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Network Management and Control

e-Health Security Management

Communications Security, Data Processing Security and Patient Privacy

Coordinated by
Omessaad Hamdi

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Overview of e-Health Architectures

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1.1. Introduction

Digitization occupies a central place in all our daily activities, and the healthcare field is particularly affected by this digital evolution, which has considerably improved patient care (Hermes et al. 2020; Gupta et al. 2021). This improvement is based on two key factors: the increased involvement of patients in the management of their health, and easy access for healthcare professionals to digital tools and services.

Digitization is also improving people’s quality of life, in terms of well-being and autonomy, and is helping respond to the growing number of elderly people worldwide. The phenomenon of aging is becoming a growing concern. To enable this population to age in a secure environment with a good quality of life, while reducing costs, several approaches have been developed.

In this chapter, we focus on e-health architectures. We begin by introducing the terms used in e-health. Next, we present the services offered by e-health systems and their requirements. The final sections will focus on security and the techniques used to guarantee the required security services. Finally, we look ahead to the future of e-health.

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1.2. Definitions

1.2.1. *e-Health*

The term *e-health* refers to information and communication technologies (ICT) combined with the Internet in the service of health.

1.2.2. *Telehealth*

Telehealth is part of e-health. It refers to the use of tools for producing, transmitting, and managing digitized medical information. Telehealth encompasses telemedicine and mobile health (m-health).

1.2.3. *m-Health*

m-Health is part of telehealth. It refers to healthcare practices supported by mobile devices, such as cell phones, patient monitoring systems and other wireless devices. The term includes, among others, applications such as wellness apps. Bashshur et al. (2011) point out that m-health is the only ICT-based healthcare field that can be justified solely based on mobility.

1.2.4. *Telemedicine*

Telemedicine is part of telehealth. It refers to the digital transmission of medical information (images, recordings, etc.) for remote diagnosis, specialist advice and continuous monitoring of a patient.

There are four forms of telemedicine (2010 decree):

– Remote consultation is between a healthcare professional and a patient: It refers to the use of communication technologies to provide health consultations to patients in geographically different locations.

– Remote education is between healthcare professionals, in the absence of the patient: It consists of a remote request for advice from colleagues based on information provided by the patient.

– Remote monitoring involves remote monitoring of a patient’s health parameters, providing assessments of the patient’s state of health.

– Remote assistance occurs when a doctor remotely guides a medical act. This can take place between two healthcare professionals or between a healthcare professional and a third-party present with the patient, for example, in an emergency.

Figure 1.1 summarizes the components of telehealth.

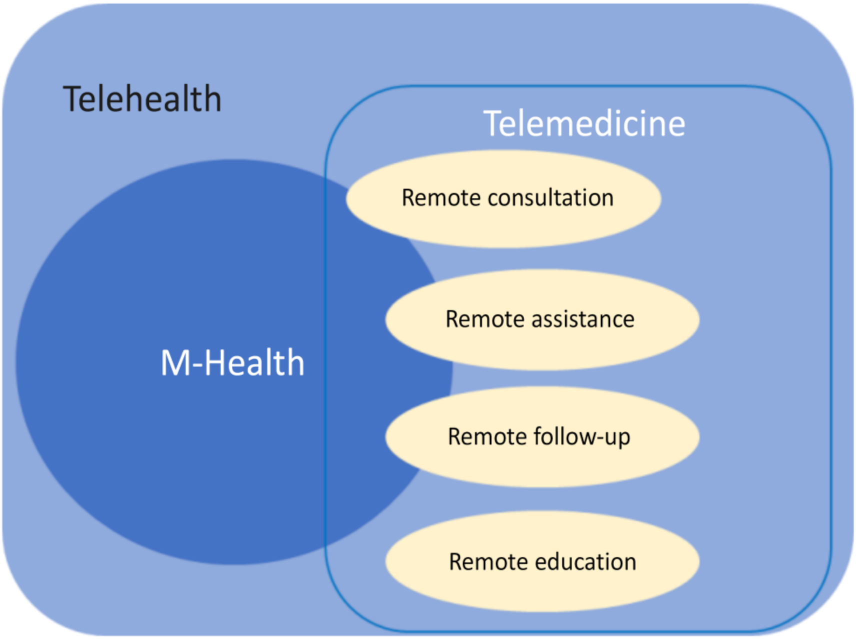

Figure 1.1. *Components of e-health*

1.3. e-Health services

e-Health offers a wide range of services designed to improve the quality of care and accessibility to medical services thanks to digital technologies:

– Cost reduction: e-health considerably reduces hospitalization and the need to keep elderly people in nursing homes. It also enables early detection of illness. Both services can significantly reduce healthcare costs (Atienza et al. 2007; Kostkova 2015).

– Social inclusion: the use of e-health technologies enables patients to remain active and independent as long as possible, enabling them to overcome their illness and/or disability without being excluded from society.

– Prevention: body and environmental data collected from sensors can be interpreted. By effectively managing these data, doctors can uncover facts and detect illness at an early stage.

– Support: e-health systems are designed to help people who are ill, elderly or disabled, and to promote their autonomy, safety and well-being. They make it possible to maintain and monitor patients at home, instead of hospitalizing them.

– Supervision: the acquisition and processing of patient data and the use of several devices enable the patient's condition to be monitored. This system is particularly interesting when it comes to high-risk patients, such as the elderly suffering from a wide range of chronic illnesses, for whom effective supervision is essential.

1.4. Requirements for e-health systems

e-Health systems must meet certain requirements if they are to be adapted by users.

In this section, we present some of these requirements:

– Acceptability: patients often wear sensors, and these are deployed in their environment to provide continuous monitoring. The sensors deployed must meet conditions of comfort and acceptability.

– Reliability: an e-health system must generate a very low false alarm rate.

– Energy autonomy: the energy autonomy of sensors plays an important role. Replacing sensor batteries is often complicated and/or costly.

– Ergonomics: it is essential that the devices and applications used are ergonomic and user-friendly to guarantee ease of use.

– Safety: devices and applications must comply with standards and regulatory requirements.

– Privacy protection: this is of paramount importance when dealing with media information, as this is sensitive data. To guarantee this protection, appropriate mechanisms must be put in place, especially in an environment where several users are involved.

Figure 1.2 summarizes the services and requirements of e-health systems.

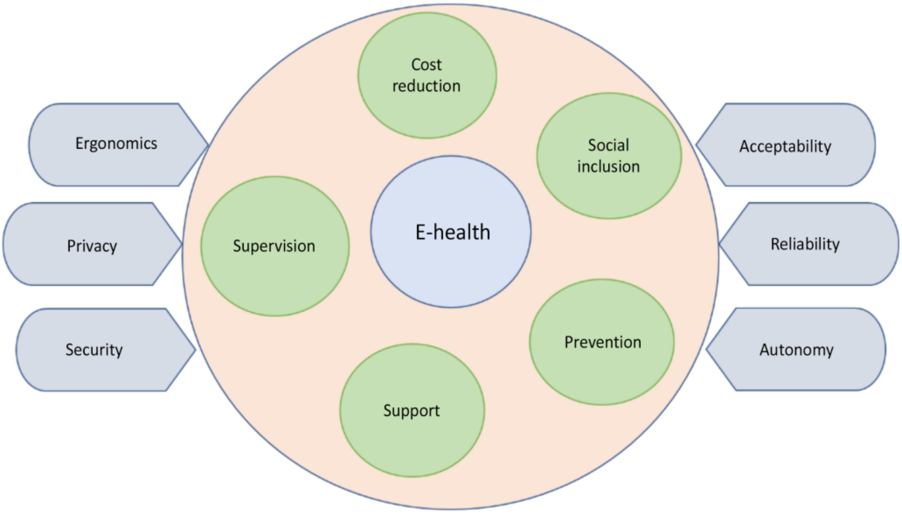

Figure 1.2. *Services and requirements for e-health systems*

1.5. e-Health system architecture

Different e-health system architectures have been developed to meet the specific needs of each project.

An architecture that summarizes most of the architectures proposed in the literature is shown in Figure 1.3.

In all e-health architectures, information flows from the patient to a medical server. Data are transferred from the sensors to a gateway that manages the sensors. Data transfer in the network can be continuous or ad hoc. Collected data are stored in a gateway, and then uploaded to a medical server.

1.5.1. *Components of an e-health architecture*

The main components of an e-health system are as follows (Hamdi et al. 2014):

– Sensors: these are devices that capture, store, process and transmit data.

– Wireless body area network (WBAN): it provides short-range wired or radio communication capability for sensors to exchange data with a gateway around an individual's body.

– Gateway: it collects vital and environmental data from sensors. It analyzes the data received from body and/or environmental measurements, compiles them and uploads them to a medical server via the network.

– Local area network (LAN): it provides wired or wireless communications for sensors to exchange data with a gateway.

– Wide area network (WAN): it provides wired or wireless (e.g. cellular) communications capability for gateways to download data to a medical server.

– e-Health systems platform: it includes servers for storing, processing and securing medical data.

Figure 1.3 gives an overview of the main components of e-health systems.

1.5.2. *Features of e-health systems*

– Data capture: this layer refers to the collection of patient data from vital signs and/or environmental sensors.

– Computation: this layer includes data analysis, management and personalization of care.

– Communication and storage: this layer covers vital signs communication, calculation and storage modules.

– Access: this layer refers to the way in which data are accessed. It often takes the form of a web portal or mobile application connected to a secure system hosted in the cloud, enabling continuous monitoring of patients' health status.

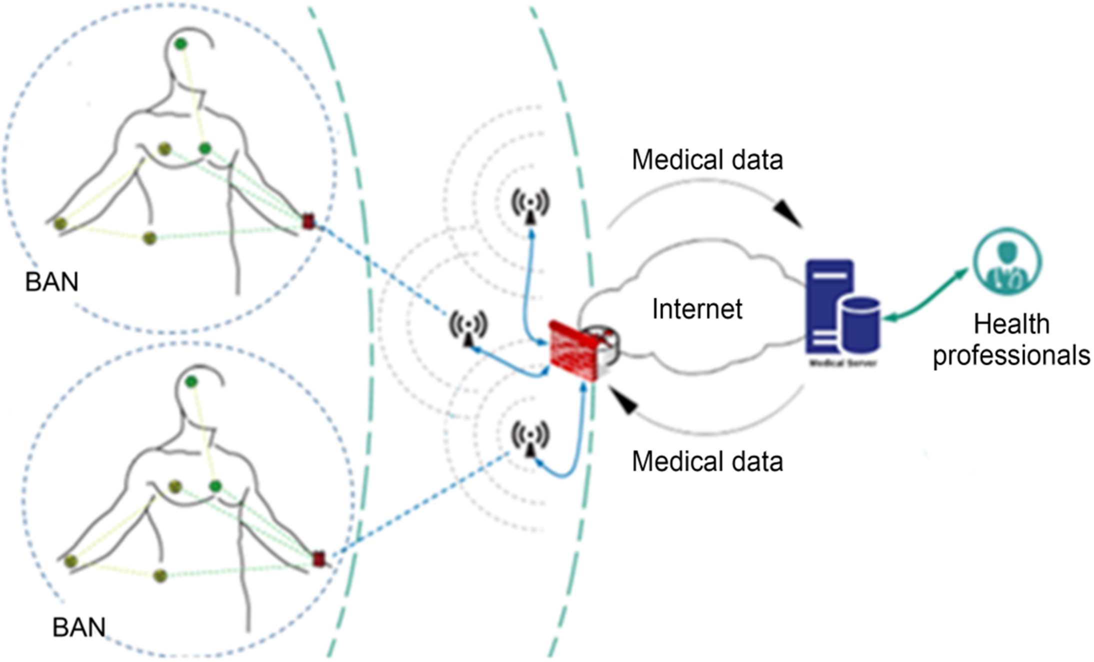

Figure 1.3. *Architecture of e-health systems (Hajar et al. 2021)*

1.6. e-Health system technologies

Connection technologies such as Bluetooth, WiFi, Internet and ZigBee play a key role in the growth of e-health applications and systems. When used in conjunction with other technologies, such as the Internet of Things (IoT), robotics, artificial intelligence (AI), cloud and Big Data, high-performance e-health systems can be created (Devedžić et al. 2021).

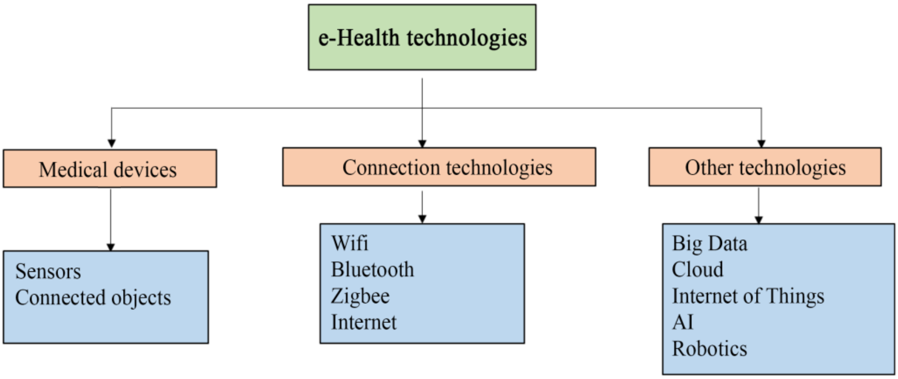

Figure 1.4. *e-Health technologies*

Figure 1.4 illustrates the main technologies used in e-health systems. These are grouped into medical devices, connection technologies and other technologies, and are detailed below.

1.6.1. *Devices*

Devices are mainly made up of sensors and connected objects, which play a key role in monitoring and ensuring the well-being of individuals, offering medical, safety and wellness services (Javaid et al. 2022).

– Sensors are devices that detect and measure specific information, such as body temperature, heart rate, blood pressure, physical activity, sleep quality and so on. These sensors collect valuable data on people's health and well-being.

– Connected objects, also known as IoT devices, are devices that can connect to the Internet and exchange data. These can include smartwatches, connected bracelets, connected scales, blood pressure monitors, thermometers and many more. These connected objects work in tandem with sensors to collect, transmit and analyze data relating to users' health and well-being (Fagroud et al. 2019; Balakrishnan et al. 2021).

Using these sensors and connected objects, medical services can provide precise monitoring of an individual's health status, detecting signs of potential health problems and enabling early intervention. Security services can use these devices to ensure the safety of the elderly or people at risk by detecting falls or monitoring unusual movements.

Several approaches have focused on the uses of sensors or connected objects in the medical field. Table 1.1 illustrates a few examples.

References	Sensor	Proposition
(Rabbani et al. 2021)	Implant	A real-time immune response monitoring system used in cancer therapy to track disease progression and provide personalized care.
(Gourob et al. 2021)	Artificial hand	Human–robot interactions to control a patient's hand gesture recognition system.
(Basaklar et al. 2021)	Smart clothing	A portable, low-energy device for personalized care without manual intervention.
(Gupta et al. 2021)	WBAN	A system for monitoring psychological parameters such as temperature and heart rate to provide real-time diagnosis.
(Hodgkiss and Djahel 2022)	WBAN	The use of biometric data to ensure strong authentication as part of an e-health system.
(Behera 2022)	Patches	Using chip-less RFID sensors to measure data and monitor vital signs in real time.

Table 1.1. *Application of sensors and connected objects in e-health systems*

1.6.2. *Connecting technologies*

In this section, we present the connection technologies used in the various components of an e-health architecture.

1.6.2.1. *ZigBee*

ZigBee is a wireless technology offering long battery life, low data rate and a secure network (Chung et al. 2013; Minakshi 2016). In addition, ZigBee is an easy network to install and configure, supports various network topologies and allows for a large number of nodes to be connected. ZigBee meets the specific requirements of WBANs.

1.6.2.2. *Bluetooth*

Bluetooth was designed for short-range wireless communications, where several Bluetooth devices form a short-range network (Negra et al. 2016). Bluetooth is widely used in WBANs.

1.6.2.3. *LPWAN*

LPWAN technology, proprietary to the LoRa (Long Range) Alliance, consists of two main elements, LoRa and the LoRaWAN protocol. This technology has been the focus of much research into e-health systems, due to its low cost, long coverage area and long sensor lifetime (Sundaram et al. 2019).

1.6.3. *Other technologies*

In recent years, e-health has become more efficient and smarter thanks to cloud technologies, Big Data, AI and robotics.

1.6.3.1. *Big Data*

The application of Big Data in the e-health sector has enabled the better exploitation of data to diagnose disease and improve quality of care.

Online e-health services and technologies generate huge volumes of data. The analysis of these data enables the transformation of conventional hypothesis-based information analysis into innovative data-driven analysis, capable of identifying links between heterogeneous information (Wang et al. 2016; Saranya et al. 2019).

1.6.3.2. *Artificial intelligence*

AI is attracting a great deal of interest due to its ability to process large quantities of data, produce accurate results and control processes to generate optimized outcomes. It is being used to aid decision-making and predict the effects of diseases, as well as longer term consequences (Kaur 2022). AI can perform processes such as logical reasoning, knowledge-based learning, drug discovery, guided surgery and advanced imagery (Sobhan et al. 2021).

1.6.3.3. *Robotics*

To ensure continuous, personalized care for patients in hospitals, or nursing homes, or homecare, solutions involving the use of robots are being proposed. These intelligent machines will help patients perform simple daily gestures, facilitate remote monitoring and communication with medical staff or relatives, administer simple therapies or be used for entertainment purposes (reading, storytelling, playing, etc.).

In addition to this type of robot, devices and control strategies for rehabilitation are being designed, such as the development of agents that can interact with the patient and provide real-time data to medical staff (Mashayekhi et al. 2020).

1.6.3.4. *Cloud*

It is known as a paradigm in which IT resources are made accessible to users. It offers many advantages, such as flexibility, cost and energy savings, resource sharing and rapid deployment. The rapid growth of e-health systems to deliver quality medical services has led to the use of cloud-based solutions. This choice makes it possible to take advantage of cloud resources to store and process large volumes of medical data.

1.6.3.5. *Internet of Things*

The IoT refers to a network of physical objects connected to the Internet and capable of communicating and exchanging data with each other and with other systems. These objects, also known as IoT devices, are equipped with sensors, software and communication technologies that enable them to collect, analyze and transmit information.

Currently, the approach used in most smart applications is to store all sensor data in the cloud and perform machine-learning processing on these data. The two worlds of IoT and cloud have seen rapid progress in the medical field. IoT can take advantage of the cloud’s almost limitless resources to compensate for its insufficient capabilities. The main drivers of IoT integration in the cloud are as follows (Farahani et al. 2018; Yang et al. 2022):

– Communication: IoT is heterogeneous by nature and relies on a variety of communication protocols. The cloud offers an efficient solution for registering, discovering and managing any type of object, regardless of communication protocol.