The Exploration of Smart Homes & Classification of Wearable Technologies

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NOMENCLATURE

IoT	Internet of Things
OS	Operating System
WLAN	Wireless Area Network
BLE	Bluetooth Low Energy
MU-MIMO	Multi-user Multiple Input/Multiple Output
IT	Information Technology

Keywords—Wearables, Smart Home, Wireless Connection, Smart Devices

I. INTRODUCTION

As the world approaches a new era of technology, humans are preparing for new opportunities. In the 1990's and early 2000's the world-wide web and e-mail revolutionized commerce and business. Today, in this new era of technology, the Internet is guiding humanity towards a connected world. Devices used in manufactured objects and for business are becoming more network-enabled, allowing better communication and interaction. Machine-to-machine communication, where everyday objects are online and able to interact, is transforming the definition of smart devices. Smart devices, which used to include laptops and mobile phones, now include cars, power grids, and industrial equipment. These intelligent devices are helping consumers, businesses, and governments find solutions for many issues.

Wearables are a type of smart device, and they are electronic accessories capable of sensing,

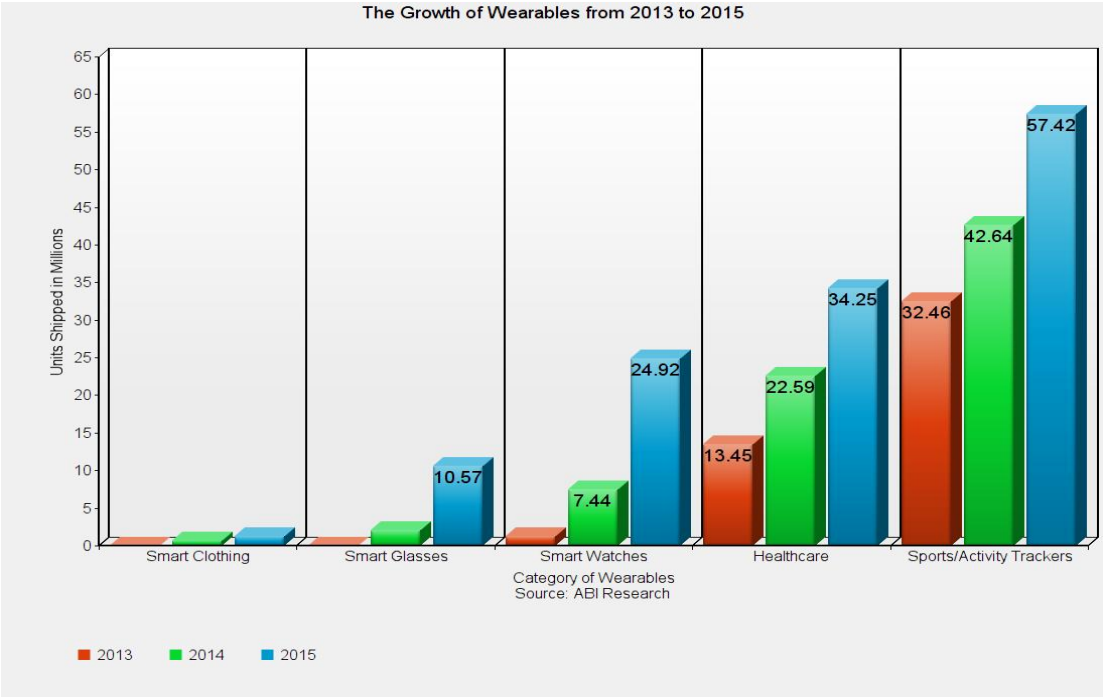

Figure 1 Wearable Shipments from 2013 to 2015

networking, and computing [1]. It has more functions than laptops and desktops, like the capability to provide biofeedback and sense physiological function [1]. Because of these additional operations, wearables require a high data rate for connection to devices. The appeal in wearables is to provide hands-free, portable access to the internet and other applications. Examples of wearables include augmented reality glasses, smart watches, accurate navigation assists, and virtual reality devices. One person can have many wearables. Their smart phones can process numerous sensor data inputs and host multimedia content for applications on the wearables' display--acting as a cumulative node [3]. The wearable market is projected to be worth 25 billion dollars, grow threefold and sell 245 million wearables by 2019 [2]. In 2015, the market was worth 15 billion and sold 84 million wearables. The main source of revenue for this market are smart watches, making $9 billion dollars in 2015 alone [2]. Figure 1 visualizes the growth of wearables from 2013 to 2015 as shipments have been rising since 2013. Smart watches in particular have experienced the largest growth on the market.

In the near future, many people will possess a wearable or many wearables. Wearables do not use cables because they need to be seamlessly incorporated into attire-- instead using wireless signals. Users do not usually interfere with each other's networks, but because of wireless signals, this can become a problem if there are too many users [4]. In situations densely packed with people (public transportation, stadiums during sporting events, campuses, etc.) there is not enough bandwidth to go around. Additionally, another possible future challenge for wearables is power consumption. They use small batteries, and their sensors are always on to gather data--meaning they have to be on for days, not hours like smartphones. This paper addresses these two issues, and offers possible solutions. Moreover, there are no consistent classifications for wearables because they are relatively new. This paper classifies the types of wearables in order to standardize them and to assist in future development. Also listed are examples of each classification in the industry.

II. LITERATURE REVIEW

The internet of things is a rapidly developing concept among different industries. IoT is a vision where every object and device has the ability to communicate with each other and the Internet, therefore enabling a wide range of applications and services. Characteristics of IoT includes scalability, availability, and applicability [6], making it an ideal network for deployment of immense numbers of wearables. Finally, security and privacy issues rise with the emergence of wearable technology that must be appropriately address since wearables will constantly stream sensitive information about users to servers.

Kortuem et al. [8] envisioned a world of IoT built upon the idea of smart objects-- devices capable of sensing, processing and networking and can be separated into being activity, policy, and/or process aware. The ideas of smart objects already exist in today's society, in the form of wearables and are widely implemented in healthcare, fitness, and entertainment. Wearables represent an aspect of IoT that is human-centered, capable of input and output and designed to interact with users. With a rapid increase in the number of wearables, torrents of sensor data will quickly overwhelm computing power of embedded hardware. Cloud computing offers possible solutions for data management through its computing capability, storage, ease of access and big data analysis [7]. In addition, the market oriented cloud computing is suitable for markets in wearables, allowing the company to deploy devices without having to worry about the logistics and hardware component of the process. The cloud computing service will be provided by third parties, allowing users easy access through internet [9]. Ganti et al. [12] discussed the potential

Table 1 Contemporary market categories for wearables

Category	Characteristics	Capabilities and Use
Smart Watch	• Not as much processing power compared to a smart phone • User interface consists of touching frame and speaking commands • GPS and contactless capability	Used to display key information the user wants or as a way to identify himself. • Payment • Fitness Tracking • Communication • Navigation
Virtual Reality Headsets	• Deeply engaging screen • Can be used by moving head, speaking commands, or moving hands.	Used when users want to simulate an environment. • Gaming • Visualization for sightseeing, touring, or different activities.
Digital Eyewear	• Screen is in sight all the time • User interface consists of touching frame and speaking commands • Not as much processing power compared to a smart phone • Frame acts as an earpiece, sending sound into the user's ear	Used when it is inconvenient to look down at a screen or as a teaching aid where the user needs to keep an eye on the activity at hand • Language translation • Visualization • Communication • Task coordination
Smart Clothing (Fitness/Healthcare)	• No user interface or screen • Has body sensors to capture data	Provides feedback on the status of the user's body • Tracking heart rate, temperature, activity, and posture (body sensing) • Fitness • Fashion

of smart devices as a part of wireless sensor networks (WSN) in IoT and coined the term mobile crowd sensing. The immense amount of data captured by smart devices currently employed could provide researchers and corporations with information on a complete different scale. However, WSN face many challenges when incorporating mobile smart devices, such as resource limitation (energy, bandwidth, and computation), privacy, and security.

III. PROPOSED METHOD

Wearables can be divided further by being basic, mid-range, and high-end devices. Building on the previous research by Kortuem et al. [8], wearables in the market today can be classified into sensing, processing, networking, or combinations of these characteristics. This paper will classify popular categories of wearable technology on market today and discuss the communication requirements, challenges and solutions.

Smart homes have four main categories: safety, privacy, convenience, and efficiency. The applications that go under these categories are everyday objects in your house. This paper will go further into the applications of a smart home.

IV. DATA RESULTS AND DISCUSSION

The four main types of wearables are smart watches, virtual reality devices, smart clothing, and digital eyewear. Smart watches do not have as much processing power as a smart phone and their UI (user interface) consists of speaking commands and a touchable frame. Their main use is to display key information the user requires or as a way to identify themselves. Virtual reality headsets have an immersive screen that can be used by moving the head or hands or through speaking. Visualization for sightseeing, touring, or gaming is a key feature of these devices. Digital eyewear consists of a touching frame that can act as an earpiece with a screen in sight at all times. Like the smart watch, it does not have as much processing power as a smart phone. This device is used mostly as a teaching aid when it is inconvenient to look down or when the user needs to keep an eye on the activity at hand. Smart clothing has no UI, but instead has body sensors to capture data. This data can provide feedback to the user about their body, such as heart rate, temperature, and posture. A summary of their characteristics and uses are listed in Table 1. Based on research on wearables market, a classification system was introduced and visualized in Figure 2.

Basic devices have a simple OS (operating system) and are implemented with sensors to monitor user activity or environments. Examples include fitness trackers and sports bands. These basic devices emphasize on sensors, with very limited requirements for processing and networking. They usually do not have any UI (user interface), and are meant to be accessories to people's smart phones. Furthermore, basic devices have ultra-low power processors that are not always on-- only triggered through certain events, like a new set of data ready for processing or user interaction. The necessity for portability and convenience caused these devices to rely on small batteries in continuous use without charging for several days. Therefore, power conservation became an important factor when implementing communication. Fortunately, these basic devices do not require access to internet and function on transmission of data to other smart devices, which can serve as nodes of communication.

With these considerations, low range and energy cost provided by Bluetooth Low Energy (BLE) best complements the needs of basic devices when compared with WiFi, NFC (Near Field Communication), and IrDA (Infrared Data Association). The limited range of NFC and IrDA technology are unsuitable for basic devices because they will not always be in communication range with smartphones. On the other hand, the power consumption of WiFi technology contradict the low power requirement of basic devices. Siekkinen et al. [5] discussed BLE as a potential candidate for the implementation of wireless sensor networks (WSN) in IoT with respect to its energy efficiency. While BLE suffer from a short range (50 m/160 ft.) and a low data rate (1Mbps), its low cost and power consumption (able to run for years on a standard coin-cell battery) are perfect for these basic devices. In addition, BLE offers the necessary interoperability (with many smart devices on the market today already implemented with BLE technology) enabling these basic devices easy connections to other smart devices.

In today's market, most fitness trackers and health-monitoring devices fall under the category of basic devices. These basic devices can also be incorporated into clothing to track user's physical condition. The sensors embedded within the device, whether it is biosensors or accelerometers, are responsible for capturing a stream of data (eye tracking, blood pressure, calories burned, etc.) and communicate it with the user's smartphone. The applications on smartphones are responsible for processing the data and display results for users or uploading the information during an emergency situation. There are many possibilities in the healthcare industry if these devices were implemented.

Mid-range devices are like basic devices, but they have greater functionality and performance. It gathers qualitative and quantitative data, but it can act on it, unlike a basic device. While mid-range devices place greater emphasis on processing powers, it inherited many of the challenges from basic devices. Portability, convenience, and appearance remained important factors during the design of these mid-range devices. Consumers expect their mid-range devices (such as their smart watch) to last longer on battery, able to process independently from their smart phone and be unobtrusive and fashionable on top of all the other necessities. Bluetooth technology is still necessary on these devices because users expect to connect their devices with their smartphones and receive notifications such as calls, message, and alerts. However, many mid-range devices are implemented with processors that are capable of running complicate applications which require higher channel capacity. Therefore, WiFi technology became necessary for these mid-range devices because it provides the necessary bandwidth, latency, and power management. The ability to connect to a wireless local area network (WLAN) provides these mid-range devices with many capabilities and functions. Users can not only monitor their physical conditions with embedded sensors, but receive news, weather, or even updates from their social media. However, as mentioned earlier, the number of wearables employed has been multiplying rapidly. In near future, the sheer number of mid-range or high end devices will quickly overwhelm WLAN. The issue will be addressed in later sections.

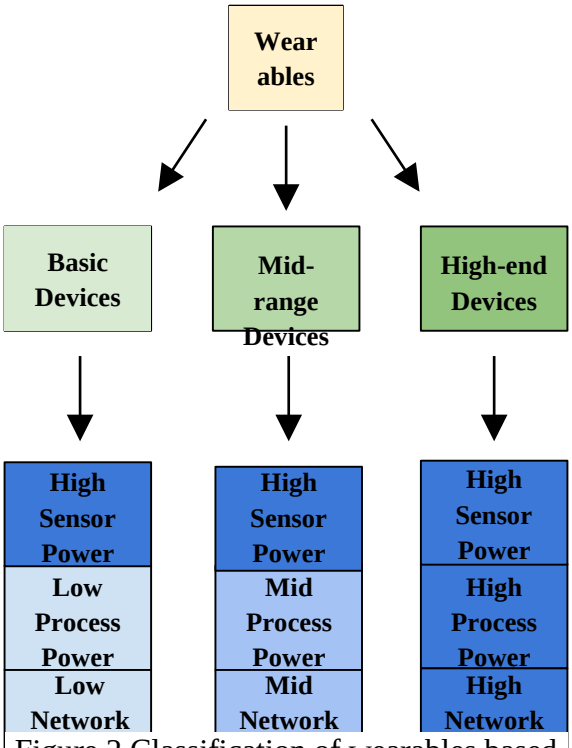

Figure 2 Classification of wearables based on sensor, processor, and network requirement

Mid-range devices on the market today consist mostly of smart watches. These smart watches are implemented with an OS and UI. Smart watches can be further divided between fitness and lifestyle. Fitness watches place more emphasis on sensors to check user's activities and well-being with less importance placed on processing powers and networking ability (may not implemented with WiFi technology). On the other hand, smart watches focused on lifestyle and entertainment has a much more powerful processor to satisfy the daily needs of user. These smart watches have higher network requirements and energy consumption similar to smartphones. Also, both devices can use the information they gather, and can warn the user of certain things--such as their heart rate going too fast or they are not doing something correctly. Many smart watch have capabilities similar to tablet or smart phones on the market today.

High-end devices emphasize sensing, processing, and networking powers while sacrificing portability and convenience. For users with high-end devices, the processing power outweighs considerations for comfort and appearance. These devices can assist users in their daily life by providing a wide range of functions typically found in their smart phones and tablet without the difficulty of manually accessing them. To provide user with easy access, these high-end devices have incorporated voice-command, gesture detection, and sensors to recognize user's eye movement. Digital eyewear in particular emphasizes on accessibility and functionality, to provide user with a hand-free experience while adhering to their daily needs, such as communicating with others and finding information. The digital screens are always within or overlays user's sight without much obtrusion to user's awareness of environment. On the other hand, high-end devices include category of headsets aimed to provide user with an immersive entertainment experiences. Virtual reality headsets included an immersive screen that separate users from their surroundings. These types of high-end devices are confined in indoor environments and provide users with simulations of virtual environments. High-end devices need proficient sensors to capture a user's voice and movement, powerful processors to manage the information, and access to high networking capacity to download large packets of data. The 802.11n standards can provide the necessary connection to WLAN.

These devices are most prevalent in entertainment, but they have been used in the industry as well. Some militaries have trained their soldiers in certain situations with virtual reality headsets, and some colleges use virtual reality headsets to give people out of state a chance to tour their campus. In the medical industry, some clinics have used eyewear to make tracking and recording patient information easier. High-end devices have greater capabilities than mid-range and basic devices, but their functionality can be improved.

In areas with high human density, such as stadiums, conventions, corporations and campus, the existing 802.11n standards are struggling to provide adequate channel capacity to accommodate thousands of smart devices trying to access WLAN simultaneously. In 2013, the IEEE (Institue of Electronic and Electrical Engineers) established new wireless protocols 802.11ac capable of establishing 1.3 Gbps and operating on the 5 GHz band. However, channel capacity alone is not enough to topple the problem as multiple users and devices will attempt to access the same AP (access point), reducing the performance of the network. In 2014, amendments were made to improve the 802.11ac standards which included MU-MIMO (multi-user multiple input/multiple output) which will significantly improve the performance of network in high density areas in addition to wider channelization and beamforming techniques. The MU-MIMO technology allows stations with multiple antennas to transfer independent data streams to multiple users at the same time [11]. As a result, each AP is capable of hosting multiple users simultaneously and

the cost and complexity is only added to the AP, not the client device. Presently, there are only few products on market supporting 802.11ac Wave 2 and few IT managers decided to upgrade their network infrastructure to the newest standard. However, with the advent of wearables and IoT, 802.11ac network and MU-MIMO technology will certainly become indispensable. Smart homes have many applications that can enhance human's lives. Smart homes are already being made to turn on the lights and change the temperature of the house. This can save energy and increase efficiency if applied to enough homes around the world. A person can log onto a secure app where they can control the house and could do things such as lowering the temperature when they leave a room. Making homes safe when a parent is not present is an important problem to tackle. Recently, there has been a rise in child deaths linked to unauthorized access to firearms. Children, when able to freely access a firearm lying around the home, pose a threat to themselves and everyone in the home. Also, there have been many occurrences of children taking firearms from home to school. Smart technology can help prevent these disasters with smart gun locks. Smart gun locks are specially designed mechanisms that attach to the firearm and don't allow it to be used. These mechanisms contain sensors can send and receive data. Gun owners can put this smart lock on their gun and receive real time alerts of when their gun is being disturbed. These gun locks are already being assembled by companies such as ZORE X. Smart homes can also provide privacy by tinting windows or setting computer locks.

V. CONCLUSION

This paper has concluded that there are different types of wearables, such as smart watches, virtual reality headsets, and digital eyewear. These wearables can be further divided into being basic, mid-range, or high-end devices. Basic devices only accumulate data, and display it to the user. There is little to none UI. Mid-range devices have greater processing power than basic device and can send messages to users based on the data they gather. High-end devices have very high processing power and their emphasize on sensing and networking. Furthermore, this paper addressed the issues of energy consumption and networking in high-density environments. BLE would best complement the ultra-low energy consumption of wearables because it is inexpensive and provides the most suitable amount of energy. Moreover, MU-MIMO, channelization and beamforming techniques would increase network efficiency in high-density environments, and let wearables scale. The development of wearables is rapidly expanding; high-end devices in the future should become more portable and convenience moving them towards the category of mid-range devices. This paper has also researched the applications of a smart home and found its benefits of privacy, efficiency, convenience, and safety. Furthermore, new innovations in wearables could invalidate this classification system and suggestions for networking and energy consumption. However, this classification system will provide the basic groundwork for the future. Future lines of research should be directed towards the implementation of the MU-MIMO and BLE as these are new and upcoming technologies that could solve the future challenges of wearables.

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REFERENCES

[1] Tehrani, Kiana, and Andrew Michael. "Wearable Technology and Wearable Devices: Everything You Need to Know." *Wearable Devices Magazine*, WearableDevices.com, March 2014. Web.

[2] Wearables Market to Be Worth $25 Billion by 2019. Retrieved June 23, 2016, from http://www.ccsinsight.com/press/company-news/2332-wearables-market-to-be-worth-25-billion-by-2019-reveals-ccs-insight
[3] K. Venugopal and R. W. Heath, "Millimeter Wave Networked Wearables in Dense Indoor Environments," in *IEEE Access*, vol. 4, no. , pp. 1205-1221, 2016. doi: 10.1109/ACCESS.2016.2542478
[4] A. Pyattaev, K. Johnsson, S. Andreev and Y. Koucheryavy, "Communication challenges in high-density deployments of wearable wireless devices," in *IEEE Wireless Communications*, vol. 22, no. 1, pp. 12-18, February 2015.
[5] The future of retail with wearable technology. Retrieved July 05, 2016, from \http://retail-innovation.com/the-future-of-retail-with-wearable-technology/
[6] J. A. Stankovic, "Research Directions for the Internet of Things," in *IEEE Internet of Things Journal*, vol. 1, no. 1, pp. 3-9, Feb. 2014.
[7] A. Botta, W. de Donato, V. Persico and A. Pescapé, "On the Integration of Cloud Computing and Internet of Things," *Future Internet of Things and Cloud (FiCloud), 2014 International Conference on*, Barcelona, 2014, pp. 23-30.
[8] G. Kortuem, F. Kawsar, V. Sundramoorthy and D. Fitton, "Smart objects as building blocks for the Internet of things," in *IEEE Internet Computing*, vol. 14, no. 1, pp. 44-51, Jan.-Feb. 2010.
[9] R. Buyya, C. S. Yeo and S. Venugopal, "Market-Oriented Cloud Computing: Vision, Hype, and Reality for Delivering IT Services as Computing Utilities," *High Performance Computing and Communications, 2008. HPCC '08. 10th IEEE International Conference on*, Dalian, 2008, pp. 5-13.
[10] M. Siekkinen, M. Hiienkari, J. K. Nurminen and J. Nieminen, "How low energy is bluetooth low energy? Comparative measurements with ZigBee/802.15.4," *Wireless Communications and Networking Conference Workshops (WCNCW), 2012 IEEE*, Paris, 2012, pp. 232-237.
[11] O. Bejarano, E. W. Knightly and M. Park, "IEEE 802.11ac: from channelization to multi-user MIMO," in *IEEE Communications Magazine*, vol. 51, no. 10, pp. 84-90, October 2013.
[12] R. K. Ganti, F. Ye and H. Lei, "Mobile crowdsensing: current state and future challenges," in *IEEE Communications Magazine*, vol. 49, no. 11, pp. 32-39, November 2011.
[13] J. Kim, S. Kim, J. Chun, S. Kong and H. Lim, "Smart Home Architecture: Architecture, detailed Protocols and Procedures"
[14] S. Kim, J. Chun, J. Kim and J. Hong, "Smart Home Application Profile Specification"
[15] "ZigBee Home Automation Public Application Profile", *ZigBee Alliance*
[16] "Smart Energy Profile 2.0Application Protocol Specification", *ZigBee Alliance*