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IoT Architecture and Applications in Healthcare Systems

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Abstract. This paper provides a detailed overview of the intelligent health system that uses the concept of the Internet of Things. Various technologies implemented together with their applications are analyzed in this paper. An increasing number of IoT devices are currently available on the market to support patients, each with different technologies are explored into this document. The paper also presents a comparison between different sensors used in the field of healthcare and their types, IoT architecture, tools and technologies used for the development of IoT systems in the field of healthcare.Introduction

1. Introduction

The Internet of Things (IoT) is an emerging technology consisting of a set of interconnected objects that connect anything, anyone, anyplace, anytime, any network, and any service with vast benefits. The IoT makes suitable solutions available for a variety of applications and services, including traffic congestion, waste management, smart cities, security, smart health, logistics, disaster services, healthcare, trade, and business control. Medical and healthcare signify one of the most striking application spaces for the IoT. IoT technology has the capability to enhance medical applications such as fitness programs, elderly care, remote health monitoring, and management of chronic diseases. Compliance with medication and treatment at home is another likely vital application. Consequently, different medical and diagnostic sensors and devices may be observed by means of objects or smart devices, establishing an essential measure of the IoT technology. The IoT has the potential to provide enhanced user understanding and improvement in the quality of human life with a minimum cost.

Due to the profound impact of IoT on the healthcare sector and its applications, the major contribution of this paper is in reviewing the following aspects with respect to IoT in healthcare:

A. IoT Architecture for smart healthcare
B. IoT in healthcare applications

2. IoT Architecture for smart healthcare

IoT architectures used in most of the IoT healthcare applications are cloud computing for long-term data processing, fog computing for short-term data processing, and wireless body area networks for providing communication between the sensors which are on or near the patient and the communication or data processing devices like routers and gateways. In this section, we will look at each one of these technologies.

2.1. Cloud computing

In simple terms, cloud computing means renting IT components, instead of purchasing them. Instead of investing heavily in databases, software and equipment, companies choose to use their computing power over the internet and pay for it as they use it. When a company chooses to "switch to the cloud", it means that its IT infrastructure is stored off-site, in a data centre that is maintained by the cloud computing service provider. The cloud provider is responsible for managing the customer's IT infrastructure, integrating applications, and developing new capabilities and functionality to keep up with market demands. For customers, cloud computing offers more availability, scalability and flexibility. Instead of spending money and resources on outdated IT systems, customers can focus on more strategic activities. Without a large investment in advance, companies can quickly access the computing resources they need and pay only for what they need.

2.1.1. Types of cloud environments. There are three different types of cloud environments: public, private, and hybrid. All this differs in terms of the volume of management required by the client, as well as the level of security provided:

Public cloud - In a public cloud, the entire computing infrastructure is located at the headquarters of the cloud environment provider, which provides these services to the customer via the Internet. The customer does not have to maintain their own IT department and can quickly add more users or computing power as needed. The cloud provider has several hosted entities that share its IT infrastructure.

Private cloud - A private cloud is used exclusively by one organization. It could be hosted in the organization's location or in the cloud provider's data center. A private cloud offers the highest level of security and control.

Hybrid cloud - As the name suggests, a hybrid cloud is a combination of public and private clouds. In general, the client will host the essential business applications on its own servers, for more security and control, while the secondary applications will be stored in the location of the cloud provider.

2.1.2. Services provided in the cloud. There are three main types of cloud services:

SaaS - Software as a Service (SaaS) is a service delivery model in which the cloud provider hosts the client's applications in its location. The client accesses its applications from the internet. Instead of paying for the maintenance of his own computing infrastructure, the customer benefits from the subscription to the service, paying as he uses. Many companies find SaaS to be the ideal solution because it allows them to become operational quickly, with the most innovative technology available. Automatic updates reduce the burden on internal resources. Customers can scale services to support fluctuating workload, adding more services or features as they grow.

PaaS - The platform as a service (PaaS) gives customers the advantage of accessing the tools for developers they need, to create and manage mobile and web applications without investing in - or maintaining - the core infrastructure. The provider hosts the infrastructure and middleware components, and the customer accesses these services through a web browser.

IaaS - Infrastructure as a Service (IaaS) allows customers to access on-demand infrastructure services via the Internet. The key advantage is that the cloud provider hosts the infrastructure components, which provide computing, storage and networking capabilities so that subscribers can run their workflows in the cloud. The cloud subscriber is usually responsible for installing, configuring, securing, and maintaining any software in the cloud infrastructure, such as the database, middleware, and application software.

Figure 1 shows a comparison of services provided in the cloud.

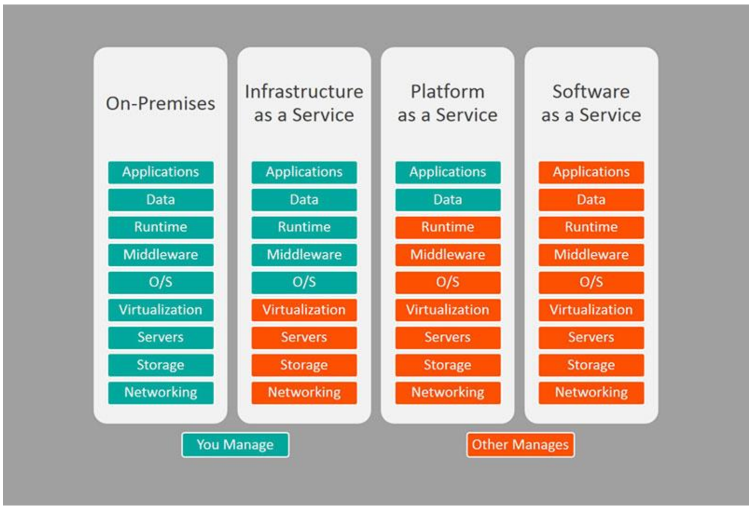

Figure 1: Comparisons between Services provided in the cloud

In the architectures of the Internet networks of Medical Things, the multitude of sensors generates a huge amount of data that can be stored and analysed using the cloud infrastructure. Cloud computing provides access to data centres, with which healthcare users can obtain useful information from data that is analysed and stored for later use. Doctors can monitor the health of a patient, whose information is collected through various sensors and stored in the cloud. Using this data, doctors may suggest appropriate medications and or advice manually or let the application do it automatically. Although the cloud offers many advantages, a challenge with it is latency. The data collected by the sensors must be transmitted via the Internet and then reach the cloud for data analysis, and again the analysed data must be sent via the Internet and then reach the doctor's devices. This process takes a significant amount of time, which may not be feasible in emergency health care providers. One way to reduce this latency is to use fog computing architectures.

2.2. Fog Computing

Through Fog Computing, intelligence and processing power can be brought where the data originates. The cloud, although it provides us with extremely easy processing, storage and networking power, is not a viable solution for analysing data generated by devices that are located far from a centralized public cloud or a datacentre. By reducing this distance as much as possible, we eliminate data processing latency. As an example, a sensor that generates a large amount of data that must be sent over a network to an entity that can analyse and store it will take much longer than if we store and analyse it somewhere close to the source, at perimeter edge (Edge Computing). This reduces latency and will allow doctors and clinicians to provide emergency medical care. Fog computing offers monitoring, pre-processing, storage and security facilities. The monitoring facility allows the node to monitor the resources and services provided. The pre-processing functionality allows the node to perform database analysis, which could be essential for providing emergency healthcare. The storage element allows data to be reproduced or segregated, and the security feature provides security services such as data privacy, data integrity, and data privacy. Due to its inherent advantages, fog computing can be used at the perception level and at the network level of the IoT layered architecture. Because the sensors detect patient data, it must be transmitted to the nearest data collection or processing node. One of the technologies that is useful for transferring data from sensors to the nearest processing node is Wireless Body Area Networks (WBAN).

2.3. Wireless body area networks (WBAN)

Wireless body area networks (WBAN) consist of wirelessly connected nodes of sensors or actuators, which are often enhanced with data processing. The nodes are placed in, on and around/off the human body forming a network for the continuous and unobtrusive monitoring of human physiological parameters like heart-rate, blood pressure, body temperature, and others. It also offers mobility, portability and flexibility to the patients. WBANs are built around the IEEE 802.15.6 and IEEE 802.15.4j, which are standardized for medical WBANs. WBANs can help to reduce healthcare costs and improve its quality by using different sensors to read the health vitals of a patient. WBANs are compatible with other wireless technologies like Wireless Local Area Networks (WLANs), Zigbee, mobile networks, Bluetooth, Wireless Personal Area Networks (WPANs), and Wireless Sensor Networks (WSNs).

3. IoT in healthcare applications

This section presents the main categories of IoT applications and related technologies in the field of healthcare, which are addressed in various technical journals:

- Real-time monitoring patients;
- Telemedicine;
- Chronic disease detection and prevention;
- Home and elderly healthcare

3.1. Real-time monitoring patients

The Real-time monitoring of various health vitals like temperature, heartbeat, blood oxygen is innovative both for hospitalized patients and non-hospitalized ambulatory patients. It is high-tech and highly informative when it comes to the development of medicine. It creates possibility for full equality among all patients in terms of reachability to diagnostic help. It creates conditions for fast reaction in urgent situations, as well as in registering rarely occurring, but life-threatening situations. The advantages of the remote monitoring are undeniable for both the health system and for the doctors and patients. This is a way to solve the problem with the lack of qualified specialists in the health system.

It may be used to monitor patients in three different situations:

- to highlight and communicate information about high risk patients, based on analysis of both acute physiology (primarily vital signs and blood profile) and factors related to age, chronic disease, frailty, functional status); and to ensure that they are monitored when subject to acute insults or any procedures;
- to allow early detection of physiological deterioration, which then allows early treatment and improved outcomes. In some situations, monitoring and rapid treatment will prevent re-admission to the ICU, while in others necessary (re)admission to the ICU will not be delayed by late recognition of deterioration;
- to provide assurance about patient status and continuing recovery when discharged from higher levels of care in the hospital (e.g., from the ICU or operating theatre recovery area to the ward; or, in some cases, from the Emergency Department to home).

3.2. Telemedicine

Telemedicine refers to the provision of healthcare to people remotely through the use of Internet facilities and communications technology (ICT). This significantly reduces the operational costs borne by medical staff and improves the efficiency of the patient's health. Providing remote medical consultation through telemedicine has recently become a common medical practice, especially for private healthcare providers. With the legislative changes in the field, teleconsultation will occupy an increasingly important segment in the field of medical consultation, especially for patients who are in areas remote from providers of specialized medical services and for which their physical presence is not required. doctor. The rapid development of IoT medical devices for monitoring the various medical parameters of the patient, will in turn lead to the increasing use of teleconsultation in the conditions in which the doctor will be able to have remote access to the medical parameters transmitted by these devices. The benefits are both for the patient who no longer has to go to the doctor except when his physical presence is necessary, but also for the providers of medical services in the army, by reducing costs and queues.

The main objectives of the patient consultation and remote monitoring system are:

- Remote medical data transfer;
- Automatic monitoring of the monitored medical parameters and alarm of the medical staff in case the limits set for each parameter are exceeded;
- Development of remote monitoring systems for intensive care units, especially in the current pandemic conditions;
- Supporting the transfer of certain medical activities from the hospital to primary medicine;

3.3. Chronic disease detection and prevention

IoT shows great promise in helping to improve the health of patients with chronic conditions like cancer, diabetes, asthma, obesity, etc. These diseases lead to depression, which is one of the most common complications of chronic illness. Combinations of remote monitoring, analytics and mobile platforms have repeatedly cut re-admissions of high risk patients with congestive heart failure (CHF) by more than half. One solution is to focus on cloud services, which uses big data technologies for data analysis, and on the Wireless Sensor Networks (WSN), which is a communication technology that supports sensors at a large scale. The system reads EEG waveforms using data collected through neurological sensors automatically, and notifications are sent to caretakers in case of any abnormal readings are detected. Notifications in case of emergency are sent through email to doctors who monitor the patients remotely. Sood and Mahajan [12] proposed a healthcare system utilizing both IoT and fog computing for detecting the chikungunya outbreak. Data from sensors is collected by a fog node and is analysed by fuzzy c-means to detect possible infection of users and generates alerts immediately for users and doctors. The patient's general and health-related sensitive data is stored in the cloud whose security is of utmost importance. Further, social network analysis is utilized to detect outbreaks across a region. Alerts are generated and notified to government and healthcare agencies in case any chikungunya outbreak is detected, which helps to improve the quality of service and curb the disease at the initial stage itself.

3.4. Home and elderly healthcare

With an increase in age, the need for medical support also grows, which may lead to unplanned visits to the doctors frequently. The recent developments in Internet-of-Things (IoT) technology can play an important role in designing suitable healthcare systems for the elderly.

IoT and related technologies can be deployed at homes for continuous monitoring of elderly patients who cannot move quickly and take more time to reach hospitals for regular or emergency healthcare services.

Yang [14] proposed a personal healthcare system leverages for wheelchair users who are alone at home. This system IoT and Wireless Body Sensor Networks (WBSNs) for providing efficient healthcare to wheelchair patients. Sensors for measuring heart rate, ECG, pressure, environment sensing nodes, and actuators are deployed around and on the patient for real-time monitoring of health. The gateway in WBAN was a mobile phone, and the communication protocols used were Zigbee and Bluetooth for gathering data from the patient and the environment. This system also addresses the mobility of the patient in a wheelchair in the sense environment sensors can track the wheelchair while it is moving from one location to another location. Yang [14] presented a new method for monitoring the health vitals of patients using IoT. The patients were equipped with multiple ECG sensors, which were used to monitor the physiological parameters of a patient. The sensors collect data and transmit that to the cloud through a wireless channel. The IoT cloud consists of powerful servers that can process and analyse the data to extract meaningful information. A web-based Graphical User Interface (GUI) was provided for visualizing the information available in the cloud.

4. Conclusions

In this paper, we provide an overview of the IoT technology in the healthcare domain. First, enabling technologies like cloud computing, fog computing, and WBANs for smart healthcare were described briefly. A specific focus was given to the key healthcare applications utilizing IoT were discussed like real-time monitoring and alerts, telemedicine, chronic disease detection and prevention, and home and elderly healthcare.

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