

Healthcare IoT

Introduction to IoT

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Introduction

- The salient features of IoT encourage researchers and industries to develop new IoT-based technologies for healthcare.
- Various IoT-enabled healthcare devices are being used for diagnosing human diseases, monitoring human health conditions, caring/monitoring for elders, children, and even infants.
- IoT-based healthcare systems and services help to increase the quality of life for common human beings.
- IoT-based healthcare devices provide access and knowledge about human physiological conditions through hand held devices.

Healthcare IoT

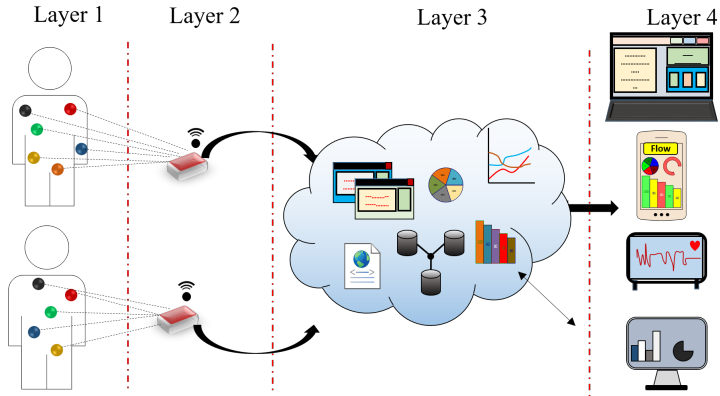


Figure: An architecture of Healthcare IoT

Healthcare IoT: Layers

- **Layer 1:**

- This layer contains different physiological sensors that are placed on the human body.
- These sensors collect the values of various physiological parameters.
- The physiological data are analyzed to extract meaningful information.

- **Layer 2:**

- Layer 1 delivers data to Layer 2 for short-term storage and low-level processing.
- The devices that belong to Layer 2 are commonly known as local processing units (LPU) or centralized hubs.
- These units collect the sensed data from the physiological sensors attached to the body and process it based on the architecture's requirement.
- LPUs or the centralized hubs forward the data to Layer 3.



Healthcare IoT: Layers

● Layer 3:

- This layer receives the data from Layer 2 and performs application-specific high-level analytics.
- Typically, this layer consists of cloud architecture or high-end servers.
- The data from multiple patients, which may be from the same or different locations, are accumulated in this layer.
- Post analysis of data, some inferences or results are provided to the application in Layer 4.

● Layer 4:

- The end users directly interact with Layer 4 through receiver-side applications.
- The modes of accessibility of these services by an end user are typically through cellphones, computers, and tablets.

Components of Healthcare IoT

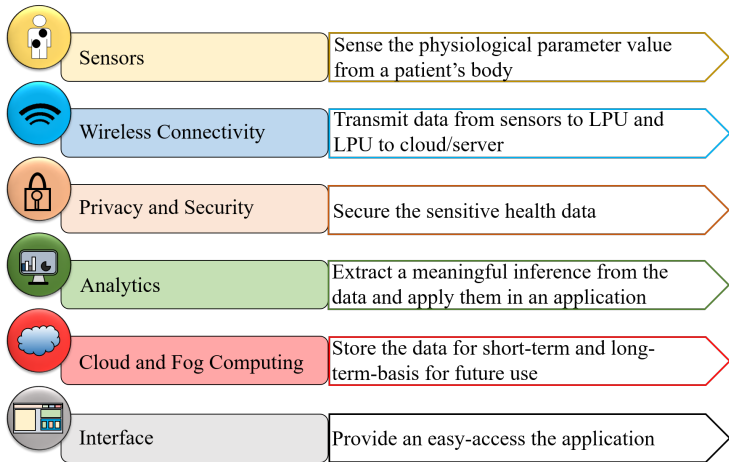


Figure: Components of Healthcare IoT

Components of Healthcare IoT

- **Sensors:**

- Sensors are the essential part in an healthcare-IoT architecture.
- a few of the sensors are: SpO₂, temperature, airflow, blood pressure, glucometer, Galvanic skin response (GSR), Electrocardiogram (ECG), and Electromyogram (EMG).

- **Wireless Connectivity:**

- The communication between the wearable sensors and the LPU is through either wired or wireless connectivity.
- The wireless communication between the physiological sensors and LPU occurs with the help of Bluetooth and ZigBee.
- The communication between the LPU and the cloud or server takes place with Internet connectivity such as Wi-Fi and WLAN.
- The communication for accessing the data in a personal device, the communication protocols vary depending on the type of device in use.

Components of Healthcare IoT

● Privacy and Security:

- The privacy and security of health data is a major concern in healthcare IoT services.
- If any of these devices are compromised, it may result in the theft of health data of a patient, leading to serious security breaches and hefty lawsuits.
- In order to increase the security of the healthcare data, different healthcare service providers and organizations are implementing healthcare data encryption and protection schemes [3], [4].

● Analytics:

- Several actors, such as doctors, nurses, and patients, access the healthcare information in a different customized format.
- This customization allows each actor in the system to access only the information pertinent to their job/role.
- Analytics plays a vital role in providing different actors access to meaningful information extracted from the raw healthcare data .
- Analytics is also used for diagnosing a disease from the raw physiological data available [1], [2]

Components of Healthcare IoT

● Cloud and Fog Computing:

- For storing the huge amounts of heterogeneous health data, produced from the physiological sensors, efficient storage space is required.
- These data are used for checking the patient's history, current health status, and future for diagnosing different diseases and the symptoms of the patient.
- The cloud storage space is scalable, where payment is made as per the usage of space.
- To store health data in a healthcare IoT system, cloud storage space is used.
- Analytics on the stored data in cloud storage space is used for drawing various inferences.
- The major challenges in storage are security and delay in accessing the data.
- Cloud and fog computing play a pivotal role in the storage of these massive volumes of heterogeneous data.

Components of Healthcare IoT

• Interface:

- The interface is the most important component for users in a healthcare IoT system.
- Among IoT applications, healthcare IoT is a very crucial and sensitive application.
- Thus, the user interface must be designed in such a way that it can depict all the required information clearly.
- An interface must also contain all the useful information related to the services.

Advantages of Healthcare IoT

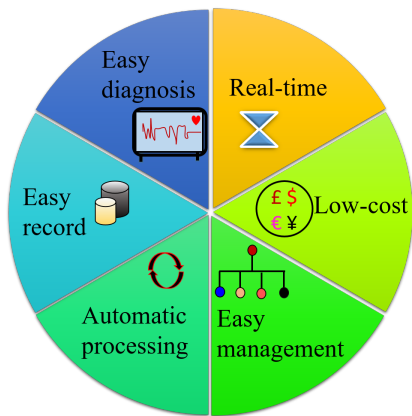


Figure: Advantages of Healthcare IoT

Advantages of Healthcare IoT

● Real-time:

- In healthcare sectors, the condition of the patients, availability of doctors and beds in a hospital, medical facilities with their monetary charges, can vary dynamically with time.
- A healthcare IoT system enables users, such as doctors, end-users at the patient side, and staff in a healthcare unit, to receive real-time updates about the healthcare IoT components.
- A healthcare IoT system can enable a doctor to observe a patients' health condition in real-time even from a remote location, and can suggest the type of care to be provided to the patient
- A users at the patient end can easily take different decisions, such as where to take a patient during critical situations.
- One of the important characteristics of an IoT-based healthcare system is real-timeliness.

Advantages of Healthcare IoT

- **Low-cost:**

- The healthcare IoT systems facilitate users with different services at low cost.
- An example: An authorized user can easily find the availability of the beds in a hospital with simple Internet connectivity and a web-browser-based portal. The user need not visit the hospital physically to check the availability of beds and facilities. Moreover, multiple registered users can retrieve the same information simultaneously.

- **Easy management:**

- Healthcare IoT is an infrastructure that brings all its end users under the same umbrella to provide healthcare services.
- The management of numerous tangible and intangible entities (such as users, medical devices, facilities, costs, and security) is a challenging task.
- Healthcare IoT facilitates easy and robust management of all the entities.



Advantages of Healthcare IoT

- **Automatic processing:**

- A healthcare unit consists of multiple subsystems, for which manual interventions are required.
- An example: To register a patient with a hospital, the user may be required to enter his/her details manually.
- Automatic processing features can remove such manual intervention with a fingerprint sensor/device.
- Healthcare IoT enables end-to-end automatic processing in different units and also consolidates the information across the whole chain – from a patient's registration to discharge.

Advantages of Healthcare IoT

- **Easy record-keeping:**

- The timely delivery of health data of the patient to the doctor is important.
- The permanent storage of the patients' health data along with their respective details is essential.
- For the smooth execution of the healthcare unit, details of the staff with their daily activity in a healthcare unit are also required for storage.
- A healthcare unit must also track its condition and financial transactions for further development of the unit.
- A healthcare IoT enables the user to keep these records in a safe environment and deliver them to the authorized user as per requirement.
- These recorded data are accessible from any part of the globe.

- **Easy diagnosis:**

- For diagnosing a disease, a huge chunk of prior data is required.
- The diagnosis of the disease becomes easier with the help of certain learning mechanisms along with the availability of prior data sets.

Risk in Healthcare IoT



Figure: Risk in Healthcare IoT

Risk in Healthcare IoT

• Loss of connectivity:

- A healthcare IoT system consists of different physiological sensors that sense and transmit the sensed data to a centralized unit.
- The continuous data transmission from the patient is expected in a good healthcare system.
- Intermittent connectivity may result in data loss, which may result in a life-threatening situation for the patient.
- Proper and continuous connectivity is essential in a healthcare IoT system.

• Security:

- The healthcare system must keep the data confidential.
- This data should not be accessible to any unauthorized person.
- Different persons and devices are associated with a healthcare IoT system.
- The risk of data tampering and unauthorized access is quite high.



Risk in Healthcare IoT

- **Loss of connectivity:**

- Data analytics helps a healthcare IoT system to predict the patients' condition and diagnosis of diseases.
- A huge amount of data needs to be fed into the system in order to perform accurate analytics.
- The management of a huge amount of data is a crucial task in any IoT-based system.
- In the healthcare system, errors in data may lead to misinterpretation of symptoms and lead to the wrong diagnosis of the patient.
- It is a challenging task to construct an error-free healthcare IoT architecture.

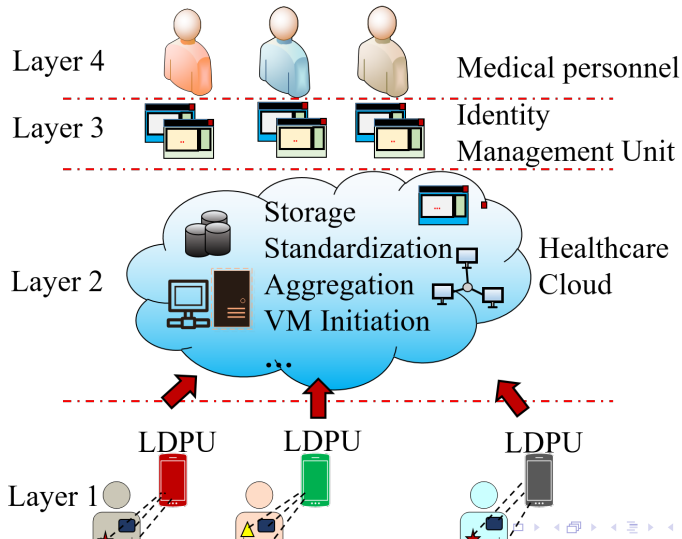
AmbuSens System

- In many developing countries, patients need to be transferred from primary-care to tertiary-care hospitals for proper diagnosis and treatment.
- During the transit, the hospitals at both ends—the referring one as well as the referred one—do not have any information about the patient's health condition during transit.
- The hospitals are unable to suggest any precautionary measures in the event of some emergency during transit.
- Many patients die during the transit due to lack of proper suggestive care by medical experts.
- To overcome these shortcomings, the Smart Wireless Applications and Networking (SWAN) Laboratory at the Indian Institute of Technology Kharagpur developed a system: AmbuSens.
- The system was primarily funded by the Ministry of Human Resource and Development (MHRD) of the Government of India.

AmbuSens System: Objectives

- Digitization and standardization of the healthcare data, which can be easily accessed by the registered hospital authorities.
- Real-time monitoring of the patients who are in transit from one hospital to another.
- At both hospitals, doctors can access the patients' health conditions.
- Accessibility by which multiple doctors can access the patient's health data at the same time.
- Provision of confidentiality to the health data of the patients in the cloud.
- In the AmbuSens system, wireless physiological sensor nodes are used.
- These sensor nodes make the system flexible and easy to use.

AmbuSens System: Architecture



AmbuSens System: Architecture

● Layer 1:

- This layer consists of multiple WBANs attached to a patient's body.
- These WBANs acquire the physiological data from the patient and transmit them to the upper layer.
- The physiological sensors are heterogeneous, that is, each of these sensors senses different parameters of the body.
- The physiological sensors require calibration for acquiring the correct data from a patient's body.
- Layer 1 takes care of the calibration of the physiological sensor nodes.
- In order to deliver the patient's physiological data from the sensor node to the LDPU, it is essential to form a proper WBAN.
- The formation of WBAN takes place by connecting multiple physiological sensor nodes to the LDPU so that the sensors can transmit the data to the LDPU, simultaneously.

AmbuSens System: Architecture

• Layer 2:

- In the AmbuSens system, cloud computing has an important role. Layer 2 is responsible for handling the cloud-related functions.
- From Layer 1, WBANs attached to the different patients deliver data to the cloud end.
- The cloud is used for the long-term analysis and storage of data in the AmbuSens system.
- The previous health records of the patients are stored in the cloud in order to perform patient-specific analysis.
- A huge volume of health data is produced by the WBANs, which are handled by the cloud with the help of big data analytics for providing real-time analysis.

AmbuSens System: Architecture

- **Layer 3:**

- In the AmbuSens system, the identity of the patients remains anonymous.
- An algorithm is designed to generate a dynamic hash value for each patient in order to keep the patient's identity anonymous.
- The AmbuSens system, at different time instants, a new hash value is generated for the patients.
- The entire hashing mechanism of the AmbuSens is performed in this layer.

- **Layer 4:** The users simply register into the system and use it as per requirement.

AmbuSens System: Hardware

● Sensors:

- Optical Pulse Sensing Probe: It senses the photoplethysmogram (PPG) signal and transmits it to a GSR expansion module.
- Electrocardiogram (ECG) unit and sensor: The ECG module used in AmbuSens is in the form of a kit, which contains ECG electrodes, biophysical 9" leads, biophysical 18" leads, alcohol swabs, and wrist strap.
- Electromyogram (EMG) sensor: This sensor is used to analyze and measure the biomechanics of the human body.
- Temperature sensor: A temperature sensor is included in the AmbuSens system, which can easily be placed on the body of the patient.
- Galvanic Skin Response (GSR) sensor: The GSR sensor is used for measuring the change in electrical characteristics of the skin.

AmbuSens System: Hardware

- **Local Data Processing Unit (LDPU):**

- In AmbuSens, all the sensors attached to the human body sense and transmit the sensed data to a centralized device, which is called an LDPU.
- The connectivity between the sensors and the LDPU follows a single-hop star topology.
- The LDPU is programmed in such a way that it can receive the physiological data from multiple sensor nodes, simultaneously.
- It transmits the data to the cloud for long-term storage and heavy processing.

- **Communication Module:**

- Each sensor node consists of a Bluetooth (IEEE 802.15.1 standard) module.
- The communication between the sensor nodes and the LDPU takes place with the help of Bluetooth, which supports a maximum communication range of 10 meters in line-of-sight.
- The LDPU delivers the data to the cloud with 3G/4G communication.

Ambusens System: Front-end

- In the AmbuSens system, three actors—doctor, paramedic/nurse, and patient—are able to participate and use the services.
- The web interface is designed as per the requirements of the actors of the system.
- Each of the actors has an option to log in and access the system.
- The confidentiality of a patient and their physiological data is important in a healthcare system.
- The system provides different scopes for data accessibility based on the category of an actor.

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