Scalable Computing: Practice and Experience, ISSN 1895-1767, http://www.scpe.org

Volume 26, Issues 5, pp. 2214–2230, DOI 10.12694/scpe.v26i5.4823

HEALTHCARE-AS-A-SERVICE PROVISIONING USING CLOUD-OF-THINGS: A CONTEMPORARY REVIEW OF EXISTING FRAMEWORKS BASED ON TOOLS, SERVICES AND DISEASES

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Abstract. With the advancements of the technologies, healthcare industry has become more digitized, data driven, patient-centric, innovative as well as collaborative. It has become possible to access and share patient information globally irrespective of time and locations. The traditional healthcare facilities have proved inadequate in facilitating better patient treatment and services as per the patient requirements. The modern healthcare provisioning involves the use of digital technologies and operations and manifest digitized healthcare facilities. The digital technologies such as cloud computing, Internet of Things and many other supports the facilitation of smart healthcare utilities and services. This paper describes how cloud computing and IoT deliver healthcare-as-a-service. Further, the various proposed healthcare frameworks integrated with healthcare field have been discussed such as based on technologies implemented, offered services, and focused disease(s). Also, this survey enlightens the comparisons of existing frameworks based on technologies used and based on the focused methodologies.

Key words: Cloud storage, Heart diseases, Personal Electronic Health Record, Robotics, Telehealth

1. Introduction. In this Contempo era, the healthcare industry is growing fast to provide better cure to the patients as well as health related improvement. From surveys, it has been observed that the world is drifting towards more digitization and technological involvement. According to several prior industrial reports it has been predicted that [1, 2] by 2020, the year will be the year of the technologist such as involvement of cloud in the healthcare industry.

The innovative and technological advancements in the information technology (IT) sector have led to adaptation of the technologies in the healthcare sector and considerable positive growth has also been observed that is considered as technology-enhanced healthcare (TEH). It has been expected and witnessed that there will be surprising growth in the use of advanced technologies by 2021 with 40% rate from $6.6 billion (Dh24.2 billion). It has also been predicted that that by 2025, there will be an unexpected growth in the IT-associated Extended Reality (XR) with the rate of $5.1 billion through the worldwide [3]. TEH is rapidly emerging as a prominent technological sector. The hospitals and certain medical centers are still following the comprehensive and traditional offline record maintaining procedures on a routine basis. With contrast to traditional healthcare provisioning, TEH is widely engaged in improving the capabilities and quality of healthcare services.

The TEH sector is witnessing a boost owing to the facility for proper utilization, management and collection of health information that plays a vital act in the detection of several medical problems [4] whilst identifying novel and innovative technological solutions for treating the patients.

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Traditional Healthcare system (THS) is categorized into two services such as personal and public healthcare services. Traditional Healthcare system also provides the services related to teaching and research. Personal Healthcare services are basically for hospitals, homes as well as organizations whereas public healthcare services offer guidelines for drugs, food and various safety policies etc. Research and teaching services are related to disease prevention, detection, tracking of disease and treatment.

The evolution of technologies has brought unbelievable innovation in the healthcare industry that provides the facilities from ground level to higher level, so healthcare has become important as it provides healthcare-as-a-service (HaaS). Enhanced technology also provides the facility to monitor and record the status of various patients' issues. Cloud computing as an emerging technology provides the platform for the effective use of resources in a secure manner to improve the quality, safety as well as efficiency of healthcare data [82]. As per the survey by Health Information and Management System Society (HIMSS) analytics and ISO/TS 18308 standards, the patient medical records are maintained electronically in the form of Electronic Medical Record (EMR), Electronic health record (EHR) and personal health record (PHR). EMR organizes the relevant information about the patient such as the patient's history, test results centrally for the purpose of further use.

1.1. Motivation for the Work. The paper presents a deep and extensive study about the significance of cloud computing and the Internet of Things (IoT) in the healthcare era. This survey highlights the role of IoT and cloud computing in the healthcare industry, focusing on the structure of IoT and cloud. The capabilities of these platforms in providing and supporting healthcare applications have been discussed. Additionally, the paper reviews different existing digital healthcare frameworks based on cloud, IoT, as well as CoT. The major contributions of the paper include:

1. In-depth analysis of the role of IoT and cloud computing in the field of healthcare.
2. Detailed description of IoT frameworks related to the healthcare industry, such as typologies, platforms, and structure.
3. Survey related to cloud computing frameworks, standards, and architecture integrated with the healthcare industry.
4. An overview of e-healthcare services and m-healthcare.

2. Research methodology. This Section highlights the objectives of the review article and discuss the factors that motivate for conducting this review article in depth and also elaborate the methodology used in detail. In this paper, an analysis of the advancements of the technologies such as cloud computing, Internet of things and Cloud of things in the healthcare sector has been discussed. A systematic approach has been followed to identify, evaluate and summarizing the survey related to HaaS. The Research methodology used in the review is as shown in the figure 2.1.

2.1. Review Plan. The review plan defines the steps involvement in the formulation of the research related queries, exploring of the relevant databases and identification of diverse resources such as springer, ScienceDirect, ACM Digital Library, IEEE Xplore and Google Scholar. Further refinement of the primary study is followed by the specific inclusion criteria for the final findings.

2.2. Review Sources and Distribution. This section signifies the findings related to the review analysis based on the taxonomy. The following figure 2.2 gives the distribution analysis of the different database sources.

3. Role of Cloud Computing and IoT Technologies in Delivering Healthcare. Technologies have greatly impacted the surroundings and have led to high-level digitization from the communication sector to the health sector as well as the entertainment sector. The latest technologies are used in various sectors such as education, the healthcare industry, organizations, and IT companies, etc. This section highlights the role of cloud computing, IoT, and Cloud of Things (CoT) in the healthcare sector.

3.1. Cloud Computing in Healthcare Sector. Cloud computing is considered as internet-based computing that helps to provide resources, software, as well as required information on-demand to computers. Cloud computing provides numerous cloud services such as database, storage, networking, and data processing through the internet instead of hard drives. All these services are also termed as "cloud," where cloud means the metaphor of the internet. In cloud computing, there is only a need to pay for the resources that are actually used, which is termed as a pay-per-use model [5, 6].

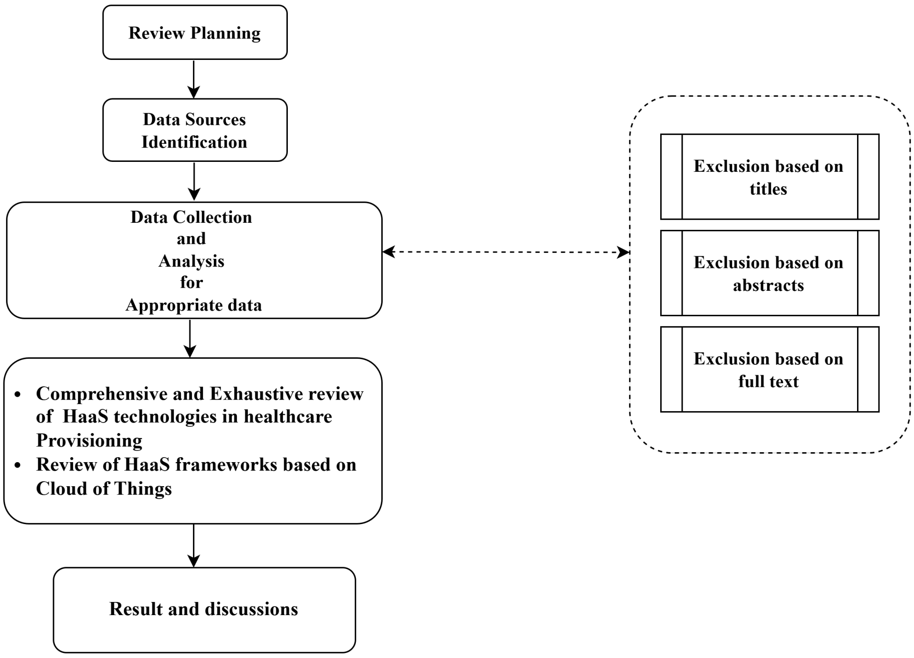

Fig. 2.1: Research Methodology

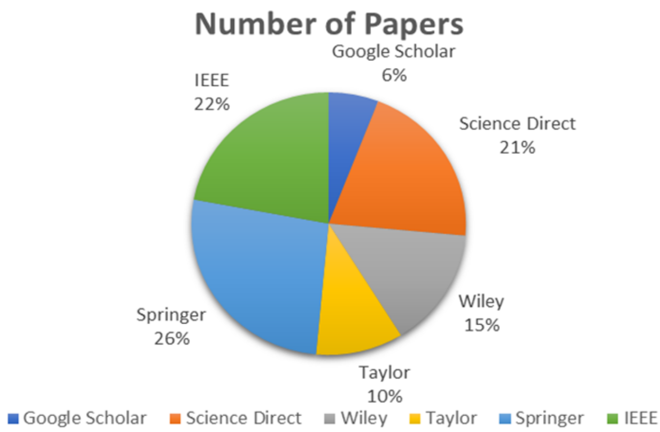

Fig. 2.2: Article Distribution based on scientific Sources

There are different service models which include Infrastructure as a Service (IaaS), Software as a Service (SaaS), Platform as a Service (PaaS), and Security as a Service (SecaaS), etc., and different delivery models such as public, private, and hybrid cloud models. In Software as a Service (SaaS), the cloud provides on-demand services for the healthcare industry such as quick access to business applications and customer relationship management (CRM). In IaaS, the cloud provides an on-demand storage facility for medical records, and lastly, as PaaS, it provides a secure environment for the deployment of web applications [7].

In the medical field, cloud computing is associated with remote servers for medical data storage, proper management, and processing. Cloud storage provides secure facilities for storage to healthcare professionals as

Table 3.1: Cloud-Based Tools in Healthcare Sector

Ref.No	Tools	Description
[10]	HIPAA-Compliant Cloud	HIPAA Cloud tool is becoming more prominent as service providers in the healthcare field, such as nimble and low-cost IT-related solutions and services. The tools integrated with HIPAA-Compliant Cloud provide benefits such as file-sharing, cost-saving facilities, expanded storage facilities, and dynamic as well as future-proof infrastructure creation.
[11]	NetApp	NetApp is a hybrid cloud service company that provides cloud-based services as a platform for healthcare management. This tool helps to provide real-time patient data for faster delivery and quick efficiency by creating backups, reducing EHR latency, data restoration, and easy access to data.
[12]	Google Cloud Healthcare API	This is a secure development environment that helps to build solutions for medical practices. It helps to make the data shareable between relevant applications on Google Cloud. This tool provides the facility of data processing, analytics, and a machine learning platform.
[12]	Medscape	Medscape is a cloud app used globally by professionals and physicians. It helps in delivering the latest information related to medical treatment and clinical innovations.
[12]	VisualDX	VisualDX is an innovative tool that improves the accuracy of diagnosis and patient care. It provides an alternative way for diagnosis, patient treatments, and helps in identifying the best treatment options.

well as medical sectors [8].

Subsequently, the cloud-based healthcare field has emerged with basic necessary requirements such as on-demand access for online storage, handling a huge amount of data in terms of EHR, radiology images related to patients, information related to patients' lifesaving, patients' treatment and diagnosis improvement, and proper analysis of patient data [9].

Cloud-based EHRs reduce the use of storage areas such as desktop computers, etc., and provide a centralized system that facilitates easier and more efficient use of records. Not only doctors but also patients can access their records for healthcare purposes. Secondly, EHR data analytics provides centralized access to the data and its functionality. EHR Analytics uses algorithms to provide effective quality to patient data.There are various existing Cloud-based tools as discussed in table 3.1 used in the healthcare sector to provide cloud-based services.

Summarily, the key highlights as inferred from Table 3.1 include:

- HIPAA-Compliant Cloud and NetApp are most relevant to Data Management. It gives you the protection of your data and expansionary storage for proper data management.
- Advanced Analytic Google Cloud Healthcare API is used that provides unique features for utilizing the concept of machine learning and data processing.
- Medscape Application help in sharing of knowledge and making sure that the Healthcare professionals know as well as updated on the latest trends and treatment in the medical field.
- VisualDX improve the accuracy and patient-centered decisions involved in or pertaining to a particular patient's care. Besides, promotes accurate and proper identification of a disease and the subsequent management of the same.

3.2. Internet of Things (IoT) in Healthcare Sector. The Internet of Things (IoT) includes the utilization of objects or "things" that are interconnected with the internet instead of computers. IoT is considered an innovative computing model in which real-world objects are integrated with the internet. These IoT objects are collaborated with sensors and innovative technologies. Such sensing objects have the capability of extracting and collecting data to perform analysis without human association to perform any function [16]. In actuality, the "things" in IoT can consist of multiple devices such as sensors forming a Sensor Network (SN), radio-frequency equipment, etc. In the IoT standard, SN constitutes an important part that interconnects the SN either using wired or wireless techniques [13].

In IoT, there exists an interconnection of billions of devices throughout the internet that are collecting and sharing data. Specifically, IoT is the connection of various devices ranging from sensors to smartphones and wearable devices. When these devices are connected with an automated system, it becomes easy to collect the required information, analyze it, and take action [6]. IoT as a technology provides better opportunities for building standards that are useful for exploring the work to be done, time efficiency, as well as money-saving.

Table 3.2: IoT Tools Used in Healthcare

Sr.No	Tools	Description
[18]	Pulse-Rate Sensor	Pulse-Rate sensor is used to know the heartbeat rate information. Another name for this sensor is heart rate sensor. The sensor helps to monitor patient health, track sleep, and monitor anxiety.
[19]	Blood Pressure Sensor	Blood Pressure sensor is used to measure the blood activity of patients, including systolic, diastolic, and mean arterial pressure levels using the oscillometer method.
[20]	Temperature Sensor	A sensor used to measure the temperature of the patient's body. Such sensors are also installed to monitor air sterility.
[21]	Sugar Level Sensor	A sensor used to measure glucose levels in the blood of patients to monitor diabetes type I or II.
[22]	Motion Sensor	A sensor used to measure the motion activity of the patient. It helps to identify physical movements or actions related to the patient to measure the BMI level.

IoT is not only a collection of things but also considered an ecosystem of interrelated resources and other technologies. Apart from interconnected devices, IoT defines resources such as hardware, software, connectivity, protocols, and middleware. It is characterized by seven prominent features: Connectivity, Things, Data, Communication, Intelligence, Action, and Ecosystem [14]. Connectivity provides the opportunity to bring the objects together, improves communication between connected devices, whilst intelligence saves time by transferring the data over the network as well as reducing human intervention. These all together in action maintain the ecosystem [15].

Predominantly, the healthcare industry is based on five major factors: electronic databases, doctors embracing mobility, testing and imaging, online database prediction, and errorless healthcare technology. Due to Technology-Enhanced Healthcare (TEH), major technological changes have been observed in the healthcare system. Electronic databases basically handle the patient health data obtained from sensors that help to generate the Electronic Health Record (EHR). IoT with EHR helps to enhance patient healthcare by providing services to monitor the patient's health anywhere and anytime [79]. The doctor embracing mobility is associated with the security of patient data as well as improvement in health data. The latest IoT technologies help with end-to-end connectivity and affordability for automating patient care with the help of mobile devices. Smartphones have become one of the ways to communicate with doctors either by voice calls or video calls throughout the world [80]. With IoT and medical imaging, it has become one of the best ways to represent patient records effectively, allowing doctors, caregivers, and staff to make appropriate decisions for the patients [81].

Data analytics and IoT for healthcare records act as a powerful tool in the transition of the healthcare system from profit to value-based care. The mobile medical devices using IoT sensors, such as wearable gadgets to examine diabetic patients and monitor their glucose levels, are gaining attention. For example, the Apple Watch can be considered a product of TEH and helps predict and measure the diet, fitness, and sleeping data of patients [4].

Compared to IoT, cloud computing is considered a computing technology with the capability of accessing a variety of resources and services. This technology has a feature of resource sharing through a virtualization process from anywhere. In addition to this, cloud computing has the ability to maintain physical resources.There are various existing IoT based tools as discussed in Table 3.2 used in the healthcare sector to provide the IoT-based services.

Summarily, the key highlights associated with various IoT tools in healthcare involve the following:

- Comprehensive Monitoring: These sensors use the holistic approach for monitoring the overall patient's health and the physiological parameters such as blood pressure, glucose levels, heart rate, and physical activity.
- Versatility: It is used in health care as wearables by the patients such as fitness trackers, CGMs and in highly technical hospitals as sterilization tools, fall detection devices etc.
- Personalized Care: These sensors help in the collection of real-time data from that is used for the proactive and personalized healthcare management It reduce the risk of chronic diseases.

3.3. Cloud of Things in Healthcare Sector. Cloud computing and IoT technology complement each other. On the flip side, cloud computing has the efficiency to address the limitations of IoT technology. To

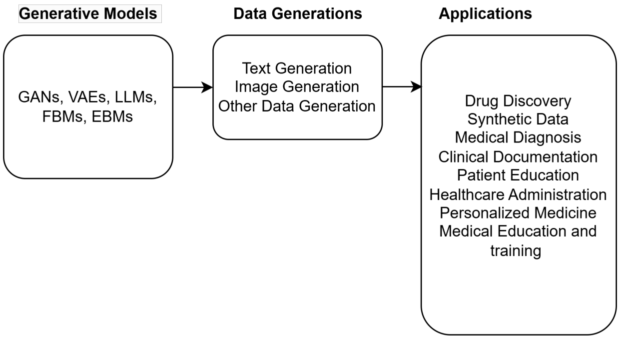

Fig. 3.1: Generative AI Applications

respond more effectively to the digital world, cloud computing and IoT are collaborated, which is referred to as Cloud of Things (CoT). With the help of IoT and Cloud, access to the medical field as well as data has become efficient at a global level and delivers better solutions based on real patient monitoring and health analysis [17].

Additionally, from a security perspective, public cloud in the healthcare field provides the facility of resource sharing, while IoT enables safe and efficient monitoring of patient health. The tools for CoT are collectively based on cloud and IoT tools and methodologies.

3.4. Generative AI in healthcare. Artificial intelligence (AI) has been emerged as transformative technology in healthcare sector that enhances the patient-care, provides effective disease diagnosis and treatment [84] [85]. Generative AI reduces the cost and time for the effective delivery of healthcare services and improve the patient care [86] [87] [88]. The applications of Generative AI are as shown in the figure 3.1.

Generative AI models such as Generative Adversarial Networks, Variational Autoencoders, Generative Pretrained Transformer etc helps in the generation of the modalities such as Text, image and other data generation formats. This generated data used for various scenarios such as drug discovery, data synthetic, medical diagnosis and healthcare administration.

4. Research Contributions of the Work. The review focuses on the analysis and review of healthcare provisioning through cloud computing. It involves addressing various research questions as listed in Table 4.1.

4.1. Analysis and Comparison of Primary Studies Focusing on Review of HaaS. Various healthcare-related existing review papers and survey papers have been reviewed to analyze the comparison in different years. Table 4.2 lists the comparative review and survey papers in the healthcare sector associated with Cloud Computing, IoT, and CoT.

5. Existing Healthcare-as-a-Service (HaaS) Frameworks. Healthcare facilitated through technology is a novel notion that has emerged recently and is significantly rising. In recent years, extensive research has been carried out in this area. This section discusses the basic frameworks designed for providing HaaS, highlighting key findings and features of existing HaaS frameworks. A detailed and comprehensive survey has been conducted on IoT and cloud computing in the healthcare industry, exploring the standard structures of IoT and cloud computing, and the frameworks and platforms that facilitate communication.

5.1. Layered HaaS Provisioning Framework. The National Academy of Engineering (US) and the Institute of Medicine (US) Committee on Engineering and the Health Care System [30] have adopted a four-level model to understand the structure of the healthcare system. Figure 5.1 provides a hierarchical ordering that describes a four-level healthcare system.

The first level is patient-centric where individual patient needs and preferences are defined. At this level the responsibilities differ from patient to patient. The patient and his/her family members have access to educational, decision support, information management as well as tools that help to integrate the information

Table 4.1: Different Research Questions and Corresponding Motivations

Sr.No	**Questions**	**Motivations**	**Sections Contribution**
RQ1	What is the significance of healthcare delivery?	Healthcare delivery helps to understand the role of digital healthcare in the e-world. This research question studies the various technologies' roles in the healthcare sector such as cloud computing, IoT, and CoT.	Section 2
RQ2	What is healthcare as a service model?	The role of this question is to explore healthcare services such as SaaS, IaaS, and PaaS related to cloud computing.	Section 4
RQ3	What is the role of technology in facilitating Healthcare as a Service (HaaS)?	This question helps to analyze how various technologies are playing a role in the healthcare sector to provide better services to facilitate HaaS.	Subsection 2.1, 2.2, and 2.3
RQ4	How has ICT impacted healthcare delivery and provision?	This type of study carries out the use of ICT in healthcare delivery services and provides the provision of digital healthcare.	Section 2
RQ5	Why use Cloud computing and IoT for offering Healthcare as a Service?	This question defines how cloud computing and IoT are used to deliver healthcare-related services by proposing healthcare monitoring frameworks and models.	Section 4
RQ6	What is the need for HaaS?	This question defines the needs of HaaS in real-time scenarios with the involvement of various factors and tools.	Section 4
RQ7	What are the existing proposed frameworks?	It helps to perform an in-depth survey of proposed frameworks associated with the digital healthcare sector.	Subsection 4.3
RQ8	How does this contemporary healthcare system differ from the traditional healthcare system?	This question helps to identify how the healthcare sector has become more advanced compared to traditional healthcare.	Section 2 and Section 4

Table 4.2: Comparisons of Healthcare Related Existing Review Papers

Sr No	**Ref.**	**Year**	**Review**	**Taxonomy**	**Cloud-Based**	**IoT-Based**	**Focus of Review**
1	[23]	2012	✓		✓	✓	ECG
2	[29]	2014	✓			✓	Smart healthcare
3	[25]	2014	✓		✓		Healthcare facility such as storage
4	[26]	2014	✓	✓	✓		Cardiovascular disease
5	[27]	2014	✓	✓	✓		Healthcare industry such as data access and sharing
6	[24]	2021	✓		✓		Diabetics
7	[28]	2022	✓	✓	✓		Cardiovascular disease
8	[72]	2022	✓		✓	✓	Covid-19
9	[32]	2015	✓		✓		Security and Privacy of Patient data
10	[34]	2016	✓		✓		Healthcare Services such as storage, data access
11	[36]	2018	✓	✓		✓	Healthcare services such as storage, data access and privacy
12	[44]	2017	✓			✓	Smart Healthcare
13	[51]	2018	✓			✓	Healthcare facilities
14	[31]	2018	✓	✓		✓	Health Monitoring
15	[73]	2020	✓		✓		Cardiovascular disease
16	[74]	2022	✓		✓		Cardiovascular disease
17	[75]	2022	✓		✓	✓	Cardiovascular disease
18	[76]	2021	✓			✓	Cardiovascular disease
19	[78]	2022	✓		✓		Diabetic
20	[82]	2023			✓	✓	Diabetic

from different sources. The second level depicts care providers that directly impact each subsequent level such as the patients, organization, and environment. At the organizational level, the care providers help for the improvement in communication as well as facilities. At the environmental level, the care providers coordination leads with the benefits for insurance companies of both public as well as private sectors.

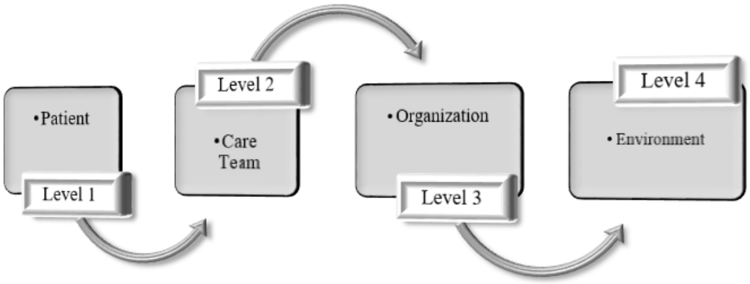

Fig. 5.1: 4-level Healthcare System

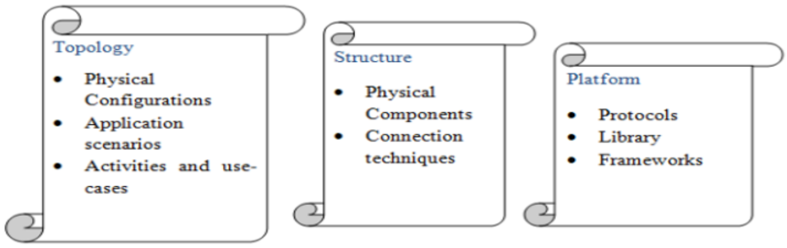

Fig. 5.2: Three Basic Components and their Main Functions in the IoT Framework for Healthcare.

5.2. General Framework for Offering Healthcare as a Service (HaaS). A framework provides protocols that facilitate the communication and broadcasting of fresh as well as raw medical data from smart devices and various sensors. Principally, IoT frameworks consist of three components: topology, structure, and platform, as shown in Figure 5.2. Each component of the framework has specific functions in the healthcare industry [31].

Figure 5.2 depicts the components with functionality related to the IoT frameworks used in the healthcare sectors. The first component is Topology that define the infrastructure related to the healthcare sector and defines physical configurations in the form of doctors, patients and protocols, activities such as EHR. Second component is Structure that defines the physical components related to the healthcare and connection techniques. Third component is healthcare frameworks.

6. Results and Discussions. This section depicts various types of HaaS frameworks deployed with the collaboration of innovative technologies. It elaborates on the classification and taxonomy of HaaS frameworks integrated with technologies such as cloud computing, IoT, etc. Additionally, the essential key aspects, such as methodologies, implementation environments, and resource utilization are discussed. The subsections provide insights into the classification and taxonomy of HaaS frameworks.

6.1. Classification and Taxonomy of HaaS Frameworks. HaaS frameworks have been categorized based on implemented technologies, delivered services, and focused diseases (as depicted in Figure 6.1).

6.1.1. Classification on the basis of Technologies Implemented. The healthcare field has become one of the innovative sectors due to the involvement of digital technologies. Various frameworks have been proposed using technologies such as cloud computing, Internet of Things (IoT), and Cloud of Things (CoT). The classification and taxonomy are illustrated in Figure 6.2.

I. **Healthcare as a Service (HaaS) Frameworks based on Cloud Computing**
The healthcare sector is boosting due to the integration of cloud based services. Various cloud-based frameworks have been proposed for better facilities in the healthcare sector [83]. This section highlights

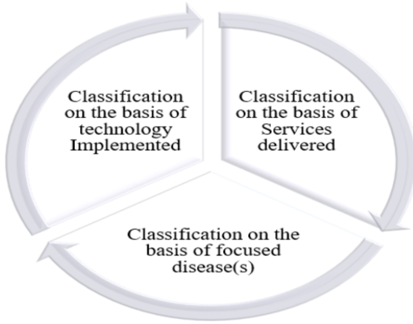

Fig. 6.1: Classification of HaaS Frameworks.

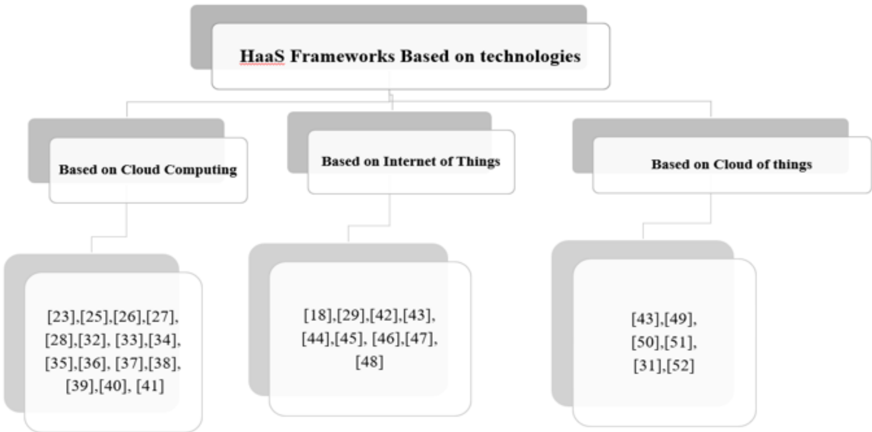

Fig. 6.2: Taxonomy of HaaS Frameworks based on Technologies.

the various existing HaaS frameworks based on cloud computing as shown in Table 6.1.

II. **Healthcare as a Service (HaaS) Frameworks based on IoT**
IoT has been broadly integrated in the healthcare field for real time health monitoring and report analysis. Various frameworks and models have been proposed for doctors, patients, and various health related fields. This section elaborates the frameworks in the Table 6.2.

III. **Healthcare as a Service (HaaS) Frameworks based on Cloud of Things (CoT)**
Cloud and IoT has been integrated as collaboratively in healthcare field for storage and health monitoring. Various advanced healthcare models have been proposed for providing such facilities. This section elaborates the various health related frameworks in Table 6.3.

6.1.2. Classification on the Basis of Services Offered. Healthtech or healthcare technologies defines the technologies used for the development of the healthcare system [53]. From telehealth to robotic-assisted surgery related services has brought a drastic change in the healthcare sector. Technology innovation advancement has delivered better services in digital format such as wearable devices, telehealth services, mhealth and so on. Table 6.4 describes the services provided by various technologies involved in the healthcare sector.

6.1.3. Classification on the basis of Focused Diseases. The effectiveness of the existing frameworks has been accessed to explore the specific disease or problem handled by them. Table 6.5 lists various existing technologies and algorithms presented in the frameworks that can handle various healthcare problems.

Table 6.1: Healthcare as a Service (HaaS) Framework Based on Cloud Computing

Sr. No	Reference	Implemented Environment	Platform	Description
1	[23]	Microsoft.NET framework	Aneka Platform	– The prototype system is developed for system design. – Stores the patient data in a cloud-based repository.
2	[25]	Matlab	iFit platform	– Cloud-based diagnosis system is proposed. – Determine the health issues based on the physiological data of the patient.
3	[26]	Java Android SDK, MySQL 5.5	AliveCor mobile app	– Identify the issues related to security and privacy in terms of cloud computing in the medical industry. – To ensure the patient about the health data shared with doctors are secure and confidential.
4	[33]	TCP/IP and Zigbee	Cloud-assisted Wireless Body Area Network (WBAN)	– Healthcare data sharing network is proposed. – Integration of Zigbee with TCP/IP for reliable interaction.
5	[34]	ICT	Cloud Network	– Cloud-based network is proposed. – Enable the communication and interaction between patients and doctors.
6	[35]	Cloud stack	SAMI healthcare platform of Samsung	– Mobile healthcare network is proposed. – Mobility cloud control software is proposed for the management of networks.
7	[36]	-	Gateways	– Indicates the opportunities and challenges of fog computing in the healthcare industry. – Proposed 3-layer architecture for the healthcare industry for the purpose of real-life applications.
8	[37]	C++	OpenMP	– Fog computing-based framework is proposed to give the response on patient mobile. – Apply the framework to reduce the response time of the prototype.
9	[38]	Cloud computing, health IoT, digital twin, and big data	CloudDTH platform	– Cloud healthcare framework is proposed based on digital twins. – Provide the services for the management as well as operations of the healthcare system.
10	[39]	C# programming and JSON	Relational Database Service and Amazon Web Service	– Privacy-preserving mobile healthcare framework is proposed based on the location. – Framework integrated with the capability of Context-based decision making.
11	[40]	Cloud Computing	SecHC framework	– Cloud-based Secure Healthcare Framework was proposed to provide the security and integrity features in healthcare and medical records. – Proposed framework modules are setup, key generation, encryption, and decryption.
12	[28]	CoreML package	Google Cloud Firebase	– HealthCloud system is proposed to monitor the health status of patients. – Machine learning algorithms such as Super-Vector classifier, KNN, Neural Network, Logical Regression, Gradient Boosting Trees are used.
13	[41]	Java and MATLAB	IoMT Cloud Environment	– Heart Disease prediction system is proposed using modified salp swarm optimization (MSSO) and an adaptive neuro-fuzzy inference system (ANFIS). – An accuracy of the prediction model is 99.45 with a precision of 96.54.
14	[73]	MATLAB	Supervised machine learning	– Heart disease is predicted using SVM and machine learning. – An accuracy of the model is 95.31%.
15	[74]	Python	– Random Forest – K-Neighbors classifier – Support vector machines – Decision Tree	– Healthcare applications are developed to detect heart diseases. – Diagnosis system is developed for heart disease.

Table 6.2: Healthcare as a Service (HaaS) Framework based on IoT

Sr. No	Reference	Implemented Environment	Platform	Description
1	[29]	Arduino	Ell-I arduino	– The proposed system is based on the IoT for the healthcare industry that is concerned with effective data transmission and IoT sensors with power. – Improves performance as well as energy efficiency.
2	[42]	PHP, MySQL	Clinical environment	– Smart gateway system is proposed for an e-health monitoring system. – Facilitates various services such as compression, storage, and security.
3	[43]	Microcontroller Unit	Mobile App	– Determine the short term as well as long term communication protocols for the purpose of communication between machines. – Identify the key findings and scope of IoT in the Medicare area and healthcare system.
4	[44]	Sensors	Machine Learning enabled cloud	– Determine the IoT basic elements in the healthcare system. – Focusing on the various types of sensors and communication methods.
5	[45]	XML	ATmega32U4 micro-controller	– Identify the consequences and future scope in the healthcare system. – Pointing to the security challenges in IoT devices as well as in networks.
6	[46]	MATLAB 2020a	FogBus, Healthcare Sensors	– A smart heart disease prediction system is proposed using IoT and Fog Computing. – Optimization algorithms are used to check the accuracy of the dataset.
7	[47]	MATLAB	Cuckoo enables classifier IoT based framework	– A heart disease prediction model is proposed using Cuckoo Search-based Conv LSTM Classifier. – Cuckoo-based deep ConvLSTM model is analyzed based on different evaluation metrics such as accuracy, specificity, and sensitivity.
8	[48]	Keras and Tensorflow	smart IoT-based framework	– Smart healthcare model is proposed using IoT with Cloud computing technology for diagnosis of heart failure. – Proposed model helps to investigate the classification of the heart diseases patient status such as alive or deceased.
9	[76]	Python language	IoT platform based on Machine Learning	– 4-tier CDPS-IoT model is proposed using machine learning for heart disease prediction. – Better accuracy is achieved with low error rates.

Table 6.3: Healthcare as a Service (HaaS) Frameworks based on Cloud of Things (CoT)

Sr. No	Reference	Implemented Environment	Platform	Description
1	[49]	XML	Machine-to-Machine platform	Proposed on Cloud-based IoT platform. Identify the efficiency of the framework based on factors such as efficiency and energy consumption.
2	[43]	Microcontroller Unit	Mobile App	IoT-based ECG monitoring system is proposed which consists of three main parts such as IoT, cloud, and GUI. This proposed system is reliable to collect real-time ECG data. Proposed system supports a high data rate and wide area.
3	[50]	Scyther	Healthcare System	A new healthcare system is proposed that contains a storage stage and data retrieving stage. Provides the facility of high data storage and security to the data.
4	[52]	Cloud of medical things	Cloud and IoT	The proposed system is the Cloud of Medical Things (CoMT) based Smart Healthcare Framework. Associated factors are resource Co-allocation, security, and energy efficiency.
5	[75]	Tensorflow, Apache Spark, and Cassandra	i2k2 Cloud platform	Risk of heart disease is predicted using Bi-LSTM. Alerts to notify the clinicians and caretakers of the patient's condition.

Effectiveness Analysis of Existing HaaS Frameworks. Various contextual frameworks identify the effectiveness of the frameworks in specific scenarios such as data complexity, real-time data analysis, and scalability. There are certain characteristics related to the frameworks that are as follows.

Table 6.4: Classification on the Basis of Services Offered

Sr No	References	Services	Description
1	[54]	EHR	EHR is a digital version that is a real-time and patient-centric record. EHR is available instantly at both global and local levels. EHR contains data related to patients' history to provide better treatment facilities and care. EHR helps to provide patient information to the hospital service providers for care.
2	[55]	Wearable Technology	Such technologies provide services to track daily activities such as steps taken, sleeping duration, heart rate, and other physical activities of the patient. Wearable technologies also help in health monitoring by observing blood sugar and oxygen levels in patients.
3	[56]	mHealth	mHealth is a mobile application used for health monitoring, digital assistance, and real-time disease analysis. mHealth service is used for phone calls with health professionals.
4	[57]	Telehealth	Telehealth provides digital ICT facilities for remote and global-level services for health care. This healthcare service provides various facilities such as patient safety, primary care, easy accessibility to health-related specialists, and improvement in communication, etc.

- Existing frameworks impacting the data quality as well as volume on the frameworks such as Machine learning-based proposed CVD-prediction frameworks utilize the cloud-based platform for the data storage more effectively and efficiently.
- Proposed frameworks are utilized for specific needs such as CVD predictions, Diabetes monitoring and Liver prediction.
- ML based algorithms are effective for patient-health monitoring and hospital-centric frameworks are focusing on patient-centric services such as EHR and high computational energy.

6.2. Technical and logistical challenges in Cloud and IoT-based Healthcare Frameworks. An amalgamation of the innovative technologies such as cloud computing and Internet of Things has empirical impact in the healthcare sector that enhance the patient-care and provide the real-time health monitoring. But, involvement of such frameworks has several technical and logistical challenges that are discussed in Table 6.6.

7. Conclusion. With the advancement in the IT sector, the healthcare field has become one of the curious fields at the global level. Various IT technologies such as cloud computing, big data, edge computing, and fog computing are playing significant roles in facilitating technology-enhanced healthcare or Healthcare-as-a-service. The paper highlights a detailed study about the role of ICT technologies such as cloud computing and IoT in delivering Healthcare. A comparative analysis of the existing technological involvement in the healthcare sector has been discussed towards the digital sector. The paper lists the various proposed frameworks pertaining to technologies such as cloud computing, IoT, and cloud-of-things. It also presents related taxonomies for Healthcare-as-a-Service based on diseases, services, and technologies. While various frameworks based on cloud computing, IoT and CoT has been proposed but also there is need for the involvement of the advanced and innovation technologies such as generative AI. Future study can analyze the impact of the advanced and informative technologies in the healthcare sector.

Acknowledgment. We thank the Deanship of Scientific Research, Prince Sattam Bin Abdulaziz University, Alkharj, Saudi Arabia for help and support. This study is supported via funding from Prince Sattam Bin Abdulaziz University project number (PSAU/2025/R/1446).

Funding. This study is supported via funding from Prince Sattam Bin Abdulaziz University project number (PSAU/2025/R/1446).

Author Contributions. All authors contributed to design and development of the system as well as the manuscript. All authors have read and approved the final manuscript.

Data availability. Data sharing not applicable to this article as no datasets were generated during the current study.

Table 6.5: Classification Based on Focused Diseases

Sr.No.	Reference	Focused Disease(s)	Techniques/Algorithm Used
1	[58]	– Heart Diseases – Breast Cancer – Diabetes – Spect_heart – Thyroid – Dermatology – Liver disorders	– K-NN – Support Vector Machine – Decision Trees – Random Forest – MLP
2	[59]	Breast Cancer	– Basic classifier – Ensemble method – Cost-sensitive method
3	[60]	Kidney	– Naïve Bayes – Support Vector Machine (SVM)
4	[61]	Thyroid	– NB tree – J48 – LADTree – BFTree – LMT – Random Forest
5	[62]	Diabetes	Enhanced class outlier
6	[63]	Diabetes	SVM, K-means
7	[64]	Cancer	SVM
8	[65]	Cardiovascular disease	Ensemble deep learning
9	[66]	Diabetes mellitus	K-means clustering
10	[67]	Cardiovascular disease	Naive Bayes
11	[68]	Chronic diseases such as diabetes, blood pressure, cardiac arrhythmia	IoT
12	[69]	Cardiovascular disease	– Deep learning – Machine learning
13	[70]	COVID-19	– Cloud Computing – IoT
14	[71]	Cardiovascular diseases	– A stacked ensemble classifier – Machine Learning algorithms such as Random Forest and XGBoost
15	[73]	Cardiovascular disease	Machine Learning
16	[74]	Cardiovascular disease	– Random Forest – K-Neighbors classifier – Support Vector Machines – Decision Tree
17	[75]	Cardiovascular disease	– RNN – Long short-term memory
18	[76]	Cardiovascular Disease	– Random Forest – Decision Tree – Naïve Bayes – K-nearest neighbors – Support Vector Machine
19	[78]	Diabetic	– KNN – SVM – ANN – Deep Neural Network
20	[82]	Diabetic	– Random Forest – Logistic regression

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Table 6.6: Technical and Logistical Challenges in Cloud and IoT-based Healthcare Frameworks

Sr.No	**Challenges**	**Description**
1	Technical Challenges	– Data Security and Privacy: Attackers make the target mostly Cloud-based systems that expose the patient health records such as PHR or EHR for unauthorized activities. – Insufficient and Expensive Data Security
2	Logistical Challenges	– Infrastructure Gaps: Not accurate deployment of Infrastructure – High Initial Cost

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Edited by: Prakash Mohan
Special issue on: Advancing Healthcare through Scalable Machine Learning: Overcoming Challenges and Embracing Innovations
Received: Sep 3, 2024
Accepted: Feb 8, 2025