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Challenges: Wearable Computing for Internet of Things (IoT)

Dr. Parul Verma[1], Dr. Ranjana Rajnish [2], Dr. Shahnaz Fatima [3]

[1, 2, 3]Assistant Professor, Amity University, Lucknow

Abstract: ***IoT is no more a new term in an IT industry. The buzz is going on from the last decade. The impact of IoT can be visualized by the fact that Cisco estimates that 50 billion devices are going to connect by 2020. The revolution in computing devices from desktop, laptop, palmtop to now wearable devices has changed the way the computing was done. The combination of IoT with wearable computing devices will definitely influence our life style. Wearable devices can connect you to the outer world and the connectivity can be extended by connecting not only your computers, mobiles but to your household devices like refrigerators, AC's, Automotive and many more. The wearable computing is still in the nascent stage, and have to go long way as there are numerous challenges in respect of power usage, networking,privacy and security, software and hardware related too. The end users can exploit the potential of IoT along with wearable computing which can lead to the big revolution in the coming future.***

Keywords: IoT, Wearable Devices, Wearable Computing, Challenges of Wearables

1. Introduction

The IoT is a huge pool of interconnected devices, sensors, vehicles, embedded software and many other things. Such things are connected seamlessly using wired/wire-less connection media. Each such device/sensor/thing is treated as a node which can be configured by itself. This globally connected network of things/nodes works on infrastructure that is dynamic in nature and well supported by the communication technologies like - GSM– Wi-Fi, RFID, GPRS etc. The concept of ubiquitous computing is quiet prevalent these days and IoT enables and supports the concept of pervasive computing. IoT can be characterized as global communication, real world processing and small storage area. There are certain issues regarding IoT like privacy, security and reliability of data.

IoT can be compared and contrasted with Cloud computing. Cloud is mature as compared to IoT. Both of them however connect at common objectivei.e. ubiquitous computing. Cloud's capabilities are boundless with respect of storage space and processing power. IoT seems to be a pool of connected devices that are linked to each other by internet. The stream of data flows continuously to and fro to the connected devices, and the outcome is the real time processing. Real time processing of IoT is enabled by Cloud. One can say both IoT and Cloud work hand in hand.[1]

The internet is becoming rich with every passing day. Access to internet is no more limited to only desktops / laptops, now it covers the wide range of devices which includes mobile devices and smart phones. The basic objective of IoT is to correct each and everything possible and to provide services to convert everything into smart functioning like – smart cities, home automation, smart learning, e-healthcare, wearable and many more. The base of IoT applications are the small devices which works as connecting points through microcontroller and interface to communicate supported by a power supply and sensors. These sensors are used to interface with surrounding environment.Basically these sensors are meant for data collection.

The networked world of IoTintroduces a huge number of new smart devices that organizations can exploit for real-time business purposes and analytics. The IoTis transforming and impacting almost all industries and individuals, new sources of operational efficiencies and revenues as well as opening up new business models.

Dependency on computers and other interfaces requires them to be omnipresent. This requirement has opened way for the development of wearable technology, computers which can assist professionals in personal activities by augmenting and aiding everyday life with the tech savvy world. ***Wearable technology merged with IoT and cloud computing offers many opportunities which trigger the thoughts and imaginations of people of all fields.***

The market is showcased with variety of wearable devices like smart watches, glasses, fitness trackers, health monitoring device and many more. There is a large variety of wearable's for kids and adults available in market and their basic motive is to monitor various health issues of kids and adults like- sleep conditions, growth rate kids, blood pressure, heart rate etc. Patients can wear such wearable's and their health progress can be monitored as well.

The organization of rest of the paper is as follows- Section 2 of the chapter will detail about Wearable computing and IoT. Section 3 will give an insight about various wearable technologies. Section 4 discuss about the wearable devices in brief. Section 5 elaborates the challenges of wearable computing. Section 6 discusses the future of wearable technology followed by the conclusion.

2. Wearable Computing and IoT

Computing has evolved over a period of time. In the latter half of 20th century, we have seen a new way of computing that is supported by miniaturization of devices and increase in pervasiveness in computing. Concept of ubiquitous computing is truly being achieved in this era. The term Ubiquitous or Pervasive refers to "existing everywhere".

Wearables are the new wave in IT sector. It is a new way of interaction between human and computer where a device is worn by the human being. The device is active and accessible to the human being all the time. Wearables can be managed by the human being by giving certain commands and they can also run in automated mode.

The wearable paradigm assumes interaction between a device with human in some way or the other. We can define wearable computer as a device that user wears as comfortably as his clothing and is always connected to its user and is available for various computing needs. Wearable computing can thus be understood as the computing that is worn and fulfills computing requirements.[2,3,4]

Use of wearable computing is not limited to any specific requirement. It solely depends on developers' creativity. Mann (Mann, 1998) defined three basic operational modes of wearable computing: [5]

- Wearing it constantly
- Expansion of senses
- Mediation with reality

The above mentioned modes actually define the working paradigm of the wearable computing which is nowadays accepted widely.

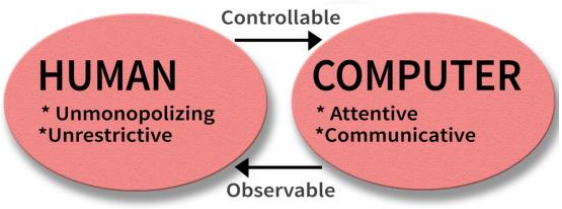

Figure 1: Wearable Computing Framework

Internet of Things (IoT) is ready to exploit network's potential to its fullest. It is ready to embrace its application to various innovative services such as smart city, smart home, building automation, and medical/healthcare services. In most of the IoT applications user interacts with their smart environment that provides them with the information and adapts itself according to the need and preference of the user, with or without user knowing about it. IoT applications follow the standard format for applications which consists of a microcontroller, power supply unit, communication interface and sensors for collecting data. One of the most visible form of wearable computing can be seen as activity trackers liktFitBit and Up by Jawbone, or more advanced devices like Google Glass and Samsung Smart gear. These devices are always connected. The wearable devices may interact with other IoT devices in order to exchange data and information as per the application needs.

A big range of wearable devices is being used in healthcare sector. Fitness sensors and other applications are helpful in collecting variety of health related data of users like heart rate, sleeping hours, temperature, blood pressure etc. which can constantly be monitored by healthcare professionals to provide better healthcare services.

Wearable devices can be categorized into two categories broadly-

Passive wearables: Wearables that are designed to passively collect data, which is used by some application, are called passive wearables. They do not require direct interaction with human and are tightly coupled with the application using generated data. Some of the examples are step counters and heart rate monitoring devices.

Active wearables: Active wearables such as smart watches and glasses,are actively connected to the end users to provide information to them. Active wearables work as a source of input to control end users and the mobile devices they use. Their connectivity can be extended to other devices located in the near proximity.

Integration of cloud, wearable sensors and smartphones has caused eruption of data that can be used in various applications such as personalized healthcare.

3. Wearable Technologies

Use of wearable technologies has increased many folds after IoT,, which may be understood as network of things i.e. "smart devices" that arewell equipped with wireless communication capabilities. Freescale is the company who launched open source Wearable Reference Platform (WaRP) based on ARM architecture. ARM Cortex – M based processor is quite popular in the market of wearables due to its robust signal processing feature. FreeScale collaborated with various companies like Circuitco, Kynetics and many more. [6]

ARM, which provides an extensive range of processor, SoC (System-on-Chip), GPU (Graphics Processing Unit) and Intellectual Property (IP), isthe world leader in developing advanced technologies for mobile and wearable devices.ARM based devices are capable of handling huge consumer base hence developers are encouraged to use it.

3.1 Requirements for Wearable Design

Basic wearable device makes use of Bluetooth connectivity, a simple operating system with simple display. A basic smart watch, may use a LINUX based Operating System, Wi-Fi, Bluetooth, graphics, audio with color display. The requirements for the high-end smart watch design will be diversified to extend their completer services to the end users. They require full fledge running OS which can support development environment of Andorid Wear, along with that good quality camera, HD video support, excellent graphics support and global positioning as well.

3.2 Basic Wearable Device Architecture

The basic architecture of wearable can be classified in two parts-

Hardware - Flash Memory, SRAM, ROM but there is not Memory Management Unit (MMU) besides that is uses 32-Bit ARM Cortex-M class MCU, VPU (Video Processing Unit) and DPU (Display Processing Unit)

Software – RTOS (Real Time OS) such as NetBSD or FreeRTOS, Android Wear.

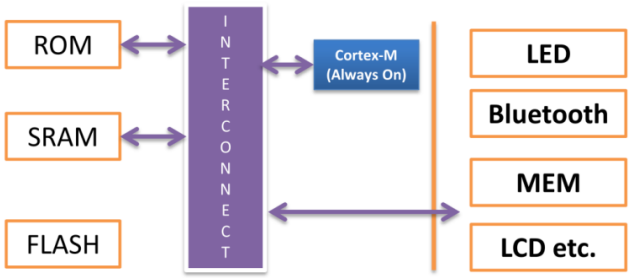

Figure 2: A basic device architecture

Figure 2 shows an example of basic wearable device architecture. It shows features on-chip memories (Flash, SRAM, ROM) and is a simple design that is suitable for a basic device such as sports band or a very simple watch. Any of the Cortex-M0, Cortex-M0+, Cortex-M3 or Cortex-M4 ultra-low-power processor cores can be used for 'always-on' sensor fusion processing, largely depending on the number of sensors required in the design. In many cases, the Cortex-M3 has already proved to be a highly suitable choice.

Many current-generation wearables are solid which have limitations in their adoption. But with the advent of technologies like "sensor-rich fabric" and "conductive fiber", fabric themselves can become device. These fibers can be fed into a loom or embroidered directly onto dress that users can wear and washed as normal. With reducing cost and increasing use, developing such threads is a rapidly growing business. Developers are trying hard to make these wearable devices more fashionable and attractive. The wearables thus can now be incorporated into the most stylish clothing.

4. Wearable Devices

Though the highest growth of wearable is in the field of Health and Fitness, there are other categories of wearables that are available in the market nowadays. Apart from its high usage in medical domainwearables are also used to improve end users lifestyle in so many ways. Wearable will definitely change our way of living by automating every aspect of our lives like –home, automotive, business, health care, entertainment and many more to count upon-

4.1 Health and Fitness

There is variety of Health and Fitness related wearables that are available in the market. All such devices help the end users to monitor their health and keep them fit. Besides the end users of such devices surgeons can also use such devices for surgery even from remote location. For example - ***Activity Tracking, Weight Loss, Virtual Doctor Consultations, Hydration Tool etc.***

4.2 Lifestyle

Wearables are making our life simple by simplifying our daily tasks and making them easier to accomplish. Wearables have their impact on every sphere of life from monitoring your car to find a new house or managing your households. For example - ***Hands-free Device to Interact with Surroundings, Automotive Monitoring***

4.3 Productivity and Organization

Wearables can also be used to improve the efficiency and productivity of the employees in the organization. Stanyfy Calendar is one the example that can be used for the similar purpose. For example ***Calendar***

4.4 Food

Wearables had touched all streams of our lives. Now we can order food from an online list using wearable devices. Canada based restaurant chain has extended its mobile application ta wearable Apple Watch. It supports the feature of menu customization as well.

5. Challenges of Wearable Computing

Wearable computing has compound challenges in respect of reaching users, privacy and security, hardware and software and many others. Following are the domains where wearable computing face challenges-

5.1 Networking

The usability of the wireless mobile is hindered by the power and the networking issue. The overall performance of the wireless network is measured by bits per second per watt.The serious issue with wireless technologies is the open standards which enable interoperability between different services. Usually one language radio is mandatory to provide telephony, text messaging, Global Positioning System (GPS) and so on. Networking is all about, communication off body for wearable computers - to the fixed network by different means, on body among devices and near body with objects near the user. The ubiquitous problem with mobile devices is that many a times they will not be in a range of network. All the three types of network require different design decisions. This is a big challenge for the designers to cater with three types of network. They have to consider possible interference between the networks.

5.2 Power Usage

Power usage is the most limiting factor of every mobile device. The mobile devices are being judged foremost by their power backup rather than their high quality electronic circuits. The researchers need to focus on power usage issue of the wearable computers. Wearable computers are like clothes that user might use in a form of a pair of Google glasses or a belt buckle or a keyboard built in their jackets. The power distribution system in such devices is quite complicated as the human beings are going to wear such devices. Since the wearable computers are mobile in nature they need to have strong battery backup and sooner or later the end user will get frustrated due to poor battery backup. The strong batteries are required to fulfill the demands of power usage of wearable computers. There are long-lasting power supplies like Plutonium -238 that can last for decades

and can be used for wearable computers. Another solution can be the batteries with 16 hours backup which can be charged when the user is sleeping at night, or having meal.

5.3 Heat Dissipation

The heat generated by human body is between 80 W to 10,000 W of power. Human being can survive in the Sahara Desert and Antarctica for the extended time period even then they can maintain their body temperature of 37 degree centigrade. Human body can be considered as the excellent regulator of heat. To match up/ regulate such conditions wearable computers need to manage such heat related issues. Keeping in mind such issues it is required that wearable computers should be lightweight, small in size and ergonomic and often must operate in wet and dirty environments for applications like marines. Wearable devices are supported by the battery pack for power; hence usage of power should be minimal. Hence, cooling devices that consume power like thermoelectric modules are not considered as the best solution. For wearable computers conductions is best mode of heat transfer, it has been postulated that if we embed the electronics in a polymer-filler composite substrate could aid these design of wearable computers in several ways-

- The design would be rougher if we surround the electronics within a protective covering of plastic.
- The plastic material can be poured into the mold which contains the electronic boards, which will make embedding process quite economical.
- Embedding the electronics helps in removing heat when the lower layer has a high conductivity.

Heat transfer can be easily managed by minimizing temperature by adding a layer of highly conductive substrate. The conductive substrate layer reduces the reliance upon the head spreader.

5.4 Privacy

Societal repercussions of wearable devices and technology are full of challenges. Among all the challenges preserving the privacy of user's personal data is the biggest challenge. According to a recent UK and US survey, 20% users called for totally ban on such devices, 62% though there should be some amendments in Google Glass and many other wearable devices and 51% users cited privacy as a big barrier to adoption of wearable devices.Privacy issue has the versatile domain and can be classified as follows-

Challenges for Existing model: The huge amount of data can be used for the analysis purpose without taking end users consent. The sharing of such private data poses a profound challenge on the existing security framework.

Surveillance Options: The latest surveillance options like baseball caps, shirt buttons etc are available with hidden cameras. These devices have the ability to constantly record the happenings. The latest wearable related to fitness technology includes variety of gadgets which can monitor health of a person like wristband which gathers information about blood pressure, your smart phones data can help to analyze your stress level. All these gadgets use your personal data related to your health issue. This is also one of the issues which need a great concern.

Contextual Collapse of Data: Mixing of corporate and personal data of a person is referred as contextual collapse of data. It happens due to the sensors that continuously interact with the end user's body and other devices in the closed proximity to collect data.

5.5 Interface Design

Wearable technology is boomed in a last couple of years. Comparing the current wearable devices with the older ones definitely shows the huge gap. The gap signifies the drastic growth in the wearable technology. Despite such growth wearable devices are still in their infancy and companies are trying to explore their usage areas and where they can be exploited at their best. Such a growth and upcoming consumer demands puts a pressure on the design issues of the wearable devices also.[7]

There is a huge range of upcoming devices like –

- Bionyn's Nymi is a new type of smart band that, besides the de-facto activity tracking capabilities, it measures the heartbeat of the user which is unique to each person. It is even used for authentication purpose also.
- Mighty Cast's NEXT Band is a smart wearable device is used by the end users to customize the various modules as per their requirements.
- Thalmic's MYO is an armband which basically measures electrical impulses in your forearm in order to detect your hand and arm movements.

There is a huge challenge for the designers of the wearables. Such devices do not focus on the interface very much. There are few devices which do not use screens at all, they simple take input in the form of pressure, gestures or touch. Their major focus is on simple communication using LED-based signals and simple visual feedback. With the growing demand of these devices designers need to upgrade these devices and introduce new features.The designers need to outgrow and need to tackle user interfaces for wearable devices with a holistic approach.

5.6 Software

The wearable technology is still not very mature. They are still facing numerous challenges at every front. Software is not at all different from that. There are numerous viewpoint about the kind of software a wearable device can use. The complicated framework of IoTand widespread usage of data of wearable devices makes it difficult to make decision on the kind of software it is going to use. Following are the software categories where wearable devices have to make certain decisions-[8]

Operating System: There are varieties of Operating Systems that are being used by versatile wearable devices. In the beginning of 2000 Japanese watch manufacturer Company launches a smart WatchPad in collaboration with IBM using Linux as operating system. Wrist device called WristPDA designed by Fossil in 2003was equipped with

PalmOS operating system. Microsoft designed SPOT system in 2004 for smart watches. Samsung released first smart watch in the year 2013 using Android as an operating system, later second generation of smart watches of Samsung used Tizen as an operating system. Google introduced Android Wear operating system in the year 2014 for smart watches. In the current scenario we have number of operating system available for wearable devices, but the difficulty is in its usage and to decide which one to use. The overall decision for selection of operating system is dependent on – convenience, effectiveness, scalability, openness and multitasking feature of operating systems.

Database Management System: The database plays a crucial role in the success of any application. The robust database should be able to manage voluminous data. Wearable devices collect volumes of data as they are active all the time and keep on interacting with the end users. The devices handle variety of data like personal data, health data, environmental data and many more. To handle such a versatile volume of data it is required to store it on cloud. The challenge for the database developers is to develop specialized database management system for their varied functionalities. The databases should be capable to manage light weight and heavy weight data with effective response time.

Network Communication Protocol: Wearable devices exchange data with other devices like mobile phones or other wearable devices. Exchange of data with various devices requires a network protocol for communication. To exchange data among various devices like wearable devices, smart phones, sensors etc. require a network communication protocol. The network protocol determines the exchange data format and communication mode. The varied range of network protocols is available for such devices. There are various protocols that are available currently for wireless communication. Few of them are ZigBee (IEEE802.15.4), NF C (IEEE 802.11), WICED etc.Wireless Internet Connectivity (WICED) was introduced specifically for wireless devices by BroadCom. Currently communication protocol used by wearables is quite simple. As the wearable technology will grow to implement functions like those in mobile phones more reliable and efficient network communication protocol will be demanded.

Application Development Interface: In the year 2014, Google released its Software Development Kit (SDK) with an emulator for Android Wear, which is a kind of revolution for the Application Development Interface for the wearables. Earlier to this, wearables though rich in hardware but lag in interface. The SDK has revolutionized the way various APP's are being developed. The Android Wear developers can use all the tools and can develop rich Application Interface.

Although there is ample growth in the software development platform for wearable computers but still it is not enough mature. The difficult choice is for the developers to decide about the specific platform for application development. Another issue is the unawareness about the various application development platforms which are already developed.

6. Future of Wearable Technology with IoT

Apple Watch is being launched and it is expected that it will drive to connect more and more wearable devices in a highly networked world of IoT. From the past few years the trend is to get more and more personalized computers. These personalized computers come in the form of clothes, jewelry, shoes, glasses, watches and many more.

Today we live in a networked world where everyone and every device is connected to each other by some means. In developed countries most of the house hold is also connected to the network. Table-1 below shows the growth of connected devices in the previous years. [9]

YEAR	NUMBER OF CONNECTED DEVICES
1990	0.3 million
1999	90.0 million
2010	5.0 billion
2013	9.0 billion
2025	1.0 trillion

Table 1: Source HP

IoT which implies the network of connected devices through a wired or wire-less media, is revolutionized the way business was done earlier, sharing of information, sharingof resources, smarter interactions with customers and greater efficiencies. Now each and every identified device is intelligent and internet-enabled. With such a kind of objects one can blend the physical world with digital world of information and can make a shared network over the ubiquitous internet. The embedded intelligence in our personalized items, cars, office equipment, clothing, household appliances and many other produces voluminous and valuable data which can be collected, analyzed and shared for a varied purpose like – business, societal and personal advancement.

Wearable technologies are progressing fast. In general with the concept of wearable's people think about personal monitoring devices like FitBit or Nike+FuelBand which are used to record various health related data such as blood pressure, heart rate, eating frequency and many more. But wearable devices are grown to be more personal. The electronic "tattoos" are introduced which can be used by would be mothers to monitor fetal heart rate.These tattoos can also detect early sign of labor and even notifies the doctor when it's time to rush to the hospital.

The combination of wearable devices and cloud can outperform and return maximum results. One of the examples for the same is SIGMO which is a language translator and can be clipped to your shirt or one can wear it on his/her wrist. After getting connected with cloud it provides real-time voice translation of twenty five languages.

The future of wearables is replaceable. The current scenario is to transplant cornea to repair damaged eyes. In the coming years the replaceable will touch new heights for example visibly impaired people will be able to transplant artificial

eyes with inbuilt sensors for night vision and zoom capabilities. The prosthetics used for limb replacement will become more flexible and powerful as compared to original organic limbs. This all will happen by the Internet of Everything which facilitates connectivity among devices, people, data and things. The devices and technologies are growing and getting advance with each passing day. It is expected that in the near future 50 billion devices will get connected this generates the need of cheap, small and robust devices.

7. Conclusion

Wearable devices will change modern way of life and in the near future wearables are definitely going to capture mainstream of the development of mobile smart devices. Currently, the development of wearable devices is still in its immature phase, and the main function of these devices focus on running calculation, navigation, remote picture and other related services. The forecast of Cisco to connect 50 billion devices by 2020 is generating more avenues for the wearable devices and computing. The application of wearable devices is now affecting every area of our life whether it is health, enterprise, lifestyle and many more.

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