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INTERNET CONNECTED CLOTHING

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Abstract: Smart clothes and wearable's have emerged as ubiquitous technology with the rise of the Internet of Technology (IoT) and enabling technologies like smart sensors, data analysis, low-cost cloud computing, and mobile and wireless connectivity. The rapid convergence of textiles and electrical materials and the development of conductive yarn allow seamless integration of sensors with textiles. Smart fabrics have the potential to communicate with smart phones to process biometric information from the human body such as heart rate, temperature, breathing, stress, movement, or hormone levels, promising a new era for retail. This article presents a smart clothing ecosystem that explains the communication architecture between the user, cloud, and the smart cloth that consists of various subsystems comprising of sensors. Some of the most recent accomplished researches in this field are studied. The article also reviews some of the applications of smart clothes; its past, present, and future to provide a holistic approach on the topic.

Index Terms **- Internet of Things, Smart Sensors, Smart-Garment, Cloud, Data, Conductive Yarn, Fabrics**

I. INTRODUCTION

Over the past few years, there has been much buzz about the Internet of Things (IoT) becoming one of the most emerging technologies. The rapid development and implementation of IoT technologies have opened new horizons in technological advancements for different aspects of life. IoT connects various physical devices such as cars, air-conditioners, watches and glasses to name a few, to the internet, making them digitally smart with the help of low-cost computing, economical sensors, the cloud services like Microsoft Azure and Amazon AWS, big data, networking, and mobile & wireless technologies for communication. All this is done by the sensors embedded in the devices, continuously emitting data about the working state and the environment they are operated in [1]. This has benefitted the users to easily communicate with different devices over the internet for richer experiences.

This rapid digitization has led to IoT soaring in every area of our lives, from smart cities to pollution control to energy saving to smart industries. With a strong focus on machine-to-machine (M2M) communication, big data, and machine learning, the IoT enables industries and enterprises to have better efficiency and reliability in their operations [2]. One such booming industry is the fashion industry which is on the cusp of unleashing the fullest potential of IoT. Smart connected clothing is opening new horizons for wearables such as wristbands, glasses, and clothes ardently desirable.

Smart wearables are electronic devices that can be comfortably placed on, in, or near the body's surface to track, analyze and transmit information such as biometrics or ambient data on a real-time basis [3]. This information is provided to the user over the internet. Wearable devices can take up the form of accessories, textiles, patchable devices, or implantable wearable's distinguished on the basis of their contact with the body. These devices contain electronics, software, sensors, and connectivity that enable the data exchange with the user or other connected devices through the internet without any human intervention [4]. These smart wearables are embedded into the garments to create smart clothes.

The idea of the smart wearable device was proposed in the year 2000, with the design interface for the next generation of the personal wearable camera that were being used as the part of surveillance movement. Also, a hidden Bluetooth microphone fitted into a pair of earrings was launched in 2008. Later in 2010, Fit bit released its first step counter to track down walking and heart rate of a human body movement. In 2013, NFC Ring, widely known as McLear that could unlock devices, pay with bitcoin and transfer authenticated information, was launched. The release of widely available smart watches, the Samsung Galaxy Gear in 2013 and the Apple watch in 2015 blazed a new trail [4]. Here is the timeline of above-mentioned researches shown in Figure 1:

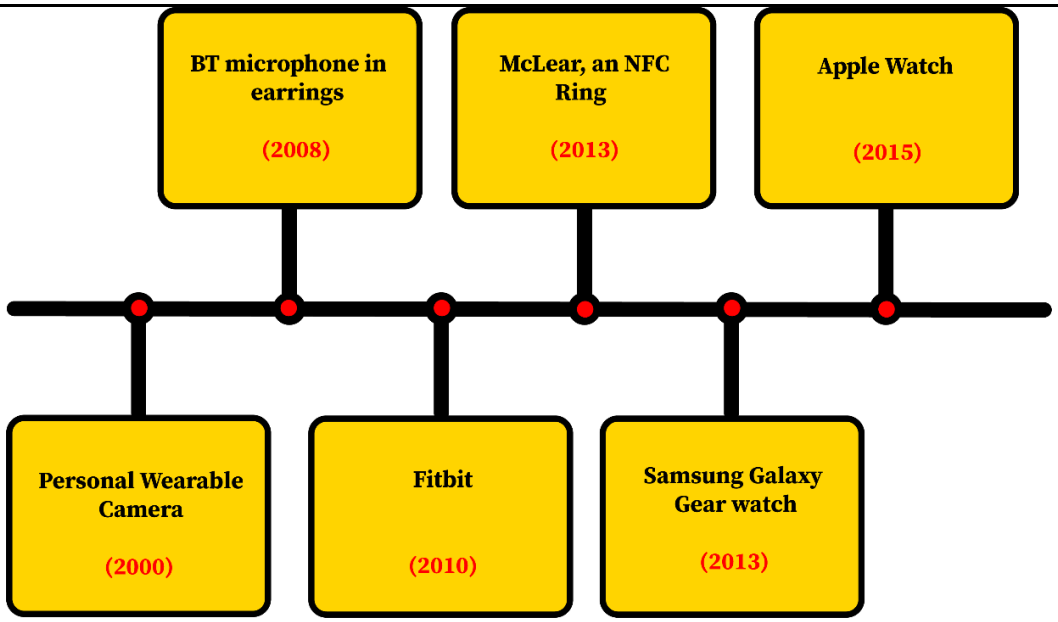

Figure 1: History of wearable technology

A report by Avnet says, in 2015, the e-textiles market was reported to be worth $100 million, which is expected to grow to $10.25 billion in the next 10 years with advancement in IoT [5]. Textiles are the ultimate wearable medium over other wearable accessories as they can track more biometric signals due to their larger surface area and closeness to our bodies. Clothes that were earlier used to cover the body can now do bizarre things, from coordinating with the washing machine to set the appropriate settings in which they must be washed, to changing the colour and pattern of LED fabrics, to playing songs on Spotify with live GPS tracking; there is nothing that a smart cloth cannot do.

According to the survey by Indian Textile Journal in 2011, "It is estimated that every year, more than 1 million tonnes of textiles are thrown away, with the most of this coming from household sources comprising of 3% of the total waste. At the least 50% of the textiles that one throws away are recyclable, but in practical only 25% of wastes are recycled" [6]. According to another estimate, the garment cutting and making process results in the loss of 25% of the fabric [7]. Connected clothing has an impactful solution to the above problem as it supports automated material sorting in the textile recycling process and garment traceability.

II. SMART CLOTHING ECOSYSTEM

The ecosystem of smart wearable clothing as explained in Figure 2 consists of various subsystems with different sensors to provide various functionalities. The communication between these subsystems can be wireless or conductive fabrics; however, the latter is preferred because of ease in production and maintenance [3].

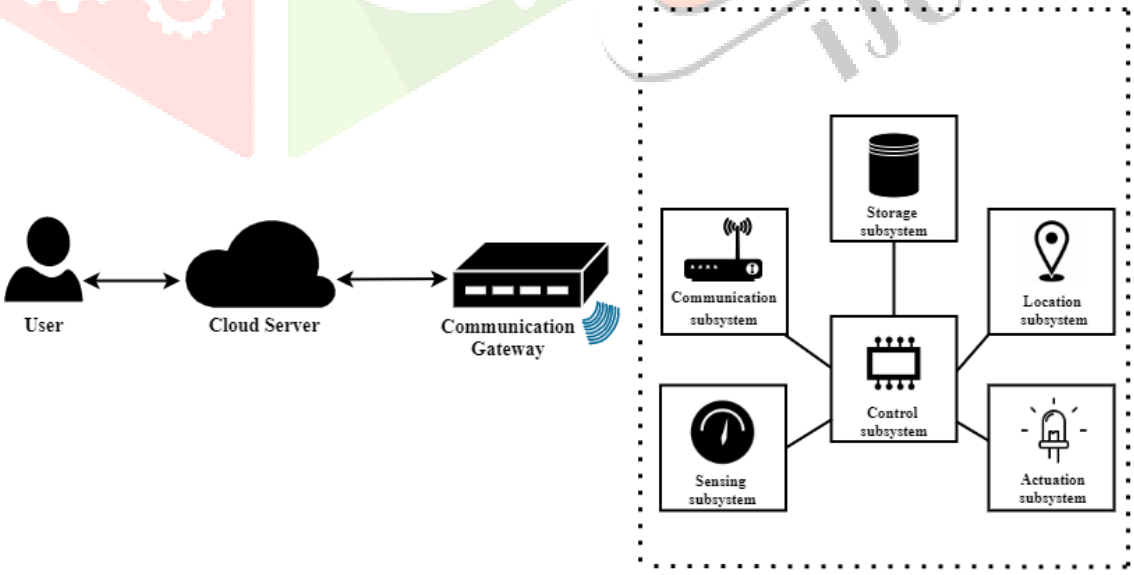

Figure 2: Smart Clothing Ecosystem [3]

Smart wearable's use advanced textiles with interwoven or printed circuitry, or sensors, haptics, and additional hardware to provide smart functionality. The sensors embedded in the clothes continuously read the data from the body and store it on the cloud server [8]. This data is interpreted using machine learning, and an appropriate response is generated and sent to the sensors to work accordingly. In some cases, the response is in the form of notifications or message alerts sent to the connected mobile phones of the user.

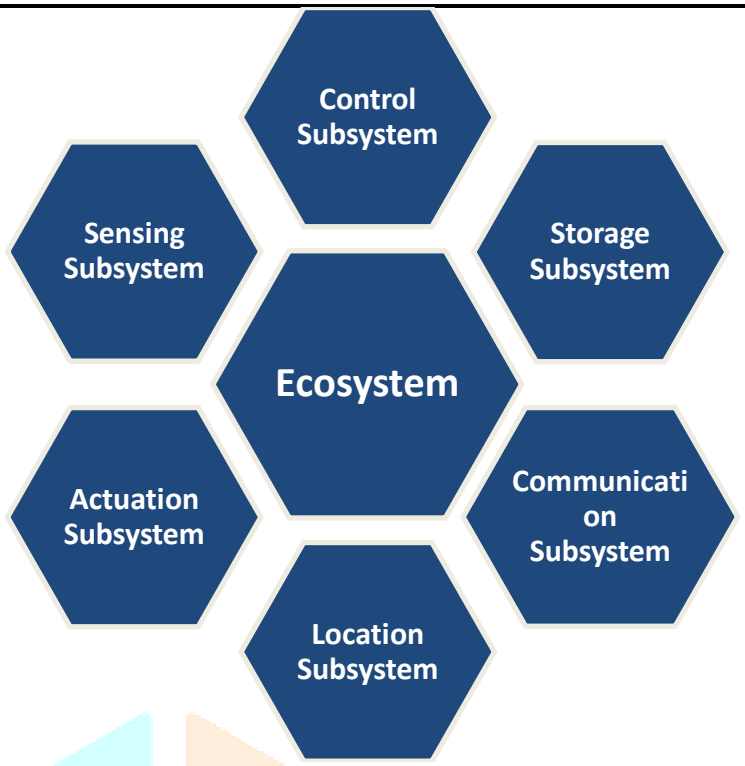

Figure 3: Smart Wearable's Clothing Sub-System

The following subsystems are largely used in the smart clothing shown in Figure 3 and explained as under:

i. Sensing Subsystem: This subsystem includes sensors that records the reading from the surroundings, such as vital sign rates for measuring heart rate, blood pressure, or location sensors to exactly locate the smart clothes and environmental sensors that measure air temperature, light, and humidity, to name a few [3].

ii. Actuation Subsystem: This subsystem includes actuators like heaters and coolers that can generate heating and cooling for the smart clothes or visual indicators such as Light-Emitting Diode (LEDs) [3].

iii. Control Subsystem: This Subsystem includes electronic devices to control and monitor the whole connection, such as Field-Programmable Gate Arrays (FPGAs) or System-on-Chips (SOCs). However, Microcontrollers like Arduino or Raspberry Pi trend because of their low energy consumption and easy programming [3].

iv. Communication Subsystem: The communication subsystem enables the smart garment to be connected with the Internet. It mainly enables two major tasks such as first, the exchange of data between a smart garment and communication gateway and another for identification mechanism for the wearer.

v. Location Subsystem: This subsystem enables efficient direction tracking to a destination using Global Positioning System (GPS) or Global Navigation Satellite System [3].

vi. Storage Subsystem: The storage subsystem takes care of the stored data collected by sensors to some server like a cloud which is further processed to the user through a mobile or web application [3].

III. ACCOMPLISHED RESEARCHES

After the rigorous study on smart wearable's and the ecosystem, the key finding results has been explained with the help of illustration mentioned in Figure 4. The two illustrations depicted here present the real-world possibilities in the field of internet-connected clothing. If the temperature is low and there are no extra wearable's, the jacket's temperature can be increased as required. Moreover, if the phone's battery is dead and there is no charger, one can put it in the pocket, and the jeans charge it. For example, a California-based fashion brand, Joe's jeans, offers innovative pants with a discrete iPhone pocket and an extra slot to hold a slim battery designed specifically for the jeans.

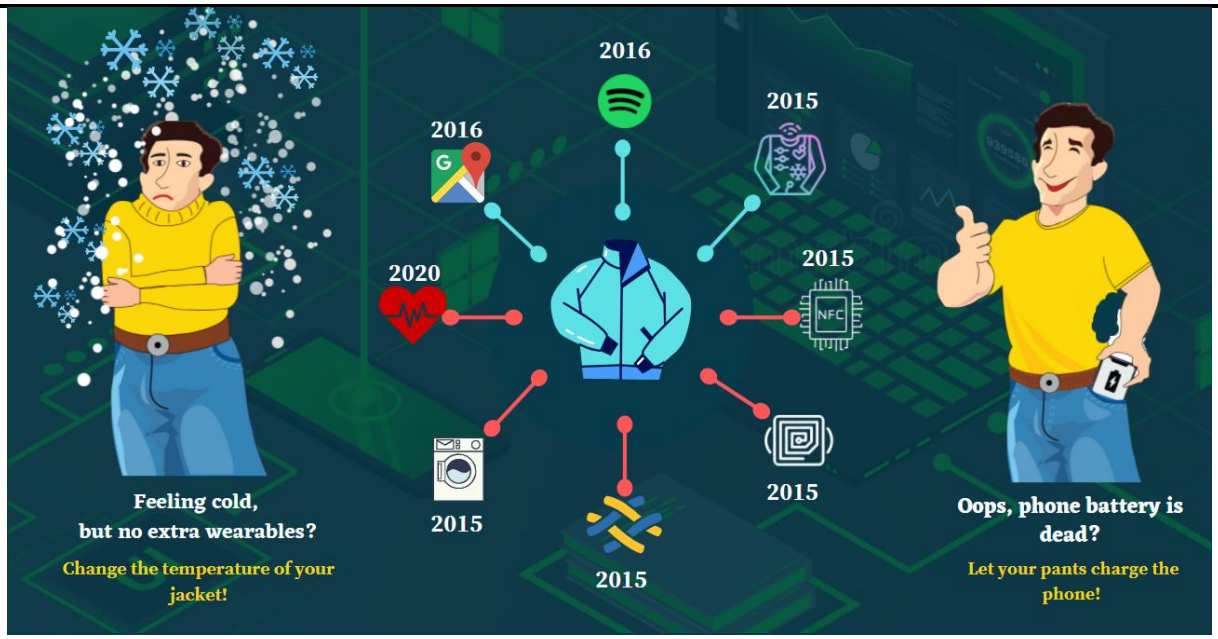

Figure 4: Research Findings

CuteCircuit, the world's first wearable-technology fashion brand, in 2015 introduced silk skirts and jackets that contain intelligent LED fabrics that change the pattern and animate under the control of an app on the Smartphone [9]. If a user accidently spilled a drink on their clothes, they are now worried about the stain. As per the proposal by CuteCircuit in 2015, the smart garment can automatically connect to the washing machine and set the correct configurations. However, a lot is still to be achieved in this field [9].

Another one is quite interesting. Dating back to 2015, Avery Dennison, a materials science and manufacturing company, unveiled a smart bomber jacket called the Bright BMBR under the fashion label Rochambeau. The jacket has an RFID Tag and personalized QR code that acts as a VIP pass to different events in New York or some aesthetic gift shops [10].

Tracking of routes along with listening to the music were the things only capable by mobile phones. However, now, these are offered by the clothing that earlier just covered our bodies. Google and Levi's collaboration dating back to 2016 resulted in manufacturing a smart jacket named Jacquard, which is fully equipped with Maps allowing for tracking the jacket and Spotify integration enabling the customer to listen to their favourite playlist [11].

Garments contain electronic components that collect data generated from skin or sweat in contact with the fabric, such as heart rate, blood pressure, body temperature, etc. For example, medical technology start-up Rhaeos in 2020 has developed a wearable for non-invasive monitoring of patients suffering from an accumulation of brain fluids. They even received the Global Med Tech award [12].

IV. APPLICATIONS

IoT has changed everything about fashion. Smart clothing has provided outstanding innovation and comfort in people's life. Some of the major applications are listed below:

a. **Healthcare:** They promote smart health, like detection of breast cancer through the wearables under the project named 'Itbra' or proper tracking of biometrics for disease prevention and healthy lifestyle.

b. **Navigation:** GPS tracking shows users the way to their destination and acts as a way to locate their clothes that get lost.

c. **Self-Care:** Automatic heating of jackets through mercury sensors that read the temperature of the body and surroundings and accordingly make the jacket warm.

d. **Aid to visually-impaired:** These garments help visually impaired patients to become more mobile and independent.

e. **Advanced Fabrics:** Enthusiasts can change the colour and pattern of the clothes as per their will.

f. **Authentication & Intelligence:** RFID-enabled clothes act as a key to the doors, authenticate transactions, or actuate on things.

Despite these advantages, a few parameters should be taken care of technology-wise. They need to be trendy and, at the same time, not compromise on aesthetics. The clothing designed must be comfortable, batteries should last long enough, and be safe from any radiations or vibrations through sensors as they will be pretty close to our skin all over. They must be flexible enough to adapt to body movements, body sweat, and frequent exposure to air and water. Lastly, they should measure the data appropriately.

V. CONCLUSION

This article reviewed the history of smart clothes and some recent researches in this field, showing the potential of IoT. The relevant subsystems with their communication architecture were described in the ecosystem. We also discussed the prevalent applications of smart clothes in healthcare, self-care, navigation, advanced fabrics, and authentication and intelligence. Finally, some parameters are discussed that should be taken care of while designing the smart garment. The booming connectivity in the apparel industry contributes to the massive success of internet-connected clothing.

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