Healthcare IoT

Introduction to IoT

S. Misra, A. Mukherjee, A. Roy

Overview

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

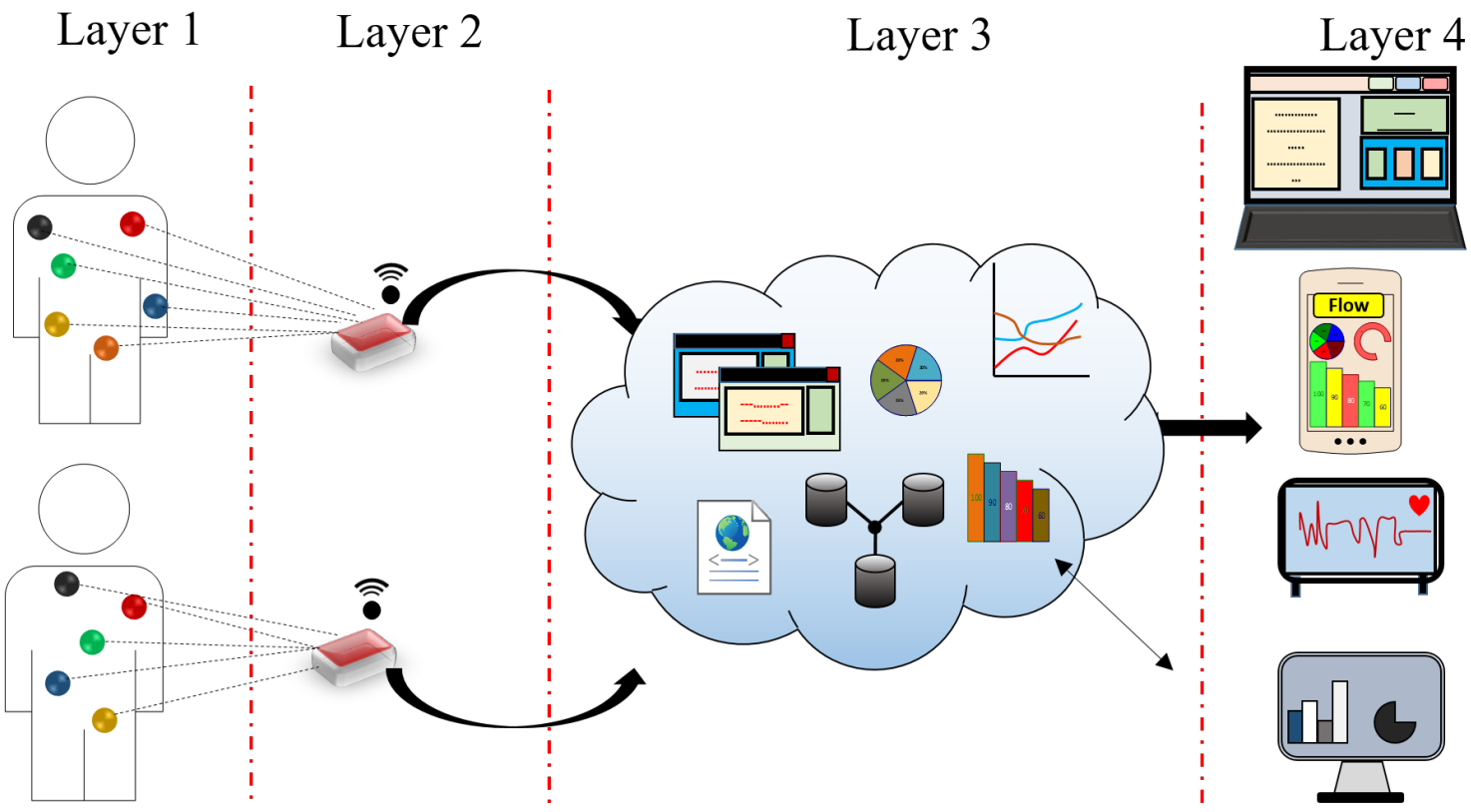


Figure: An architecture of Healthcare IoT

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

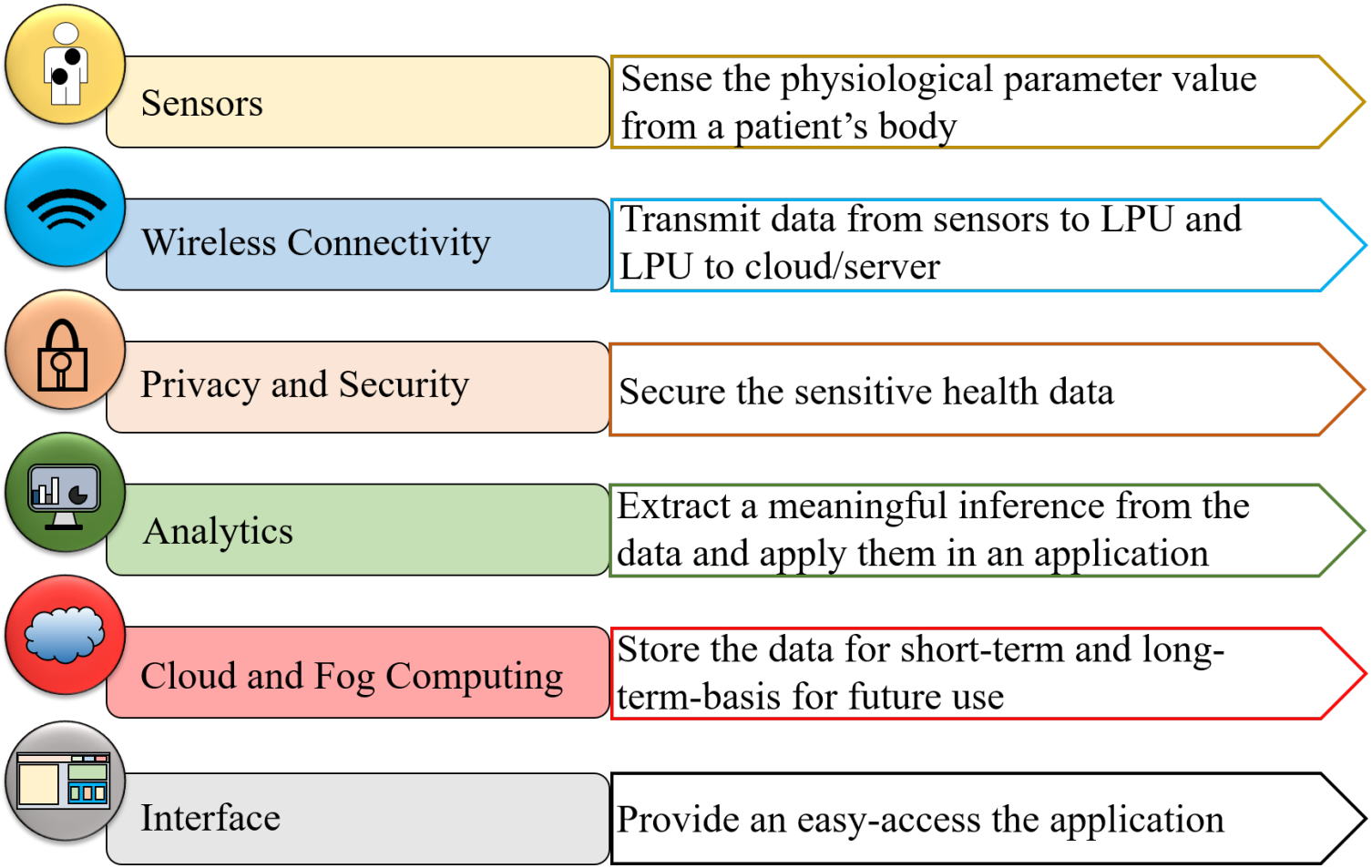


Figure: Components of Healthcare IoT

Components of Healthcare IoT

- **Sensors**:
  - Sensors are the essential part in an healthcare-IoT architecture.
  - a few of the sensors are: SpO_2, temperature, airflow, flood pressure, glocometer, 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.
  - he 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

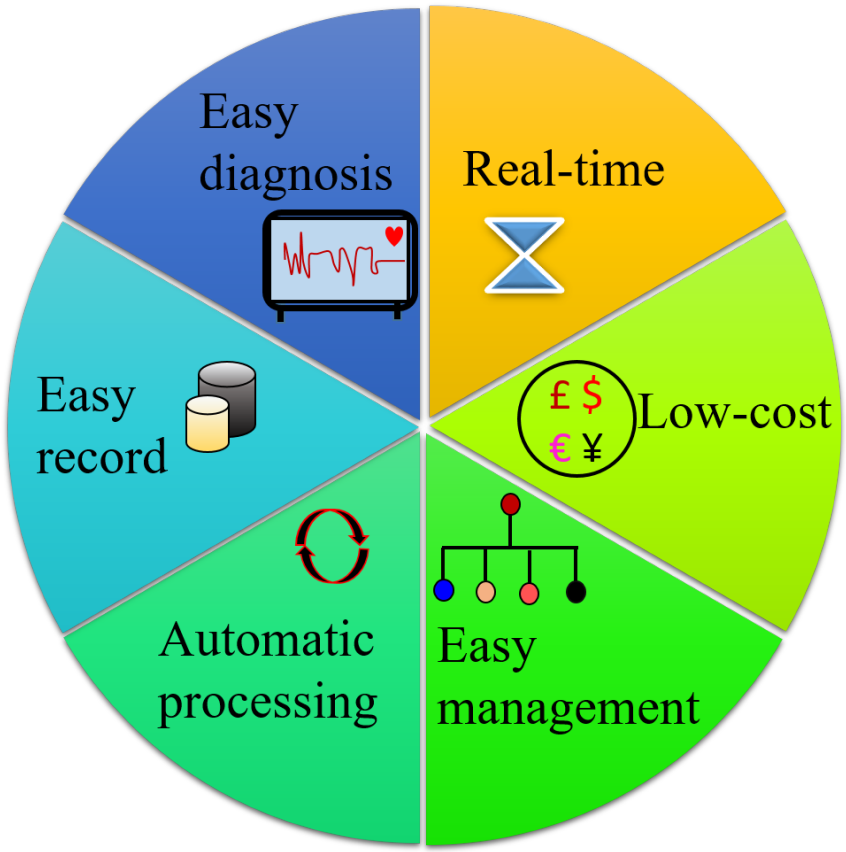


Figure: Advantages of Healthcare IoT

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

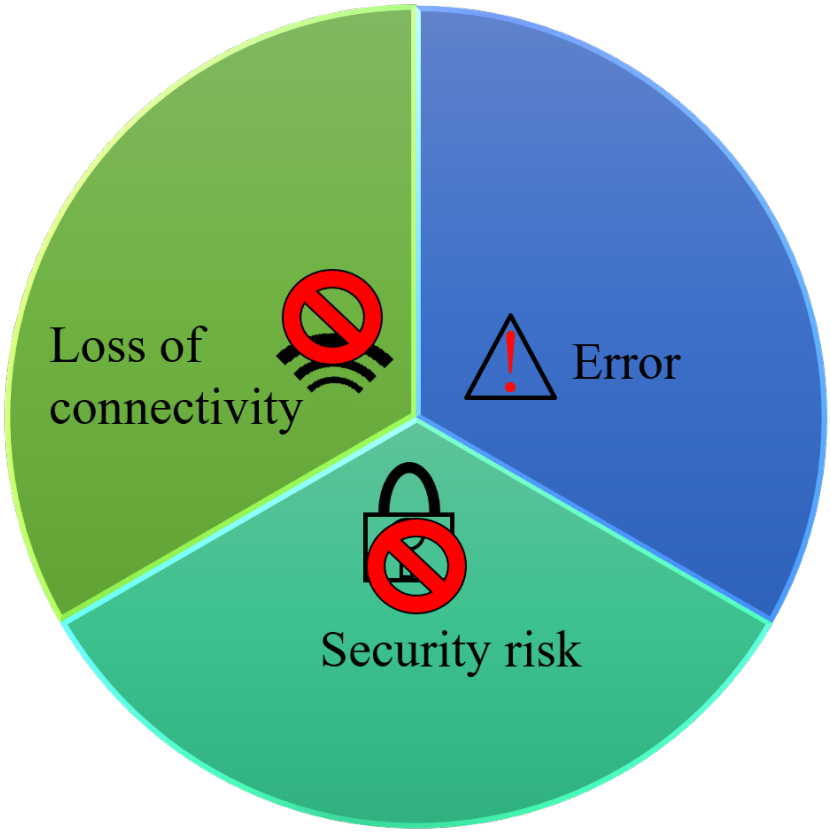


Figure: Risk in Healthcare IoT

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 authorized 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.

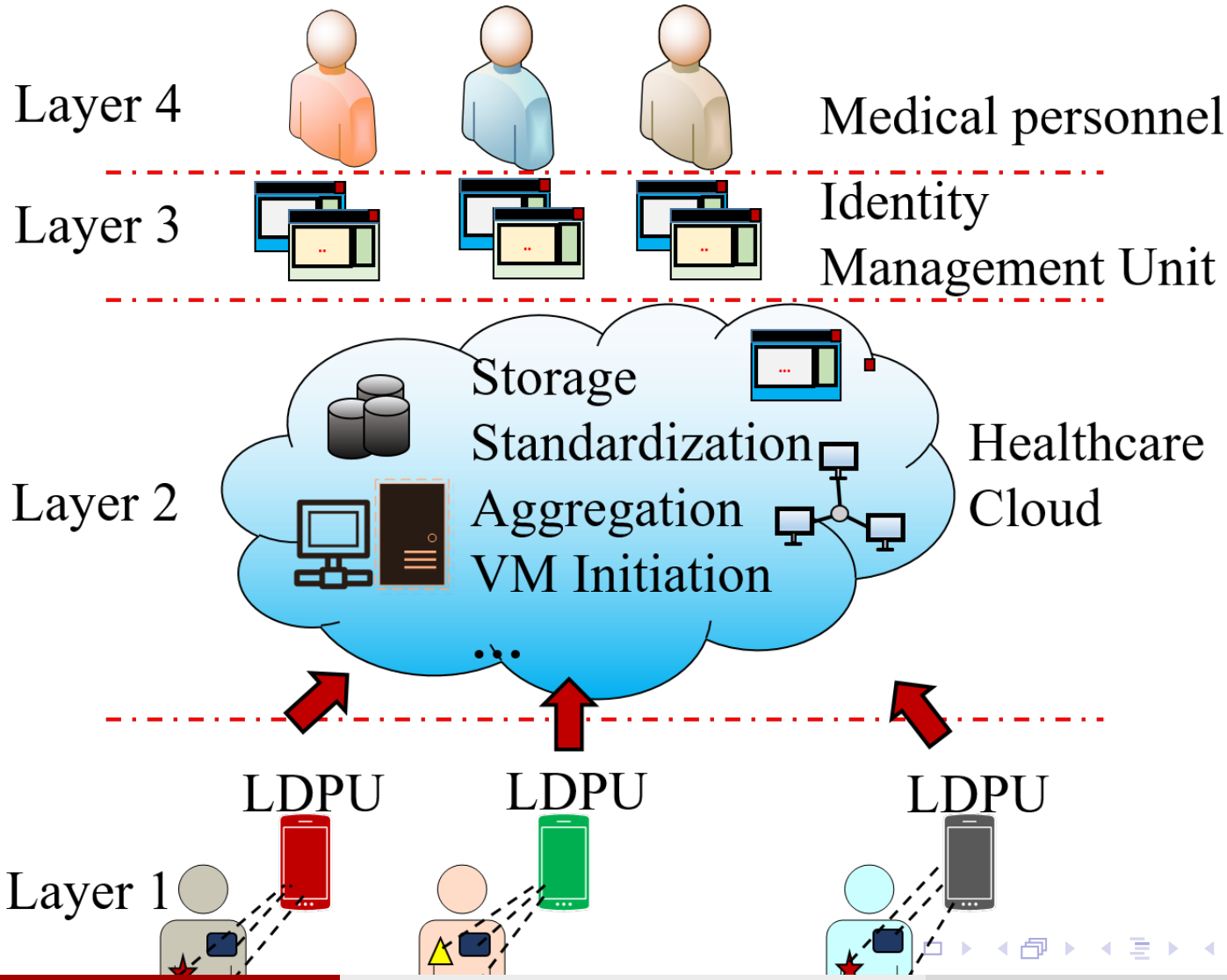
AmbuSens System

- 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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