Global Scenario, Trends, Industry Analysis, Size, Share and Forecast, 2012–2018," the wearable technology market globally is expected to grow from US$750 million in 2012 to US$5.8 billion in 2018 [2]. Figure 1 shows the market growth trends for wearable technology in various segments [2].
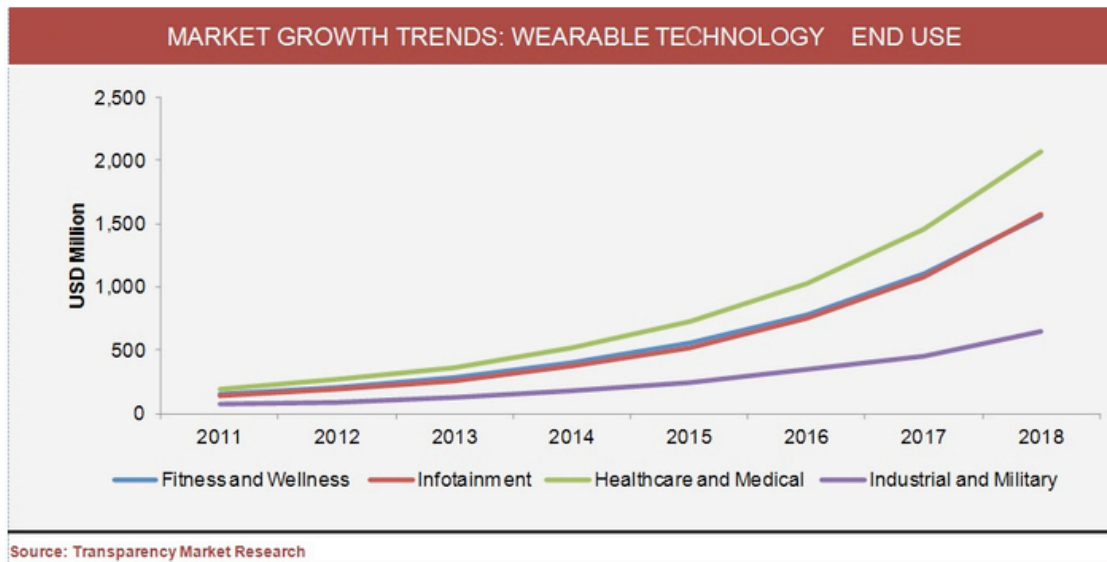
Figure 1. Market growth trends for wearable technology [2]

Table 1. Popular products in the wearable technology market [6]

Fitness and Wellness	Infotainment	Health and Medical	Industry and Military
Activity Monitors	Bluetooth Headset	Blood Pressure	Hand-worn
Sleep Sensors	Head-up Displays	Monitors	Terminals
Emotional	Imaging Products	Insulin and glucose	Heads-up
Measurement	Smart Glasses	Monitors	Display
Smart Glasses	Smart Watches	Feedback Patches	Smart
Fitness & Heart		Hearing Aids	Clothing
Rate Monitors			
Smart Clothing			
Smart Watches			
Audio Ear buds			

Consumers expect a wearable to perform many functions at a time instead of serving a single purpose. For example consumers see a smart watch not only as a fashion accessory but they also expect it to perform multiple functions such as health monitoring, tracking device, a Bluetooth device which helps in messaging and making calls. Wearables will

not only continue to evolve as the first generation IoT devices for consumers but also create new business opportunities. According to recent market assessment by IHS, wearable market sector can be divided into four segments such as Fitness and wellness, Infotainment, Health and Medical and Industry and military. Some of the popular products listed in these segments are shown in Table 1 [6].

5. Role of Mobile Devices In Handling Consumer IOT

Wireless connectivity and mobile devices have evolved drastically in the past few years. According to Cisco's 2013 global mobile data forecast there will be 7 billion mobile devices on earth, almost one for each person [7]. Moreover the products that enable IoT need to be mobile, portable, intelligent, easy to carry and low power consuming systems and high communication capability devices. Hence instead of using a computer with software or an another device to operate a smart home or smart TV a consumer would prefer using a small app on the smart phone to operate it. . IoT is changing the way we use mobile phones and there is an evolving trend of Mobile phones turning into devices that can manage things remotely [8]. For example we can manage Google glass and smart watches by connecting it to a mobile device using Bluetooth connection.

6. Need to Integrate IoT and Mobile Cloud Computing

Since mobile phones do not have the capability for high end processing or memory enough to support huge data, we are aware that Cloud Computing seems to be the ideal solution for these mobile phone users [12][13]. Mobile Cloud computing is defined as the availability of cloud computing features such as Infrastructure, platform and software with high-end computational, processing and storage capabilities to mobile devices. With a new trend in development of mobile applications for Internet of Things, the emerging technology of Mobile Cloud computing makes it possible for the devices (things) with limited resources such as sensors with less memory capabilities and actuators with low processing features to

perform the assigned task effectively. Though both the technologies evolved independently, there are several advantages for IoT in integrating them.

Data is always being generated in real time as an exhaust process from these things while they are processing their job. It is generally the data generated by every health app, every temperature manager, wearables along with other sensor data. Managing such data since already connected to the Internet makes it easy for data processing and storage on the cloud.

With more and more data being acquired [9], there is a need to use analytics on this data to make the thing smart and so, things may require huge computational resources and real time processing. The resources such as energy, storage and computational power are very limited in mobile devices. The cloud can effectively provide such computational resources for real-time processing with dynamic response. Every IoT device is IP enabled and are on IP connected network based on dedicated hardware. Exchanging information related to sensor data in such an environment is expensive. Mobile cloud can be a most promising & cost-effective solution to connect, manage and track the IoT.

So combining the features of mobile cloud computing with Internet of things called mobile cloud of things (MCoT) facilitates greater innovation and a new proactive computing approach. This also drives the growth of IoT market in a way that new types of applications will be delivered more effectively and quickly [10].

Cloud models suitable for IoT are [11]: IaaS-Infrastructure as a service for sharing resources and running applications on cloud. PaaS-Platform as a service that provides access to the IoT data and a platform to develop deploy and control services. SaaS-Software as a service to manage and access the service provided by the application.

7. Challenges in Integrating IoT and Mobile Cloud Computing

According to International Telecommunications Union (ITU) - Internet Reports for Internet of Things, "the vision of IoT is to enable anytime, anyplace connectivity for anyone and everything" [18]. So, integrating IoT and Mobile cloud computing technologies is very challenging since they are composed of high heterogeneity of protocols, varied technologies and devices of different nature. Some of the challenges in the integration are:

7.1.1. Existing Mobile Cloud Computing challenges

Mobile cloud computing technology has some existing challenges; when integrated with IoT poses even more challenges. Mobile cloud computing is different from traditional wired network in different aspects such as security and privacy related issues, issue with maintaining consistent signal quality, handling hand-off delay, battery and power management issues, low processing capability [14]. In addition external factors such as weather, antenna distance, solar flares, buildings influence the quality of signal. Quality of service also changes due to network overlay whereas in wired network the bandwidth is consistent. Another important limitation for mobile devices is resource-constraint. Smartphones have fewer specifications when compared to computers in terms of CPU, processing capability, storage, energy resources and operating systems. Mobile cloud computing enables high end processing on the cloud saving CPU, storage and processing capabilities but there is a need to increase the bandwidth to support the feature. Some other challenges related to security include data ownership and privacy issues. Heterogeneity in mobile cloud computing is also one of the major challenge [15]. Heterogeneity in mobile devices is because of variation in software and its versions (Android, Mac OS X), hardware communication medium. Heterogeneity in clouds is because of different cloud vendors such as Google, Amazon, IBM and heterogeneity in wireless networks is because of different communication mediums such as WLAN or satellite communications.

Many of these challenges are being worked upon by the researches by defining a standard architecture for Mobile cloud computing.

7.1.2. Standardization of IoT

Standardization is the prerequisite for the growth and advancement of any technology and beneficial to not only consumers but it also gains lot of business market. Even though there were multiple contributions on standardization of IoT and mobile cloud technologies there is a need for standard protocols, APIs and architectures in order to facilitate the interconnection among heterogeneous smart objects and the creation of enhanced services. [16].

Hence many scientific communities such as OGC Family of standards (working on sensor web for IoT standard), IEEE (working on lower protocol layers such as Physical and Mac layer), IETF (working on network and transport layers), ITU-T: International Telecommunication union (working on telecommunication standardization), IERC, ETC, ITS, CEN/ISO, W3C are striving for standardization of IoT.

7.1.3. Business challenges

IoT of things is evolving technology but has many business challenges. Creating awareness among consumers is important factor to promote business of IoT. Many of the consumers had not heard the term IoT but are aware of latest products in the market such as Google glass and smart watches. Price of the IoT devices is also a major factor and a business challenges. High-end devices with high prices are a hit but unaffordable to wide range of consumers. So devices and chips with high quality and low cost need to be developed. Also billing of cloud resources in case of integration becomes a challenge to implement and difficult to track because of multiple devices accessing the cloud at the same time.

7.1.4 Technical challenges

1) Identity: Since the number of things connected to the Internet is increasing exponentially, the number of devices using IPV6 is also increasing. But many of the existing systems still using IPV4 and the transition of these systems to Ipv6 is very slow. Ipv4 and IpV6 are both not interoperable i.e. things configured with Ipv4 cannot communicate with things of IPV6. So IoT6, a European research project on Internet of Things aims at exploring IPv6 technologies to overcome the existing challenges to develop a well-defined IPv6 based Service Oriented architecture.

2) Connectivity: Due to heterogeneity of mobile devices and support of different wired and wireless network protocols like IEEE 802.3, Ethernet, Bluetooth, Wireless USB, ZigBee, Thread, 6loWPAN there might be issues pertaining to connectivity of the devices like

sensors. Each of these sensors might support only few protocols. Hence standards have to be developed for the devices to integrate these protocols to all wireless and wired protocols.

3) Energy Consumption: Managing power in smart devices such as wearables is critical. There is a need to develop low power micro controllers that enable low power wireless connectivity for IoT devices. The idea of developing innovative charging solutions and self-sustainable devices will be a key advancement to the development of intelligent devices.

4) Security and Privacy: Internet of things enables connectivity and data exchange between different devices remotely via Internet. This increases the risk of security and privacy concerns. For example if a hacker intrudes into home security systems or fire safety systems that could lead to serious security concerns. Data stored on the cloud can be susceptible to DDOS attacks to due Internet connectivity. Hence there is a need to develop built-in hardware security technology. Security issues must also be addressed in all layers such as connectivity and software such as installation of firewall gateways, antivirus software should be mandated in the devices. Also a standard protocol should be followed to check if the IoT device functions properly. Moreover it is important to make sure that privacy of user is protected using trusted communication paths and handling identity management [17]. New approaches should be considered while providing authorized access to cloud data related to home security monitors and health data of consumers from the apps without relaxing user privacy. Cryptographic techniques enable the consumers to store data on to the cloud without providing unauthorized access to others.

8. Conclusion and Future Work

The integration of Mobile cloud computing and Internet of things gives rise to a new paradigm coined as Mobile Cloud of things (MCoT). Though each of these technologies have their own challenges, the integration of each of these technologies paves a path to a better solution for smart future and changes the way the consumers interact with the world. Even though other related work exists, but the purpose of this paper is to highlight the trends in evolution of IoT into Mobile Cloud of things considering the perspective of consumers and how the existing issues in the mobile cloud computing technology and IoT pose various challenges in integrating these two technologies. Future work can be done to improve the

integration capability of these two technologies and research can be carried out to provide more effective solutions to these problems by proposing a standard architecture for MCoT.

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