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Modeling an Integrated Network for Remote Patient Monitoring, Based on the Internet of Things for a More Preventive and Predictive Health System in West Africa

By M. H. Ahouandjinou[1,2], D. Medenou[1,2], L. Pecchia[3], R. C. Houessouvo[1,2], T. R. Jossou[1,2]

[1] Département de Génie Biomédical, Ecole Polytechnique d'Abomey-Calavi (Department of Biomedical Engineering, Ecole Polytechnique d'Abomey-Calavi)
[2] Laboratoire d'Electrotechnique de Télécommunications et d'Informatique Appliquée, Ecole Polytechnique d'Abomey-Calavi (Electrotechnical Laboratory of Telecommunication and Applied Informatics, Ecole Polytechnique) Université d'Abomey-Calavi, Benin (University of Abomey-Calavi, Benin)
[3] School of Engineering, University of Warwick, Coventry, CV4 7AL, UK.

ABSTRACT

Background: As a result of globalization it is important to examine health systems organization in Africa to highlight the failures and propose possible solutions in terms of patient care.

Objective: Modeling was based on the Internet of Things (IoT) an Integrated Network for Monitoring Patient Data in West African Health Systems.

Methodology: To achieve the objective three steps were followed. (1) Identification of the different characteristics of IoT-based health surveillance systems, Wireless Body Area Network (WBAN) systems, and the physiological parameters that are monitorable on a patient. (2) The modeling of the architecture of West African health systems in the form of a cloud of technocenters. (3) Cross analysis between different IoT technologies, characteristics, and identification of any functional requirements. All this was based on wireless medical sensor networks in the WBAN systems.

Result: This work has been used to model health systems in Africa as a remote monitoring network for patients.

Conclusion: The implementation of this model of monitoring networks will be a tool to support large-scale decision-making for health systems in Africa. It will enable an information database for the West African health system.

Keywords – *Modeling, Integrated Network, Internet of Things, health system, Technocentre.*

RÉSUMÉ

Contexte: Du fait de la globalisation des systèmes sanitaires, il est important d'examiner l'organisation des systèmes de santé en Afrique, sous l'angle de prise en charge des patients, pour mettre en évidence les défaillances et proposer des pistes de solutions.

Objectif: Modéliser à base de l'internet des objets (IoT) un Réseau Intégré de Monitoring de données des patients dans les systèmes sanitaire de l'Afrique de l'ouest.

Méthodologie: Pour y parvenir, trois étapes ont été suivies. (1) Le recensement les différents caractéristiques des systèmes de surveillance sanitaires basés sur IoT, des systèmes Wireless Body Area Network (WBAN) et les paramètres physiologiques monitorables sur un patient. (2) La modélisation de l'architecture des systèmes sanitaires ouest-africain sous forme d'un nuage de Technocentres. (3) L'analyse croisée entre les différentes technologies de l'IoT, les caractéristiques et les exigences fonctionnelles identifiées. Tout ceci en se basant sur des réseaux de capteurs sans fil médicaux dans les systèmes WBAN.

Résultat: Ce travail a modélisé les systèmes sanitaires d'Afrique comme réseau de monitoring de données des patients.

Conclusion: La mise en œuvre de ce modèle de réseaux de monitoring consistera un outil d'aide à la prise de décision de grande envergure pour un système sanitaire en Afrique. Il permettra au système sanitaire ouest africain de disposer d'une banque de données d'information.

Mots-clés – *Modélisation, Réseau Intégré, Internet des objets, Système de santé, Technocentre.*

INTRODUCTION

The current challenges and goals of information and communication technologies (ICTs) are to provide effective and efficient healthcare. One of the latest advances in ICTs is the Internet of Things (IoT) providing global connectivity and management of sensors, devices, users, and information. The IoT concept provides the ability to search for information about a tagged object or person by browsing Internet addresses or a database entry that matches a particular active Radio Frequency Identification (RFID) with a detection function. In the last decade, wireless medical sensors, smartphones, and other mobile devices have attracted growing interest as tools that can be used for personal healthcare, and monitoring activities and physical condition.

Some research has been done on the clinical applications of these technologies in remote healthcare surveillance architectures for long-term management, registration, and clinical access to patient physiological information

Based on these current technological advancements, it is easier to plan or schedule your physical examination, which is preceded by a period of a few days of continuous monitoring of your physiological state with less expensive wireless medical sensors. During this monitoring, wireless medical devices continually record signals correlating with the patient's important physiological parameters and sends them to a database of medical records. This scenario allows the medical professional (doctor and other) to have more information about the patient's state of health before the next appointment. Using this information and making it available to health professionals who also have access to a vast body of observational data for other individuals, the medical professional can make a better diagnosis and recommend appropriate treatment regarding early intervention and particularly effective lifestyle changes that can improve the patient's quality of health. These technological advances have a transformative impact on global health systems by dramatically reducing health costs and improving the speed and accuracy of diagnostics.

The vision presented previously from the technological point of view has been available for some years now in several sanitary systems around the world not within the African health systems and especially West Africa despite the technology already on hand. The West African health system presents for the most part the same configuration and structuring inherited from their time as colonies.

In this article, we are particularly interested in modeling an architecture that takes into account the current structure of West African health systems while implementing the healthcare surveillance architecture.

METHODOLOGY

It is very important to choose the appropriate techniques and methods in the literature search and data analysis. To ensure the integrity of the data, the means used to perform the analysis will depend on the information provided by the various search engines such as Google Scholar and scientific databases such as PubMed, Wiley, NCBI, IEEE Xplore, Scopus, and Web of Science. Google Scholar and IEEE Xplore are the two most used in our research.

The keywords used for data collection were: "IoT and Health Surveillance", "Internet of Things and Health System", "Remote Patient Monitoring with IoT". These three combinations of keywords were used on Google Scholar for the documentary review.

This review of the literature revealed that the challenges of health surveillance are very topical. Most of the work has not been in favor of a particular health system from a country, region, or area depending on its configuration but has shown there is an opportunity presented by technological progress to aid in monitoring several aspects of a patient's state of health including managing patient data,[1,2] WBAN networks and architecture, security in health data management systems and many other areas.[3,4] All of militated in favor of the results obtained.

RELATED WORK

A total of 128 articles between 2010 and 2019 were found, with an emphasis on research between 2014 and 2016. The 128 articles were then sorted to rank those that best met the criteria of research. In the end, 34 articles were excluded and 94 were included as the subject of our study. The results are shown in Table 1.

TABLE 1.

Year	Number of articles found per year	Number of articles excluded per year
2010	3	0
2011	4	0
2012	3	1
2013	3	0
2014	27	2
2015	37	1
2016	29	18
2017	19	12
2018	2	0
2019	1	0
TOTAL	**128**	**34**

The IoT is of great potential interest for medical applications and healthcare. Many technologies are related to IoT. Technologies such as wireless medical body sensors, advanced healthcare systems, wearable sensors, cloud-based platform for wireless transfer, storage, and display of clinical data (see Table 2, in appendix) carry particular interest. In conclusion, we note that the challenges of any medical surveillance system lie in the proper design of the network architecture. In light of this, our work aims to model an integrated patient monitoring network (RIMP) in the West African health system, based on the IoT. This article presents the methodology adopted for the work, the results obtained, and the analysis, discussion, and perspectives envisaged.

RESULTS

Despite the specificities observed in each country, the health pyramid of West African countries generally includes first-level structures (dispensaries, health huts, etc.), so-called reference structures (general hospital), specialized structures (dedicated to a disability or illness), and university hospitals. In principle, so-called primary health care is the foundation of health systems, whose national health development programs (PNDS) stipulate that the structures responsible for it must cover n thousands of inhabitants in a given geographical area [Org]. Such a health pyramid has enormous advantages for mastering health data from scratch when it comes to diagnosis and care, so it has a modern remote monitoring architecture. For better monitoring of patients in African health systems, we propose an architecture integrating the different levels of each health system facilitated by a cloud of technocentres from remote monitoring networks. This would include surveillance centers allowing centralized accessible health information.

IoT Architecture of an Integrated Patient Monitoring Network

Several physiological parameters can be monitored Sixteen different groups of physiological parameters can be monitored using IoT sensors placed at 17 different locations on the patient's body.5 Figure 1 shows an outline of some of the physiological parameters ([A] blood pressure, [B] electrocardiogram, [C] pulse oximeter, [D] electromyogram, [E] inertia).

The IoT architecture of the Integrated Patient Monitoring Network shows the interaction of the different IoT components of our system and its network and computer technologies. The different IoTs in this architecture include intelligent medical sensors of different sizes and types that monitor patient health parameters and also process and record the raw data from the sensors. The transceiver modules of the medical sensors communicate with the base stations via a wireless interface. The most powerful base stations will act as data aggregators, well nodes, or gateways to servers. The different IoT Gateways work with the different types of devices and associated network protocols to provide overall connectivity.

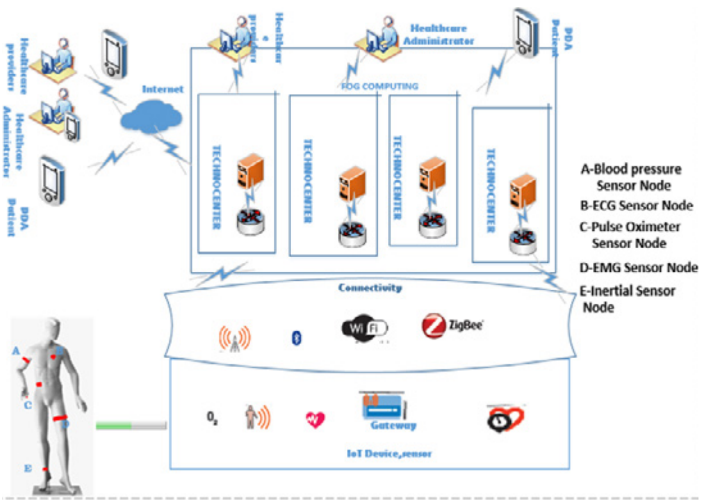

FIGURE 1. IoT architecture of an integrated patient monitoring network.

The integrated IoT patient monitoring architecture is made up of several levels. The first level is the IoT sensor level, which fits the patient with several sensors to measure the desired physiological parameters (EMG, ECG, blood pressure, heart rate...). The second level of the architecture shows the connectivity elements. This level shows the symbols of the different communication networks used to route the data collected by the sensors to the treatment centers. Depending on the application, wifi, Bluetooth, or zigBee can be used to route measured physiological data to the sensor nodes and then to the treatment centers called here technocenters. Technocenters are data processing centers available at all levels of the health system including those in village health centers, district health centers, communal health centers, departments, and zones at the national level. These technocentres are interconnected through a network. To allow different requests from users of the network including healthcare providers, the healthcare administrator and the patients, we are implementing a DNS service so the users can successfully request the data from the closest server with a different zone access from the internal and external users of the network. The patient's personal digital devices (PDAs) will allow healthcare providers to capitalize on the capabilities in smartphones that patients already carry. Since these smartphones can be connected to the Internet through their GSM network, it would be enough to install eHealth applications allowing the patient's phones to receive and send the necessary information to and from the treatment center. Recommendations could easily be made for these smartphones regarding their specific characteristics as needed.

Functional Architecture of the Hospital Platform

We propose the functional architecture of the hospital's platform detailed in Figure 2 to enable the West African health system to monitor patients effectively.

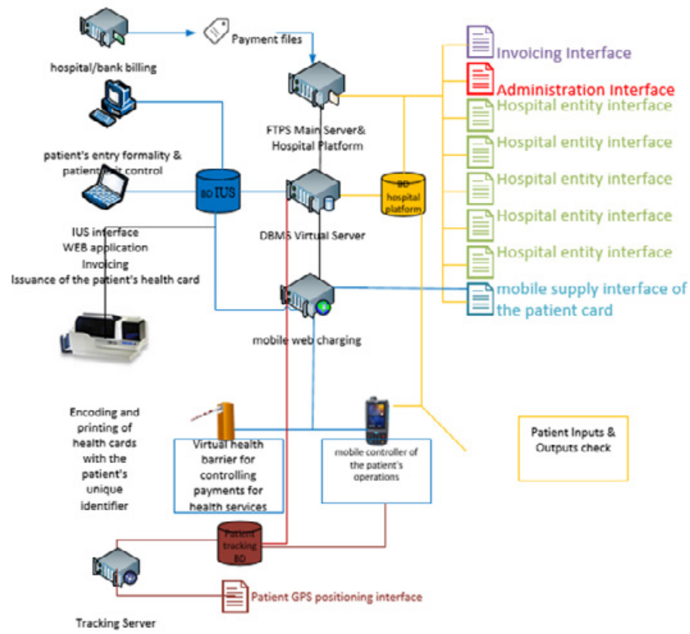

FIGURE 2. Functional architecture of the hospital platform.

The functional architecture of the hospital platform that we propose takes into account several aspects for the monitoring and the traceability of the patient inside and outside the hospital. We propose the use of the Country Unique Patient Health Identification (CIUS-P) for patients in the West African health system. This will allow a patient in Benin or any other African country to have a unique identity card from his country of origin. This new health card will make it possible for any hospital in the African health system to have access to the patient file and will make it possible to know any health antecedent of a patient wherever they are. This multifunctional health card will also allow the payment of the patient's health services since it integrates a virtual account. The patient's localization feature will be integrated with the patient's CISU-P card to find it through GPS on an integrated platform. This feature will allow a patient's hospitalization to be known in real time. More interesting in this architecture is that the position of the patient is known even outside of the hospital in real time as long as they have the health card on them. The architecture of the platform integrates all the entities (surgery, medicine, emergency, laboratory ...) of the hospital so that the patient record can be seen by all (except for any access restrictions added as required).

DISCUSSION

Faced with the challenges of the West African health systems and in particular, the Beninese health system, which are (i) to provide quality health care to a growing population, (ii) to optimize the availability of health care personnel, and (iii) to utilize patient health data in a more predictive health system; we proposed in this work an integrated IoT architecture for patient monitoring and the functional architecture of the hospital platform whose implementation could revolutionize the West African health systems in general and Benin in particular. The implementation of this solution would go through several stages: first, choosing a health zone in Benin that has village, district, and communal health centers, departmental hospitals, and university hospitals. Once the expected positive results in this first zone were confirmed we would consider the extension of the architecture to other health zones.

Constraints of WBAN networks (i.e., scalability, quality of service [QoS], energy consumption, wireless technology) will have to be taken into account.[6,7] There is a large amount of work in the literature that deals with the application of WBANs in a healthcare setting.[8,9] This research outlines the characteristics and requirements of the medical application of WBANs as well as the characteristics and design factors.

Another consideration in the design of WBAN networks involves security requirements (WBAN and traditional networks have the same security requirements).[10,11] However, this does not present a functional issue for the architecture of the hospital platform, which is the focus of our work. Moreover, we can see that the multitude of work in the literature does not consider a global architecture of a health system but often speaks of service architecture, while at the security level the security of patient and billing data will be considered when implementing the proposed solutions. Security threats or attacks, such as modifying and eavesdropping on medical data, detecting and locating activities, and hacking into security systems and alarms, can occur and must be taken into account.[10,11] Also, data flow and network capacity are also among the parameters that have an impact on system performance. In this scenario, the choice of high-speed wireless technology offers advantages to meet the scalability of the network and increase the number of people being monitored. On the other hand, other technologies allow for lower power consumption, but have higher delays (production) and/or lower transfer rates. The technology chosen will therefore be a compromise between throughput and energy consumption. As several technologies are used in patient monitoring architectures to provide multiple services[9,12] we started to identify all technologies used within the different services. On this basis, our work extends this knowledge by proposing the essential characteristics of any monitoring system adapted to the Beninese health system as well as the different possible positions where the sensors could be placed on a patient's body as mentioned in our previous work.[5,13]

CONCLUSION

In this work, we modeled West African health systems by proposing an IoT architecture for patient monitoring and the functional architecture of the hospital platform. This model incorporates the CIUS-P which allows the patient information to be available in all areas across the West African health system. This architecture will allow the West African health system to respond to health challenges and provide data for better health forecasting. Future work will allow this architecture to be implemented in Benin to analyze its effect and any limitations. The implementation will occur through the choice of a health zone in Benin and take advantage of the unique identification database of the population set up, the project to interconnect all the health systems in Benin, the national data center, and the availability of the GPRS network of GSM networks in the various health zones in Benin.

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APPENDIX

TABLE 2.

N°	Ref.	Aspect covered
1	[14]	Put in place a solution to address drug issues based on IoT technologies like smartphones and the Web to support ubiquitous access, 6LoWPAN technology for ubiquitous patient data collection, sensors and hospitals, RFID / NFC (Near Field Communication) and barcode identification technologies.
2	[15]	Propose IoT Communication Framework as Primary Tool for Healthcare Applications Spread Around the World. They presented the IoT protocol stack and the benefits it brings to health care scenarios.
3	[16]	Proposed a cooperative approach of IoT to improve the monitoring and control the health of rural and poor human health parameters.
4	[17]	Analyze the possibility and related issues of providing advanced services for human health management in the real world of medical technology on IoT.
5	[18]	Shows an overview of the challenges and opportunities of IoT.
6	[19]	Present a prototype of a cloud-based system, compliant with the IoT concept. Including those related to the authentication of entities and data confidentiality. The proposed system manages the data collected by the portable sensors and transmitted them to a gateway using cloud infrastructure techniques.
7	[20]	Worked on interoperability and security issues related to the limitations of devices used in the IoT, preventing their proper use in health systems.
8	[21]	Presents with a cloud-centric vision for the global implementation of the IoT. The authors' work allowed to make a cloud implementation using Aneka, based on the interaction of private and public Clouds
9	[22]	Showed how RFID, multi-agent technologies and the IoT can be used to allow people access to affordable and quality health services. The authors show that using the IoT and multi-agent technologies can reduce medical errors, improve patient safety, and optimize healthcare processes.
10	[23]	Presents an ontology-based design methodology for intelligent reeducation systems in IoT.
11	[24]	Worked on home health services based on the IoT. They proposed a smart home platform, named iHome Health-IoT.
12	[25]	Presented a mobile home health system (mHealth) for wheelchair users, based on emerging technologies of the IoT. The authors focused on the proposed system architecture and the design of Wireless Body Sensor Networks (WBSN).
13	[26]	Review the current research on the IoT, generic key technologies, key IoT applications in industries, and identify trends and challenges in research.
14	[27]	Structured in this work a review of the state of the art on IoT by bringing out its history, the different technologies of IoT and its different applications.
15	[28]	Present a novel architecture model for IoT with the help of Semantic Fusion Model (SFM).
16	[29]	Present H3IoT, a new architectural framework for a home health center based on the Internet of Things, which aims to monitor the health of elderly people at home.
17		
	[30]	Present the integrated services that are part of a ubiquitous health system that enables automated and intelligent monitoring and utilizing IP and Internet connectivity for end-to-end communication.
18	[31]	Present the definitions, architecture, fundamental technologies, and applications of IoT. Various definitions of IoT are introduced, emerging techniques for the implementation of IoT are discussed.

N°	Ref.	Aspect covered
19	[32]	Worked on self-care through IoT through personal health devices. By introducing the collaborative protocol that transfers risk factors between IoT personal health devices.
20	[33]	Worked on data security and confidentiality in the healthcare sector given the increasing data growth in this sector.
21	[34]	Examined the applications of IoT in personalized health care to obtain excellent health care at affordable costs through detection and wireless techniques.
22	[35]	Worked on the concept, the architectural components of the wearable IoT because of their detection and communication capabilities.
23	[36]	Worked on the energy efficiency in the architectures of the IoT in exploiting the advantages related to the standard POE (Power over Ethernet).
24	[37]	Worked on an IoT architecture and system implementation for health applications to offer a simple and economical way to analyze and monitor health data in real time.
25	[38]	Worked on the security and confidentiality of tracking physical conditions through portable connected objects.
26	[39]	Have worked on the different opportunities and challenges of IoT.
27	[40]	Worked on the development of a general architecture for IoT-based health care systems to ensure and increase patient safety, quality of life, and other health care activities.
28	[41]	Worked on the use of RFID for personal health care based on the IoT.
29	[42]	Secure medical data transmission model in health systems based on IoT.
30	[43]	IoT and Big Data for intelligent healthcare, individualized telehealth to enable healthier lifestyles.
31	[44]	Operation of the gateway between the network of medical sensors and the Internet in a health care surveillance system to offer several services.
32	[45]	A semantic interoperability model for Big Data in the IoT.
33	[46]	IoT architecture to identify and control the Chikungunya virus.
34	[47]	a reliable IoT architecture based on oneM2M for personal healthcare devices
35	[48]	IoT-based healthcare surveillance architecture to move to proactive and preventive healthcare.
36	[49]	WBAN sanl fil <Au: Please clarify sanl fil> network based on IoT for healthcare.
37	[50]	Smart city cloud platform with IoT
38	[51]	Three-level IoT architecture composed of the device layer, the fog layer, and the cloud layer.
39	[52]	A new architecture for health services based on ISO / IEEE 11073 on the IoT platform. The proposed architecture meets oneM2M and ISO / IEEE 11073. Standards with a stack of protocols for constrained healthcare devices on the BLE network.
40	[53]	A cooperative key establishment protocol to create a secure end-to-end connection for resource-limited sensor nodes with any remote server or entity. Security analysis and performance appraisals prove to be a considerable improvement in security as well as protocol resilience against known attacks and security breaches.
441	[54]	A cloud-integrated Health IoT monitoring framework, where health data is watermarked before being sent to the cloud for secure, high-quality, health monitoring.
42	[55]	A new user-oriented world of IoT. In this world, users are empowered by their ability to control access to the data that has been knowingly or unknowingly generated and belongs to them. This data can be requested by other users and organizations to be analyzed collectively and potentially bring value to society.

N°	Ref.	Aspect covered
43	[56]	security and confidentiality issues in health applications using the body sensor network (BSN). They proposed an IoT-based secure health system using BSN, called BSN-Care, which can effectively meet various security requirements of the BSN-based health system.
44	[57]	An IoT system capable of improving assistance requests and the detection of anomalies in an ALF <AU: Please expand ALF> using portable devices. With this healthcare support system, caregivers can be automatically alerted to potentially dangerous situations that occur to residents while they are out of sight. The system design focused mainly on portability and ubiquity.
45	[58]	An IoT H2U predictive health care system to provide early treatment and detect danger signs early enough to avoid the need for hospitalization. Hospital stay is minimized and doctors and nurses can be connected and monitor patients based on the report generated by the sensors in real time and daily clinical updates by the patient on the base server of data. Interaction via this IoT system is quite profitable and guarantees a higher level of security in terms of communication.
46	[59]	Exploited the concept of self-awareness to create a personalized EWS Alert Score System<AU: Please expand EWS> based on the IoT. The system is designed to be adaptive in various situations and to be able to be automatically personalized according to the needs of the patient.
47	[60]	The use of the Internet of Things for the efficiency of the health system by exploring the challenges of these systems. Their work provided an architecture / methodology for extracting information from health care data.
48	[61]	The use of the Internet of Things for the efficiency of the health system by exploring the challenges of these systems. Their work provided an architecture / methodology for extracting information from healthcare data.
49	[62]	Implementation of a data aggregation solution for interdisciplinary healthcare research after comparing the different existing IoT applications which focus mostly on the physical condition of people. They proposed the architecture for monitoring healthcare with multiple functions for the acquisition of bio-signals (EEG, EMG, ECG)
50	[63]	Computer haze in the IoT in health surveillance systems by exploiting the concept of calculating fog with intelligent gateways applied to ECG signals.
51	[64]	The security of private information in a health care information system using the Internet of Things. The authors have implemented an algorithm to secure health data. a prototype based on both software and hardware has also been implemented.
52	[65]	Implementing a system for continuous monitoring of the EEG and other vital parameters using algorithms based on Raspberry pi. The Raspberry Pi is a small computer with an integrated microprocessor card.
53	[66]	The different opportunities and benefits of using the IoT in remote health monitoring. the use of portable sensors is necessary to record data in various environments for health surveillance.
54	[67]	The security requirements of RFID authentication schemes for Internet of Things-based healthcare surveillance systems. The authors presented the overall architecture of the RFID-based authentication system and their requirements
55	[68]	The security of IoT-based health systems. They proposed a communication architecture based on sensors in health service systems integrating a secure authentication scheme and a protocol for the coexistence of multiple health systems operating under the technology of the IoT.
56	[69]	implementation of the IoT in a hospital system using ZigBee which is a mesh protocol.
57	[70]	The classification and structuring of IoT applications in healthcare. The results of the authors' work show that applications in the health of the IoT can be classified into three categories of systems.
58	[71]	A new approach to the IoT with devices compatible with IoT thanks to the XMPP protocol.

N°	Ref.	Aspect covered
59	[72]	Share the use of medical equipment used in a health service or office through the IoT. They proposed a personalized health service model that can be used in family or public offices.
60	[73]	Health self-management systems for support. They proposed the establishment of a personal health monitoring system adapted to the needs of the user (Do-It-Yourself).
61	[74]	Medical data capture and confidentiality architectures. The work allowed the authors to develop an architecture of authentication and authorization that is secure and efficient for healthcare based on IoT while taking into account the constraints of the resources of medical sensors.
62	[75]	Big Data technologies, IoT and complex event processing (CEP) and their importance in the healthcare system revolution.
63	[76]	A remote health monitoring system based on IoT, after identifying the main network requirements and studying the CoAP, MQTT and HTTP protocols.
64	[77]	Smart gateways in e-health which is a transition point between the sensor and Internet networks. They proposed an intelligent e-health gateway between the sensor and the Internet for remote monitoring of health care.
65	[78]	An intelligent collaborative security model to minimize security risks; and propose how different innovations such as big data, ambient intelligence and portable devices can be used in healthcare establishments.
66	[79]	IT fog which is a new architecture for migrating certain tasks from the data center to the periphery of the server. The authors present the characteristics of fog computing and the services it can provide in the health system by ensuring low latency of applications in health services.
67	[80]	The IoT remote healthcare monitoring system that provides patient status via a web browser using OS Contiki with the 6LoWPAN protocol.