# INTERNET OF THINGS BASED SMART HEALTHCARE SYSTEM: CHALLENGES AND APPLICATIONS

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***Abstract*: Internet of Things (IoT) based Smart Healthcare System (SHCS) has rapidly evolved in past decades. It has tremendous potential to change the way healthcare services are being delivered. The vital signs monitoring system is becoming essential in the timely delivery of healthcare services. The paradigm has shifted from traditional and manual recording to computer based electronic recording. IoT Based SHCS plays a vital role in the delivery of healthcare services in rural and remote areas where essential medical amenities, necessary infrastructures, and qualified medical practitioners are not available. This research is focused on three important aspects of healthcare; real time vital sign monitoring, remote health monitoring and interpretation of multiple vital signs for health status prediction and abnormality detection. An IoT enabled vital sign monitoring system (VSMS) has been implemented to monitor various vital signs in real-time and store the recorded trends locally. IoT and integrated cloud computing technologies are used for the implementation of the remote health monitoring system (RHMS).**

***Keywords*: IOT, SHCS, Wi-Fi, Healthcare, Heart Diseases**

## I. INTRODUCTION

Equitable global healthcare means access to good healthcare services to all the people worldwide is one of the major challenges specially for developing countries [1]. The existing healthcare system is overburdened due to the increasing population and chronic diseases. Furthermore, the present situation is worsening due to the lack of healthcare services in terms of medical amenities, necessary infrastructures, qualified medical practitioners, and diagnostic equipment [2][3]. The healthcare service provider and researchers are tirelessly working to manage and mitigate the effect of rapidly increasing chronic and potentially fatal diseases like heart diseases, hypertension, asthma, and the emergence of new diseases which are growing rapidly in every county. Apparently, there is a need for an integrated healthcare solution that can monitor the different physiological parameters in real-time and provide immediate detection and diagnostic tools for chronic diseases and various health related issues. The IoT based Smart Healthcare System (SHCS) is emerging as an alternative solution to the existing healthcare system to bridge the gap of equitable healthcare services to all [4]. It is playing a vital role in reforming and restructuring the way healthcare services are being delivered [5]. IoT based SHCS provides various healthcare services and solutions to overcome the issues of the conventional healthcare system. The advancement in sensors and communication technologies set the latest trends to make IoT based healthcare systems smart and step forward to become smarter [5].

In the present scenario, health is a fundamental piece of life. Peoples are busy with their hectic schedules and failing to take care of their health periodically. Consequently, various cardiovascular and chronic diseases like heart problems, asthma, blood pressure, diabetes, cancer, etc., are increasing rapidly [6]. These diseases require continuous monitoring and timely diagnosis to keep people healthy and to avoid a medical emergency. Elderly people and infants belong to the group of people who need continuous monitoring of their health for the timely detection of abnormalities. It requires substantial medical infrastructure and a large number of medical practitioners [7]. Also, due to the ever-increasing population, the existing healthcare system is incompetent to provide medical services timely to a large number of people. Despite advancements in medical infrastructure and the availability of high-grade medical equipment, medical facilities are neither affordable nor approachable to everyone. Therefore, the primary objective of the SHCS is to make people health conscious and help them to monitor and keep records of their medical status with the empowerment of self-management of emergency [8]. It helps in remote health monitoring and reduces medical expenses with improved quality and better medical experience. It also helps healthcare professionals and practitioners extend their services to remotely located persons without geographical limitations. Finally, with the help of emerging technologies making the healthcare system smarter, the medical practitioner is getting quick and updated health information of the patients and people at large having better health monitoring facility with greater control and flexibility in its operation [5].

## II. CLASSIFICATION & CHARATERSTICS OF SHCS

The healthcare system is categorized as conventional healthcare system (CHCS) and smart healthcare system (SHCS). The purpose of SHCS is to support and supplement the traditional healthcare system. The support and services of SHCS

are offered in terms of Remote Healthcare System (RHCS), Smartphone-based Healthcare System (SPHCS), Personal Healthcare System (PHCS) commonly known as Ambient assisted living (AAL), and Wearable Healthcare System (WHCS) and as shown in Fig. 1.1.

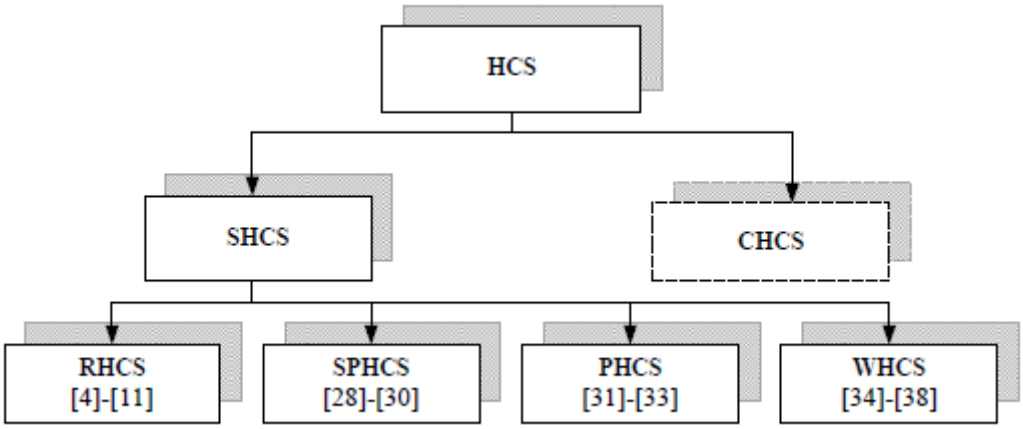


Fig. 1.1 Classification of smart healthcare services

In RHCS, real-time data is transmitted from a remote location to medical professionals with the help of communication technologies [9]. RHCS is applicable for people living in a rural or remote area where medical facilities are not easily accessible. In the RHCS, different vital signs of the patient are monitored and communicated in real-time to the medical practitioners located far away from the patients. Based on received physiological parameters, a medical practitioner examines the health condition, detects the abnormalities, and makes a timely intervention. RHCS help to reduce medical expenses, hospital infrastructure, and clinical time significantly [4] [10]. In SPHCS, smart applications are used to track and monitor the patient's health condition. Moreover, smartphone applications can provide useful information such as hospital information, booking details, a reminder of appointments, and emergency services [11]. The objective of the PHCS is to enhance the independence of elderly, disabled, or incapacitated people in their space of living in a secure, convenient, and assorted form by providing services as a personal assistant [12]. PHCS is based on ambient assistant living and refers to intelligent systems for assistance. It is used to improve wellness, prevent and cure the elder, infants, or disabled people [13]. This service offers a better, healthier, and safer lifestyle in the specified living environment [14]. It is mainly developed to monitor and detect different activities such as sleeping, running, walking, standing, falling, lying, etc. [15]. WHCS, as the name indicates, comes in the form of wearables devices such as watches, shoes, clothes, belts, etc., which is a composition of different smart devices attached to the body. These devices can extract the various physiological parameters like body temperature, pulse rate, blood pressure, respiration, ECG, body positions, etc. [16].

### 1.1.3 CHARACTERISTICS OF SHCS

The integration of the IoT based technologies with the healthcare system makes it more advanced and smarter. In IoT based SHCS, devices are connected to each other, and intelligent medical sensors collect data from patients and send it to the cloud. Data can be accessed and monitored from anywhere and anyone from the cloud. Incorporating IoT technologies with healthcare systems enables different characteristics such as services, medical devices, sensors, applications, communication technologies, system management, and end-users are shown in Fig. 1.2. The SHCS can effectively provide efficient services in

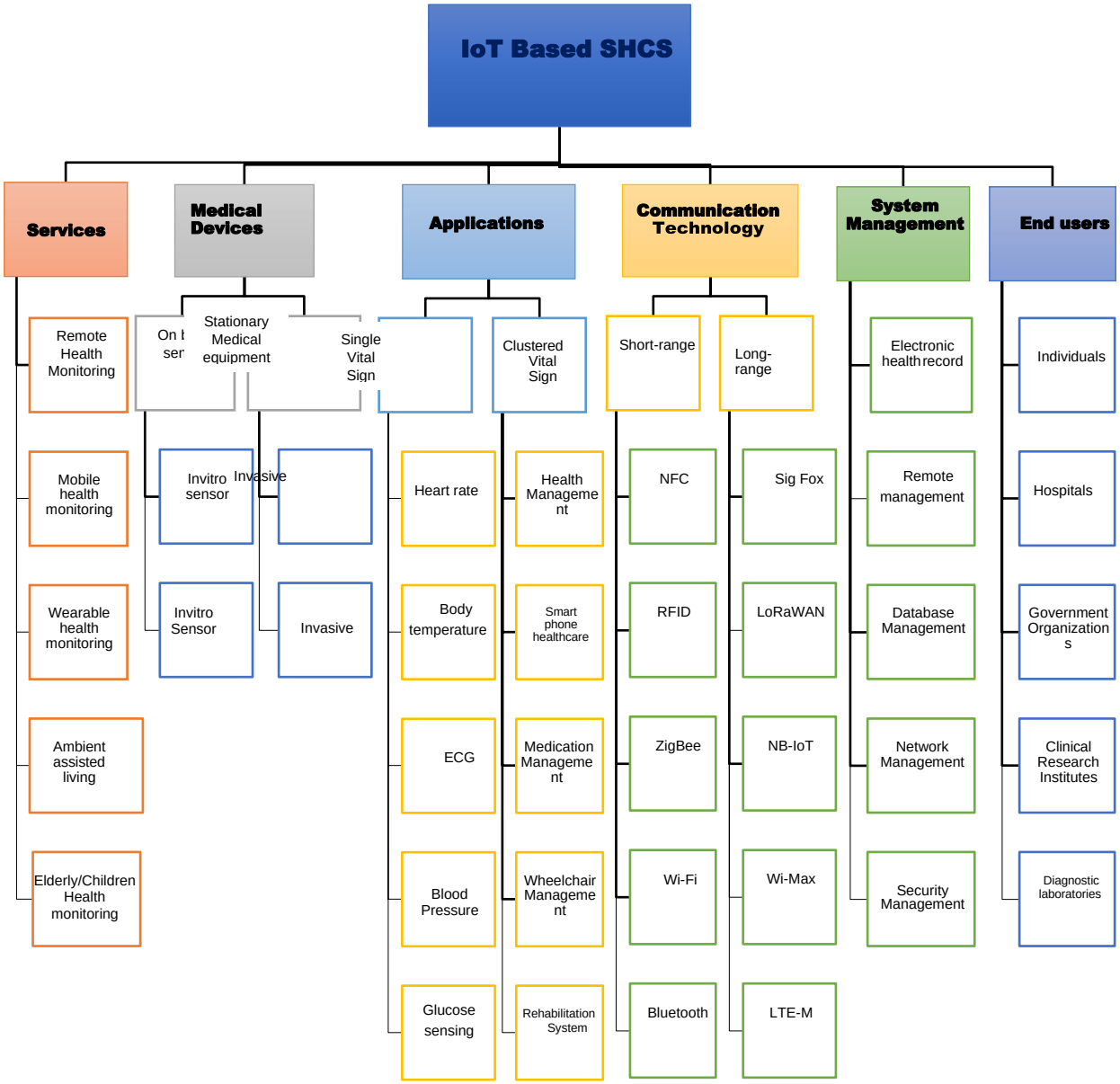


Fig. 1. 2 Different characteristics of IoT based SHCS [17]

remote health monitoring, mobile health monitoring, wearable health monitoring, ambient assisted living, followed by elderly and children health monitoring. These services are possible due to advancements in medical devices, which are classified as portable body sensor devices and stationary medical devices [18]. On-body sensors are of two types invitro (placed outside the body), and Vivo (placed inside the body), whereas the stationary medical equipment is invasive (placed inside the body) and non-invasive (placed outside the body) in nature. These medical devices are found wide applications in the measurement of single vital signs (heart rate, body temperature, blood pressure, ECG, glucose sensing, etc.) and clustered vital sign measurement for healthcare management, mobile app-based management, meditation management, etc. The information obtained by these measurements is transmitted over communication technology classified as the short-range (NFC, RFID, ZigBee, Wi-Fi, Bluetooth) and long-range (SigFox, LoRaWAN, NB-IoT, Wi-Max, LTE-M) technology. These transmitted data are used in system management to prepare electronic health records, remote management, and provide database, network, and security management. These all systems are joined together to serve the end-users, who could be the individuals, hospitals, government organizations, clinical research, and diagnostic laboratories.

## III. RELATED WORK

IoT based SHCS provides various healthcare services and solutions to overcome the issues of the conventional healthcare system. The advancement in sensors and communication technologies, setting the latest trends to make IoT enabled healthcare systems smart and stepping forward to become smarter [5]. The recent works are comprehensively analyzed to elaborate on the recent trends and advancements in technologies and techniques. The combination of these technologies and techniques gives birth to a new approach towards the development and deployment of symptom-based

diseases prediction, prognosis, early detection, diagnosis, treatment plan, and management of health records [19]. In the field of IoT based SHCS, huge literature are available that deal with different aspects of SHCS such as configurationally architecture, constituents of SHCS, implementation of IoT based SHCS for different applications, IoT based RHMS, Cloud Integration, application of machine learning algorithms for the development of decision support system, etc. An exhaustive literature survey pertaining to IoT based SHCS and its different aspects has been carried out.

Different physiological sensors are used for measurement of different physiological functions for monitoring of general diseases, heart disease, Parkinson disease, Chronic diseases, etc. In [28], the system is developed for the detection of different physiological parameters for the prediction of chronic heart failure at home and automatically sends the real-time information to the hospital. Similarly, the work reported utilizes wearable and environmental sensors for activity tracking and health monitoring with the objectives of continuous health monitoring of chronically ill persons comfortably being at home. The integration of the Wi-Fi and Bluetooth technology enables the interventions of the Doctor and caretakers to manage the critical situation. A personalized healthcare system has been developed in [21][25] which uses multiple sensors (body temperature, respiration, accelerometer, pulse rate, blood pressure,) and BLE and Wi-Fi modules for communication, cloud computing for storage and machine learning for diseases prediction.

Existing systems highlight that communications are also essential for an IoT based SHCS. In several existing system models, short-range communications, such as Bluetooth, are suggested for transferring sensor data to a smartphone to be processed. Long range communications such as LTE can then be used to transfer the processed information from the patient to the healthcare provider, typically a doctor, through SMS or the Internet [5].

There is a growing trend for health monitoring and fall detection of elderly persons either in-home environment or in hospitals. Different sensors such as accelerometer, gyroscope, and magnetometer, along with microcontroller and GPS modules, are used for fall detection, tracking of location, and alert notification. In addition to this, an accelerometer is also used for monitoring of sleep activity of adult and elderly persons [22]. The monitoring of the sleep activities can further be extended for study and analysis of deep sleep-in adults, a sleeping disorder in elderly person and detection and diagnosis of obstructive sleep apnea (OSA).

IoT based SHCS system is a network between patient and medical equipment, like, IoT based e-Health systems for electrocardiography [53], heart rate [54], diabetes [55], and other different kinds of monitoring of vital signs based on biomedical sensors. It includes pulse, oxygen in the blood (SPO2), airflow (breathing), body temperature, glucometer, galvanic skin response, blood pressure, patient position (accelerometer), and electromyography [54] [56].

Heart diseases or Cardiovascular diseases are considered high-risk diseases. ECG monitoring is widely studied and analyzed for heart diseases detection and diagnosis. An SHCS for ECG monitoring is developed to detect and diagnose heart disease [30]. Integrating the ECG monitoring system with the smartphone through BLE or Wi-Fi will enable IoT application and cloud computing to provide timely ECG reports to the users and caretakers [54]. Also, artificial intelligence is being used for the detection of heart attacks along with IoT and GSM modules triggering alert notifications [32]. An ECG sensor is used to measure heart activity, which is processed by a microcontroller. This information is forwarded via Bluetooth to the user's smartphone, where the ECG data is further processed and is presented in a user application. The authors identify that developing heart attack prediction software would improve the system for in time intervention. A lot of researchers have proposed their work in these fields. Such as [20] proposed IoT based framework, which is interconnected with cloud computing technology to increase scalability and availability. It proposes a 3-tire architecture, Tier-1 for data collection. Tier-2 for data storage and Tier-3 for data analysis uses Apache Mahout. Apache Mahout is used in the proposed health monitoring system for building the logistic regression-based prediction model for heart diseases.

With the emergence of IoT, the concept of remote health monitoring is proven to offer more efficient and reliable health care services to elderly people and indigent patients [4] [37]. A brief overview of IoT based AAL systems and their applications in the healthcare sector are presented by [10][17]. Recently, [4] presented the concept of the Internet of Health Things (IoHT), where the techniques based on IoT for health monitoring are presented. They have considered the recent publications in this region, identified the various technological advancements, and described the challenges and future courses. [18] have proposed an ambient intelligence system for the Elderly in Home Assistance (EHA). Its objective is to sense, react, predict, and take action in response to the activities of elderly people. The key element of this work is the context awareness. In [15], a communication architecture for health monitoring has been designed that makes use of artificial intelligence to detect the patient’s behavior through the data collected from the sensors. [19] presents a context-aware system to predict the upcoming vital signs irregularities of the patient in the AAL environment. Their framework detects the illness symptoms at early stages to assist healthcare professionals using machine learning algorithms. They developed the Hidden Markov Model (HMM) to identify the abnormalities in the patient daily activity sequences. Recently, Forkan et al. [60] have proposed an innovative architectural model (BDCaM) for personalized knowledge discovery in assisted healthcare. In this work, they have extended their previous work [61] by incorporating the learning and knowledge discovery process to assist the patients in the AAL environment.

The area of health in recent years has been rapidly integrating technology in the monitoring, diagnosis, and treatment of patients remotely. [47] evaluated a remote self-monitoring of blood pressure to detect raised blood pressure in

pregnancy in 50 women, out of which 45 of them agreed that the remote monitoring adopted is easy to use and 39 women prefer the proposed model of testing at home. A body sensors network platform is discussed in [52]. Sensor's data are directly transmitted to the users' smartphones to receive the collected data. The data is processed and stored in the cloud to allow access and monitoring by healthcare providers. In [25] published a review on advanced Internet of things enabled personalized healthcare systems (PHS) considering current works about IoT enabled PHS and enabling technologies, major IoT enabled applications, and successful case studies in healthcare, besides main challenges and future perspectives about the Internet of Health things (IoHT). A patient health monitoring system is presented in [40] [53]for integrated cloud computing and Internet of Things technologies and applied in the real-time monitoring of a patient suffering from congestive heart failure using ECG. The proposed system offers a flexible, scalable, and energy efficient remote health monitoring system.

Furthermore, an early warning system is proposed in [33] by integrating IoT, big data, cloud computing technology, and machine learning which is physically linked among personal communication devices of patients, caretakers, doctors, cloud systems, and hospital medical information systems. The recent collaboration among smartphones, IoT based cloud architecture, and data analytics have attracted significant researchers' attention for developing rapid disease detection and diagnosis systems. Further, the researchers strongly recommend that the application and implementation of the machine learning tools would be highly beneficial for developing a decision support system in SHCS. Moreover, it is leveraging connected technologies in various areas enabling patients record-keeping in an electronic spreadsheet, telemedicine, patient monitoring, wearable devices, asset tracker (for medical equipment's), and facility utilization (sensors and data analytics provide the most efficient use of clinical infrastructures like operation theatres, ICU, etc.).

To summarize the literature survey in IoT based SHCS and its different components, comprehensive investigations in terms of the year of publication, services, target monitoring, the environment used, type of physiological sensor employed, framework, communication technologies, computation techniques, and analysis tools is presented in Table 1.1

Table 1. 1 Comprehensive analysis of the IoT based SHC

| Ref | Year | Services | Vital Sign Monitoring | Environment | Integrated Sensor | Hardware / OS | Communication Medium | Computing Technique | Analysis Tool |
|---|---|---|---|---|---|---|---|---|---|
| [48] | 2020 | WHM | Vital sign monitoring | Home/ Clinical | ECG, RR, HR | Arduino | Bluetooth | Cloud | - |
| [49] | 2020 | WHM | Respiratory monitoring | Home | RR, $SpO_2$ | - | Wi-Fi/ Bluetooth | - | ML |
| [50] | 2020 | RHM | Cancer | Home | ECG, EMG | - | - | Fog | DL |
| [51] | 2020 | RTM | Vital sign Monitoring | Home/ Hospital | Glucose, ECG, PR, BP, BT, Sweat | - | - | - | ML |
| [1] | 2019 | RHM | Vital sign monitoring | Home/ Clinical | BP, $SpO_2$, PR, ECG | - | Wi-Fi/ Bluetooth | Cloud | ML |
| [52] | 2019 | RHM | Glucose level | Home/ Hospital/ Clinical | BG | Arduino | NFC/ Wi-Fi | Cloud | Data Mining |
| [53] | 2019 | WHM | Vital sign monitoring | Clinical | $SpO_2$, PR,ECG, BP | - | Bluetooth | - | - |
| [54] | 2019 | RTM | Heart Diseases | Home/ Hospital | RR, HR, BG, BP, BT, $SpO_2$, ECG | Raspberrypi | Wi-Fi | Fog/cloud | ML/DL |
| [55] | 2019 | RHM | Heart diseases | - | RR, HR, BG,BP, BT | - | Bluetooth, Wi-Fi module | - | ML |
| [39] | 2018 | AAL | Parkinson's Diseases | Home | Accelerometer, HR, BP | - | - | Cloud | SVM |
| [20] | 2018 | RHM | Vital Health parameter | Home/ Outside | ECG, HR, BT | - | Wi-Fi module | cloud computing | Notused |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| [22] | 2018 | WHM | Sleep monitoring | Hospital | Accelerometer RR, HR, BT | - | 6LowPAN, Bluetooth | Fog \Cloud computing | Big data |
| [43] | 2018 | SPHM | Diabetics | Home | BG, uric acid test strip | - | Bluetooth, Wi-Fi | - | Not Used |
| [23] | 2018 | RHM | Health monitoring, Tracking | Battle field | HR, Accelerometer, BT | Arduino MEGA 2560 | Zigbee, LoRaWAN | cloud computing | ML |
| [32] | 2018 | RTM | Heart diseases | Home/ outside | HR | Arduino UNO | - | - | FL |
| [21] | 2017 | WHM | Physiological parameters | Outside/ Home | BP, PR, BT, RR | - | Wi-Fi, Bluetooth | Cloud computing | ML |
| [33] | 2017 | WHM | Heart diseases | Home/ Outside | Accelerometer, PR | - | Bluetooth | cloud | ML |
| [24] | 2017 | WHM/RHM | Health monitoring | Home/ Hospital | BT, BG, BP | - | Wi-Fi, Bluetooth | Cloud computing | Not Used |
| [25] | 2017 | AAL | Personalized health care | Home/ hospital | BT, ECG, BP, HR, Accelerometer | Raspberry Pi B+ | Wi-Fi module | Cloud computing | ML |
| [26] | 2017 | WHM | Breathing monitoring | Home | RR | Arduino UNO | RFID | - | Not used |
| [44] | 2017 | RHM | Blood pressure | Hospital | SpO2, ECG, PR, BP, BT, BG | Arduino mega | - | Cloud computing | ML |
| [45] | 2017 | WHM | Stress detection | Outside/ Home | PR | Arduino UNO | Wi-Fi | - | LR/ SVM |
| [34] | 2017 | SPHM | Heart diseases | - | HR, BT | Arduino UNO | Bluetooth | - | Not used |
| [40] | 2016 | WHM | Fall detection/ Parkinson | Home | Accelerometer, HR, BP | - | Bluetooth | - | FL |
| [35] | 2016 | WHM ` | Heart diseases | Home | ECG | - | Wi-Fi, | Cloud computing | Not used |
| [31] | 2016 | SPHM | Heart diseases | Home | ECG | Arduino UNO | Bluetooth | - | Not used |
| [36] | 2015 | AAL | Chronic diseases | Home | Accelerometer | - | BLE | Cloud Computing | - |
| [37] | 2015 | RHM | Heart diseases | Outside/ Home | BP, Accelerometer | - | Bluetooth | cloud | Not used |
| [41] | 2015 | WHM | Parkinson diseases | Home | BP, PR, BT Accelerometer | - | Bluetooth, application | - | Not used |
| [38] | 2015 | SPHM | Heart diseases | Home | BP | - | Bluetooth | Cloud computing | ML |
| [56] | 2015 | SPHM | Health monitoring | Hospital/ Home | BT, HR, SpO2 | Arduino UNO | Bluetooth | - | Not used |
| [27] | 2015 | WHM | Personal health monitoring | Outside/ home | HR, BP, SpO2, ECG, BT | - | BLE | - | SVM |
| [47] | 2015 | RHM | Elderly persons Fall detection | Home | Accelerometer, Gyroscope, Magnetometer | Arduino UNO | Bluetooth | - | Not used |
| [46] | 2015 | AAL | Health Monitoring | Home | BP, RR, PR, BT | - | BLE, Wi-Fi | - | ML |

The investigation can be summarized to mark the growing trends in the identified field from literature. The research trends in the last five years show that wearable and remote health monitoring in real-time are the two major service areas that are growing rapidly and heading towards technological maturity. In WHM and RHM, apart from monitoring different physiological parameters or vital signs, the research has been directed toward monitoring of specific diseases (CVD, PD, BP, Diabetics, Fall Detection, Sleep Apnea, etc.) oriented parameters to keep the records of the patient for timely intervention and diagnosis. Moreover, there has been growing trends of smartphone-based personal health tracker to keep records of personal health for fitness, prognosis, and prediction. The recent trends in SHCS are presented in Fig. 1.3.

The existing literature in the field indicates that there is plenty of work dealing with general health monitoring, disease specific monitoring, and diagnosis; however, there is a lack of sustainable IoT based SHCS, services, and application. Also, the ever-growing demand for continuous monitoring and measurement of highly complicated human physiological parameters has governed the recent trends toward advancement in associated technologies that shape the healthcare system's future. To meet these demands, the innovation has sprouted from necessary embedded solutions, and it is still progressively growing towards IoT based SHCS to create a pervasive environment. Also, the existing technologies and techniques have different levels of usage and implementation in different healthcare applications such as traditional health monitoring, wired and wireless monitoring, pervasive and ubiquitous monitoring, wearable and non-wearable monitoring, etc. Depending upon the services and applications along with design consideration, these technologies and techniques can be reconfigured and implemented for the development of new approaches towards sustainable SHCS. The literature review on IoT based smart healthcare systems has been carried out, and the following research gap has been identified,

- Lack of medical grade devices for measurement of different vital signs for general health monitoring accurately.
- The existing devices are expensive and are not fully automated to support the decision making for diagnosis.
- There is very limited work reported for effective demonstration of remote patient monitoring in real-time.
- The application of machine learning tools is limited in the existing literature and yet to be explored widely in the healthcare system.

## IV. CONCLUSION

The existing literature in the field indicates that there is plenty of work dealing with disease-specific monitoring and diagnosis however, there is a lack of sustainable IoT based healthcare systems, services, and application for general health monitoring and diagnosis. Although many solutions are provided in the literature, they have their own limitations, and none of them provides a simple, reliable, portable, cost-effective and user friendly solution. Thus, it is necessary to provide a simple, reliable and cost-effective solution for health monitoring locally and remotely in real-time. Therefore, in this research work, an attempt has been made to implement a simple, cost-effective, and reliable solution for health monitoring locally and remotely in real-time.

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