Internet of Health Things: A Review

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Abstract

In today's knowledge-based economy, ICT is deriving unlimited opportunities for healthcare platforms to emerge alike in industrial engineering, manufacturing, and business sectors. In future the people would be connecting to the Internet using Internet of Things (IoT) technology devices like smart wearable (smart watch, smart clothes, smart shoes, and smart glasses etc.), where people can connect to work, home, and health to make life easier, well-organized and safe. Precisely, IoT connectivity is developing the patient-doctor relationship always-on connection around the clock and it brings up personalized, on-time, ubiquitous, and cost-effective health services to patients via Internet of Health Things (IoHT), and connected health wearable. This curious development in ICT may potentially transform the modern healthcare as smart healthcare in enhancing healthcare quality and delivery, minimizing medical errors, and increase efficiencies with real-time data analytics. The purpose is to give insight into concept of "Smart Healthcare" that meets the needs of digitally linked society by 2025. More, the paper presumes to present the upcoming trends in healthcare and contribution of IoHT in reforming healthcare practice in a robust and optimal control anywhere anytime.

Keywords: *Smart Healthcare, IoT Sensors, Sensor Health Shield, Smart wearable, IoHT.*

1. Introduction

Kevin Aston, principal of Auto-ID center proposed the concept of Internet of Things (IoT) in late 90s. IoT is a network system established on the utilization of sensible devices, actuators, innovative connectivity, and programming into ordinary things from street lights, automobiles to home appliances that empowers these items to sense information perception and decide consequently as smart devices. Each second thousands of smart things are connecting to the Internet that have the ability to sense and communicate, for all intents and purposes, IoT system depicts situations as a horde of keen gadgets to convey through broadband advancements (3G, 4G), share data, and break down data on an aggregate guarantee to fulfill shared goals. The incessant interconnectivity and context awareness of smart things emerge with the opportunities to new smart platforms in healthcare, automobiles, and smart traffic management etc[1]. Schneider Electric (2017), earning its major portion of profit more than 45 percent is with IoT-based considerations:

- "IoT enhances business with connectivity & analytics, maintains and increases competitive advantage by connecting all of the assets".

- "IoT builds new offers and business models unlock trapped efficiency value with connected offers and subscription business models".
- "IoT changes customer engagement to build lasting life-cycle relationships that allow us to offer value and experience, targeted at specific needs".

1.1 Applications of IOT

Currently, it is second development phase of IoT devices worldwide, before the plentiful reception and deployment phase (Smart Cities Council, 2014). Relatively yet few dynamic organizations have detected to get up to speed the commercialization of IoT in keen areas such as smart healthcare, smart urbanization, and smart industry et cetera [1]. Figure 1 depicts assorted IoT-enabled smart objects.

Figure 1 IoT-enabled smart Objects, Source: [31]

HOME CONSUMER	TRANSPORT MOBILITY	HEALTH BODY	BUILDINGS INFRASTRUCTURE	CITY INDUSTRY
• Smart light bulbs • Smart security • Smart pet feeding • Smart irrigation controller • Smart smoke alarm • Smart refrigeter • Smart TV • Smart washer/dryer • Smart stove • Smart monitoring • Smart Home • Smart Watch • Smart Google glasses	• Smart traffic routing • Smart parking • Smart public transport (airlines, trains, metero) • Smart cars • Smart telematics • Smart supply chain	• Smart healthcare • Smart hospitals • Health Sensors • Smart patient care • Elderly monitoring • Equipment monitoring • Hospital hyiene • Bio wearables • Food sensors	• Smart heating vantilation and air conditioning (HVAC) • Smart lighting • Smart transit • Smart • Smart emergency alerts • Smart structural integrity • Energy credits • Smart buildings	• Smart city • Smart governance • Smart grid utilities • Smart electrical distribution • Smart surveillance • Smart waste management • Smart signage

Figure 2 Applications of IoT, Source: [10]

1.2 Modules of Internet OF Things

However, IoT system framework follow the codependent four-layered architecture i.e. i) IoT Sensors and Actuators, ii) IoT Network Connectivity, iii) Process and People, iv) IoT Stowage platform. IoT would dominate the numerous smart arenas like healthcare, smart industries, smart homes, smart cities and more through high-speed heterogeneous network access, network gateways, data centers, and cloud storage platforms. Figure 3 shows the four-layered architecture[2].

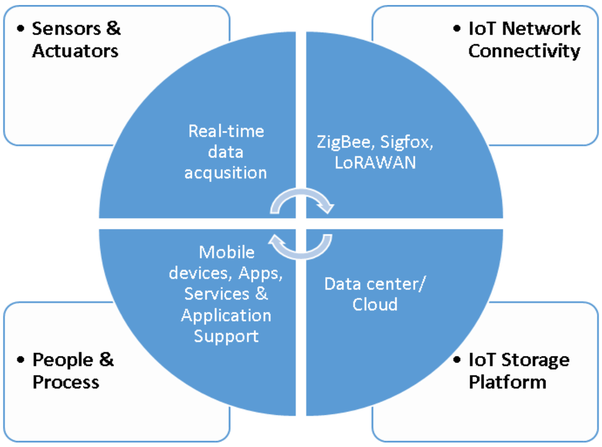

Figure 3 IoT system framework [32]

1.3 IOT Sensors and Actuators

IoT is equipping each new device with an electronic sensor system as depicted in figure 4.0, which entails the use of the sensors and actuators in everyday life progressions from simply locating the topographical presence, proximity, and posture of objects to measuring temperature, heart rate, pulse, electrocardiogram (EKG), glucose, blood pressure, and oxygen in blood etc.[3]. IoT network of smart objects, each smart object or device is equipped for detecting, inciting, and information preparing capacity through different sensing and actuating mechanisms. The genuine capability of smart things detect and apprehend massive nonstop information transfer to the central cloud [4].

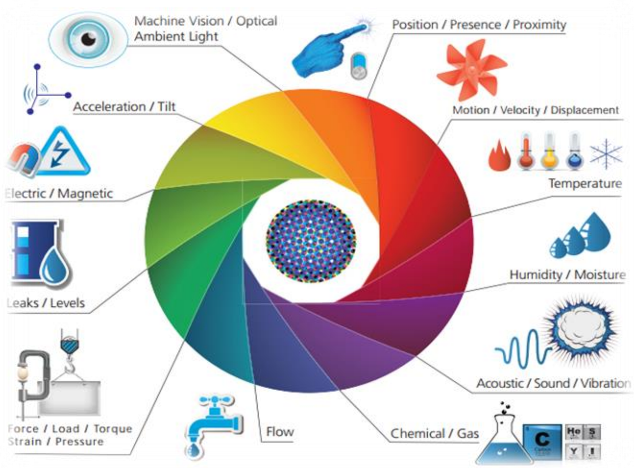

Figure 4 Sensors in IoT devices, Source: [33]

1.4 IOT Network Connectivity

Context-aware computing in Internet of Things empower smart objects to embrace and deal with environmental circumstances and behavior of people, places, and other smart objects anticipating the solutions to conjoint problems preemptively with gathered information, contents, functions and experiences. In addition, the emergent communication and network technologies such as ZigBee, Sigfox, Bluetooth Low Energy (BLE), Long Range Wide Area Network (LoRaWAN), 3G, 4G etc. offer the prompt and ubiquitous interconnectivity to share information amongst smart IoT devices, other IoT infrastructure, people and digital clouds. As result of this ubiquitous connectivity, new applications and services are emerging in healthcare, industry, business, smart cities, smart homes, smart governance and all other divisions of modern digital world. Figure 5 shows IoT connectivity[5].

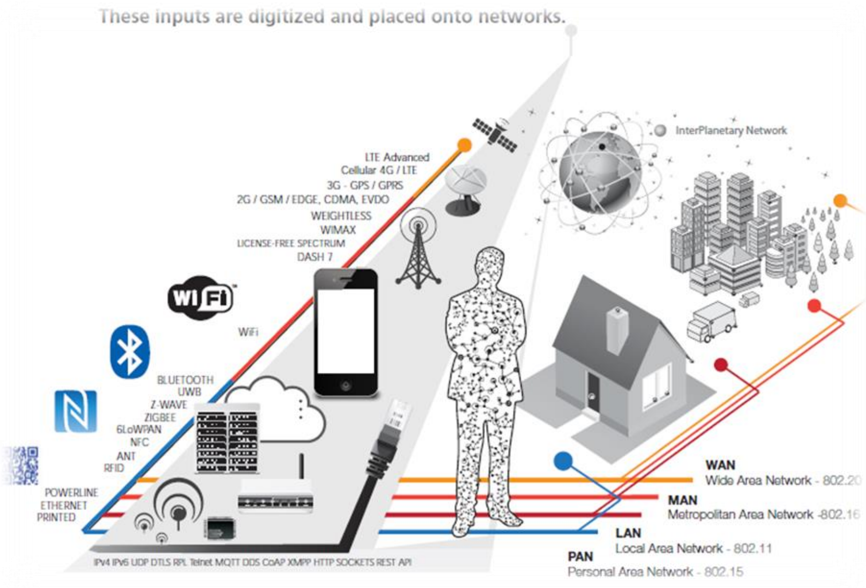

Figure 5 IoT Connectivity Source: [34]

1.5 IOT People and Processes

IoT can upgraded individuals' work, wellbeing, and lives. It can empower better way of life practices and more social focused on. People can use IoT, distributed computing, information analysis, and related advances to offer associated individuals new facilities progressively. [6] By linking people and societies with smart objects and smart services, IoT will change the manner in which people work and live lives. These organized information sources would then be able to be joined into bi-directional frameworks that incorporate info or data, entities, procedures and frameworks intended for basic decisive actions. Nevertheless, IoT is emerging with the presence of always-on interconnectivity of things so called Internet of Everything (IoE) that mirrors the idea of a network of any smart thing connectable whenever, wherever needed. IoT is no more a fantasy. Ultimately, it is a reality and builds up its existence because of the collection of a few innovations, for example, low power wireless network devices (cell and non-cell), sensors, micro-electrical frameworks, and obviously, expansion of the Internet. Hence, the Cisco anticipating fifty billion devices connecting to the Internet by the year 2020[3] is reformed by IBM estimating 1 trillion gadgets connecting to the Internet by the year 2020 [7].

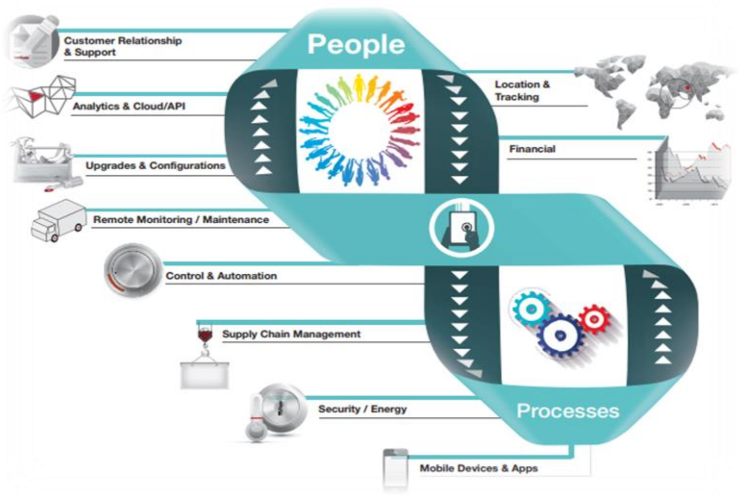

Figure 6 IoT People and Processes Source: [35]

1.6 IOT Storage Platform

IoT structure may work all around the clock, agreeing on-call support, sharing resources, in establishing future framework using IoT cloud[8]. The futuristic cloud structures may show up possible foundation to IoT systems inclusive accessibility of hardware, software, communication, mechanization, and amalgamation of IoT devices for secure concurrent data stream on the web [9]. Massive information stream among billions of IoT devices might divert the exploration phase to Big Data and its security. Cloud computing is another example to administer, procedure, and offer IoT infrastructure produce transparent, dynamic and wide-reaching sight of sensors data on the web. Cloud computing is getting critical change into IoT industry, a champion among the most basic pieces of IoT automation and integration of future models. [9]. This kind of cloud stage allows programming specialists to create applications that continue running in the cloud, and use the cloud benefits remotely. This kind of cloud stage allows programming specialists to create applications that continue running in the cloud, and use the cloud benefits remotely. IoT Cloud Stage gets a handle on the data from the end-clients to the cloud, contributes security, scalability, versatility, open APIs and extensibility across different structures to use the cloud services and infrastructure. Today, mostly individuals and health organization are connected to Google Health and Microsoft Health Vault cloud infrastructure for keeping personal health records worldwide.

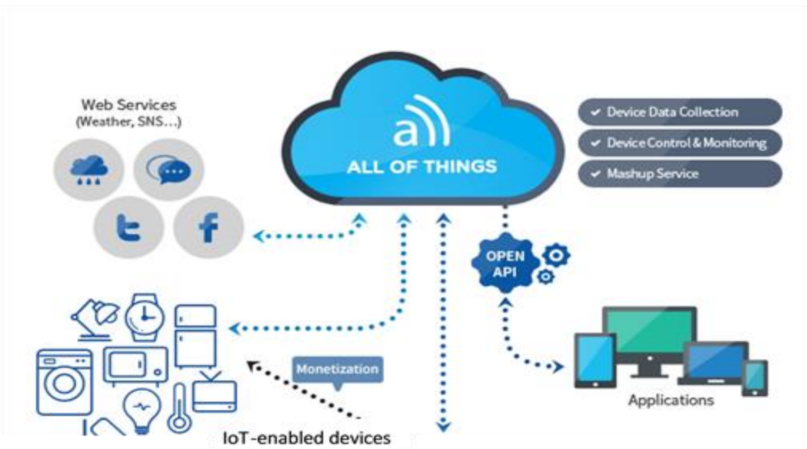

Figure 7 Source: Korea IoT Association ICT DIY Forum Newsletter

2. Background

This segment unwraps various utilizations of Internet of Things (IoT) in healthcare and expounded most recent biomedical equipment that are introduced to comprehend the current information in the field of IoT and medicinal services for a preliminaries of practicality in modern smart health outcomes. Earliest, Information and Communication Technologies (ICT) enforced implementation of robust digital services enriched health sector designated as e-Health, telehealth, and Mobile Health. Lately, the Internet of Health Things (IoHT) described as advanced deployment of broadband system connectivity has rousing impact on smart healthcare capability and developments in advanced nations [10]. The combination of IoT devices has elegantly improved the medical professionals' practices in modern healthcare longitudinal study done from year 2017 to 2020[11]. With the approach of IoT equipment, the load forced on medical attendants for continually assembling and putting away vital signs data of patients may halfway or completely be automatized in future[12]. Context-awareness and artificial intelligence (AI) in IoT devices may be useful to react proactively to patient health debility and upcoming analysis for the treatment[13]. Internet of Health Things (IoHT) is likewise identified with the thought of utilizing handy and Interned-enabled biomedical equipment permitting omnipresent and versatile data processing of future patients from anyplace around the clock [12].

2.1 Internet of (HEALTH) Things (IOHT)

IoT is predicted to boost the health sector in providing not only smart but preemptive healthcare with IoHT embedded health sensors which would be helpful in assessing, assisting and treating massive population suffering from chronic diabetic, cardiac, and general illnesses or infections economically via high speed Internet connectivity. IoT-based healthcare would be helpful in both treatment of diseases and medication delivery for patients and hospitals [14]. Medicinal services arrangement framework may completely be digitalized by 2025 and there might be the advancement of continuous information diagnostics about human fitness and health symptoms. All medicinal services suppliers may overwhelm with data sharing and interoperability [15]. Effective arrangement of IoT framework can take tremendous possibilities administer medicinal services in coming years [16]. Today everything progressively connects itself to the net, therefore IoT-based healthcare systems can manage the critical emergencies proactively by assessing patients' vital information in real-time. The intensifying healthcare appeal can reach competent and self-monitoring health system development assessing, helping and treating the patients itself. Simply dominant progression of smart healthcare, the health management facilities are set up to exploit with use of IoT. In the meantime, IoT advancement has continually accepted the acute part in managing health services effectively and efficiently[17]. In addition to gain the innovation control, the software application can enable clinicians to facilitate improved carefulness, hence accepted by over 86% of doctors according to the study [18].

Recognizably, IoT quick development has massive projections in health services that can advance lifespan of humanity and it can accumulate the computing and communication power ubiquitously in smart objects to broadcast and share appropriate information among other smart health objects and people [19]. Peoples' are expecting more noteworthy desires, more secure consideration, and quality consideration have been expanding, indicating the inborn need of prevalent medicinal services whenever and anyplace around the world. To build the medicinal services adequacy level, IoHT gadgets are accessible altogether to conveying health facilities and upgrade the hospitals or clinical processes with patient-driven structure approach constantly, while not depending on doctor's facility arrangements, timetables or doctor's physical accessibility. Additionally, IoT may suit the capable usage of biomedical frameworks to watch and screen patients remotely, oversee and assess fundamental clinical information of the patient [20][21]. Smart hospitals and health services providers implant health sensors to patients' body, garments to patients' surroundings that can gather persistent ongoing clinical information to help diminish misdiagnosis, bolster different clinical work processes and consistent observing for critically diseased patients. Furthermore, the Internet of Health Things are equipped with the ability to provoke doctors and family members to help them proactively, intercede to lessen the severe consequences of critical illnesses.

2.2 Workflow Implications

The future healthcare models are perceived to perform intelligent actions to evaluate and assist the patients' triage and essential treatments using biosensors, and robotic gadgets. [22]. Typical health services might be delivered smartly and remotely by utilizing remote sensors attached with patient to monitor the patients' activities, exercises, and underlying measures, prescriptions, and accumulate their indispensable health info. Medical doctors and relevant family members can access and share the information via cloud.

2.3 Benefits of IOHT

The distinctive and smart healthcare setup activities and procedures delivered utilizing advanced networks and cloud servers via global network may expose security dangers in information sharing and exchange between patients and medical team. The patients might prevent in adoption of smart connected healthcare [23]. The absence of technological attentiveness and its fear is also a reason of security rupture in IoT health systems[16]. Thus, future IoT healthcare systems should be intelligent to ensure secure data exchange and alerts to integrated apparatuses.

2.4 Improved Access

Ongoing IoHT checking and dynamic revealing of key clinical data will enhance the proficiency, viability and interconnectivity between patient and doctor, which will guarantee health service delivery inevitably on a wide-ranging. Later on, patients may visit their physicians digitally using the Internet of Health Things. While, most of the patients feel convenient to interconnect with the doctors using smart health solutions according to the study [18].

2.5 Improved Disease Management

In future, doctors can follow analysis of patients' clinical data and share it with other hospitals and clinics to refer the patients for higher level of treatment and altogether the always-on connectivity of Internet of Health Things may provide the capacity of cooperative supervision of patients. Hence, the smart health network may contribute better and improved patient care.

2.6 Reduced Errors

An exact accumulation of health information may help doctors and supporting staff to make accurate and on-time decisions and eliminate medical errors. More, the automated processes in smart healthcare may enhance the quality, lessen medical errors and ensure quicker health services delivery [24].

2.7 Optimized Costs

Future IoHT health systems may support the provision of cost effective and improved quality health management on patient centric settings [25]. The delivery of health care would be enhanced with utilization of modern smart health devices to diminish expenses [26]. Consequently, later on, symptomatic testing of fundamental conditions might be pushed under the control of patients, while the medical specialists are by one way or another open to depending on utilization of technology to support patients distantly. The patients may share the basic medical test results with doctors and medical staff using smart health wearable and may save time and expenses of paying physical visit to doctors for every basic tests results. The constant observing and stream of clinical data shared among patients and doctors would help to treat the patients themselves.

3. Smart Health and Medical IOT Development Platform

Libilium, Google, IBM, Intel and Cisco have been chipping away at the generation of IoHT-based systems to enhance health facilities, oversee and screen individual and offer the sharing of information with concern doctors, family and companions.

3.1 My signals KIT (EHealth Medical Development Platform)

IoT platform is a smart health product with twenty biosensors to measure vital health information as shown in figure 8 and Table 1. This health gadget is centrally managed and supported by cloud storage accessibility to share health data in extremely secure and encoded format using simple mobile apps. Thus, this data helps ongoing patients' biometric information investigation. Integrated advanced wireless solution supports secure remote access to and from both ends.

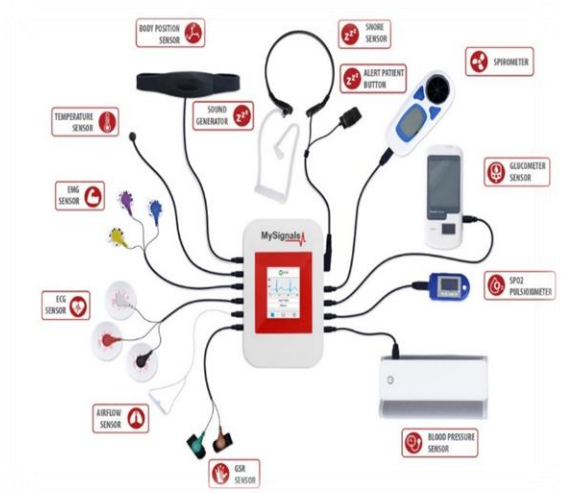

Figure 8. eHealth Medical Development Platform Source: [27]

Table 1. MySignals SW Complete Kit Sensors Source: [27]

S#	List of health sensors
1.	Electromyography Sensor PRO
2.	Galvanic Skin Response Sensor PRO
3.	Airflow Breathing Sensor PRO
4.	Blood Pressure Sensor PRO
5.	Glucometer Sensor PRO
6.	Spirometer Sensor PRO
7.	Body Temperature Sensor PRO
8.	SPO2 Pulse Oxygen in Blood Sensor PRO
9.	ECG Electrocardiogram Sensor PRO
10.	Body Position Sensor PRO
11.	Snore Sensor PRO

3.2 E-Health Sensor Shield V2

The e-Health Sensor Shield V2.0 (eHSSV2) in Figure 9 is furnished with nine diverse biosensors tabulated in Table 2, and compatible with Arduino, and Raspberry Pi to program medical services like estimating patient's heartbeat, Oxygen level, (SPO2), temperature, electrocardiogram, sugar **levels etc.** This data helps constant checking of the condition of a patient and get delicate information for biometric investigation in this manner that data might be stacked onto the Web cloud utilizing current system network like ZigBee, 4G, or Wi-Fi and so forth.

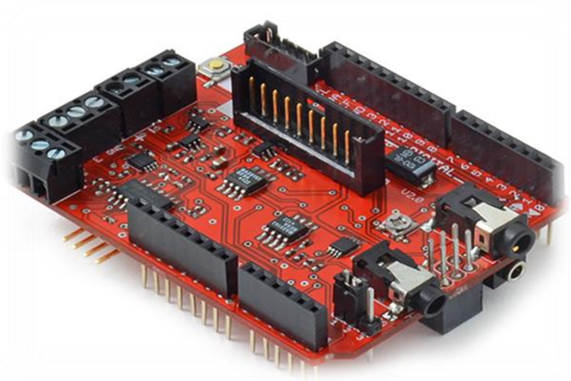

Figure 9. e-Health Sensor Shield Source: [36]

Table 2. e-Health Sensor Shield V2.0

S#	Sensors supported in Shield
1.	Electromyography Sensor (EMG) New Sensor
2.	Airflow sensor (breathing)
3.	Body temperature sensor
4.	Galvanic skin response sensor (GSR - sweating)
5.	Glucometer sensor
6.	Patient position sensor (Accelerometer)
7.	Blood pressure sensor (sphygmomanometer) V2.0 New Sensor
8.	Electrocardiogram sensor (ECG)
9.	Pulse and oxygen in blood sensor (SPO2)

3.3 WASPMOTE V15

Waspmote V15 is one of the Internet of Medical Things (IoMT) which utilizes extreme low power. It underpins in excess of 110 sensors coordinated on I/O board sensor programmable ports to evaluate and control urban population and contamination of hazardous gases, discharges from homesteads and incubation centers, switch of substance, manufacturing procedures, fire, security, vibration, corridor impacts (entryways and windows) and individual location. Moreover, utilized in activation regulatory divisions, for example, smart management of water system to monitor pH, nitrates, dissolved oxygen, salinity, and pollution level in potable water. Several sensors to handle security, emergencies, control of goods in logistics. Waspmote supports the sensors to implement precision agriculture and irrigation systems i.e. knowing leaf wetness, fruit diameter, soil moisture, humidity, temperature, solar radiation, and wind pressure etc. Furthermore, smart urbanization of metropolitan areas, smart traffic management, smart business, and smart surveillance sensors are boosted. Waspmote in Figure 10 is equipped with special board to measure and monitor radiation wirelessly (beta and gamma radiation) without embracing life loss of the work force or security forces. Table 3 shows the list of supported sensors.

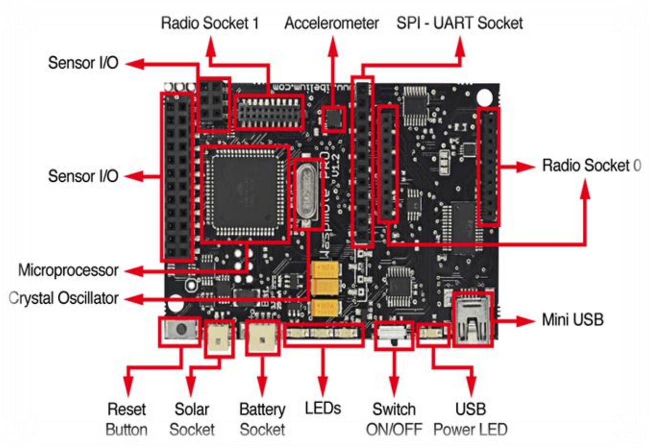

Figure 10. Waspmote input/output Source: [28]

Table 3. Waspmote Radio Interface

S#	Input/output
1.	3G, 4G, Wi-Fi,
2.	RFID/NFC
3.	LoRaWAN 868 / 900-915 / 33MHz
4.	LoRa 868 / 900/915MHz
5.	802.15.4 / ZigBee
6.	GPRS + GPS
7.	Bluetooth Low Energy (BLE) 4.0
8.	Sigfox
9.	Waspmote Gateway
10.	Expansion Radio Board

3.4 Health Wearable

Smart health apparatuses are worn close to the body, on the body and even in the body. Generally, all wearable devices are interconnected to the web via low powered Bluetooth interface of the smart phone. Wearable devices are supported by mobile apps and cloud platforms to organize and share the patients' health information with hospitals and family members for the sake of more investigation and diagnosis. In health industry, health wearable is "Dr Google" in future. The penetration of health wearable devices i.e. fitness trackers and smart watches has increased to from 9% to 33% in year 2018 [29]. In future, due to high rising population rate, the health services are not viable to stand, the encumbrance of chronically diseased aging population and general healthcare is manageable by prompt implementation of smart health wearable devices only. Individuals to manage proactive health data analytics as well as ongoing disease [30] may adopt these devices. It is expected quantity of associated wearable gadgets is to reach more than 830 million by 2020 in Figure 11.

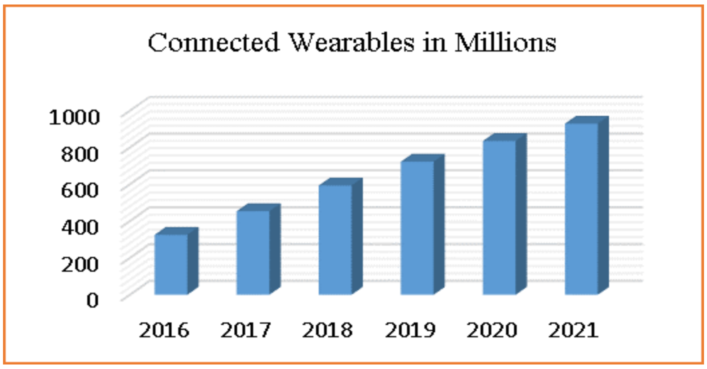

Figure 11. Connected wearable by 2021 Source: (Statista, 2019)

4. Conclusion

In future developments various businesses, industrial, and principally medical sciences may adopt IoT to bring optimum delivery of budget operative and enhanced health organizations through network cloud. Internet of Health Things with wearable health sensors, twenty-four hours a day, seven days a week; all the time connectivity may fetch individual-centric pervasive healthcare immensely penetrating every day. The implementation of smart wearable health gadgets may be marvelously compassionate in supervising chronic disease and old aged patients and continuous real time analysis of those patients. The stimulating technology improvement might modernize personal healthcare with possible minimized errors, increased efficiency, and cost-effective results. Referring to IBM's forecast the IoT network would push billions smart devices that may cause massive penetration of information using diverse connectivity protocols. The mutually shared real-time medical info may definitely be impacting healthcare more positively and the interactive power of the smart objects would create smart applications and services in personalized smart healthcare anytime anywhere. IoHT devices would significantly deliver health organizations to accommodate patients remotely and ensure quality care from real-time health data analytics, information sharing and interoperability among associated health institutions and medical professionals worldwide. More, future Internet-enable technology health gadgets may benefit evaluating and controlling pollution and contaminating diseases among metropolitan population for sustainable environment smart society development. However, the future research is required focusing security and privacy issues in a network of billions of devices and study the patients' perception for better application of reviewed innovation.

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