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IoT-based Applications for Healthcare in Brazil: A Brief Review

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Abstract: Internet of Things (IoT) has emerging a solution with tremendous potential for healthcare solutions. This paper presents a review of the related literature and market available solutions on IoT for healthcare. After a market and scientific publications outlook it will be discussed the development stage of this technology in Brazil. This work is very useful for researchers, healthcare providers, and technology professionals that are interested to develop IoT solutions for healthcare. It was observed that IoT technologies present a strong potential to Brazil as well as considered worldwide, however, the country should continue investing on them to reduce the gap to the world technology leaders.

Keywords: Internet of Things; IoT; Telehealth; Healthcare; Medical Devices.

1. Introduction

Internet of Things (IoT) is the next step of current Internet being considered the enabler of the next generation Internet; this evolution focuses on connecting any object (a "thing") to the Internet. IoT allows people to remotely access and control things, such as medical devices, agro-machines, self-driving cars, and so on. In industry or academic/research scope, it generates new possibilities allowing the development of a vast number of devices and applications. Today, IoT stills being more a vision than a real solution; therefore, it has lots of challenges to overcome [1]. IoT is a big tendency for the technologies that will emerge in the upcoming years. It is predicted the impact caused by this technology and it is expected that it will be so significant and may embrace any industry segmentation. Big companies are already exploring new possibilities that IoT brings to the industry as well. Some of the key IoT trends are smart homes, grid, transportation, agriculture, industry automation, education, security, and healthcare. In fact, smart healthcare is a very promising topic to explore, representing more than 20% of the IoT market [2]. An illustration of an IoT-based solution for healthcare is presented in Figure 1.

Many medical applications receive a new improvement and offer possibilities in consequence of the IoT revolution, such as smart remote health monitoring, fitness programs, chronic diseases, and elderly care, including smart assisted living and well-being [3]. For healthcare providers, it is a great opportunity to increase patients' quality of life, offering new services, enriching the user's experience, and reducing costs [3].

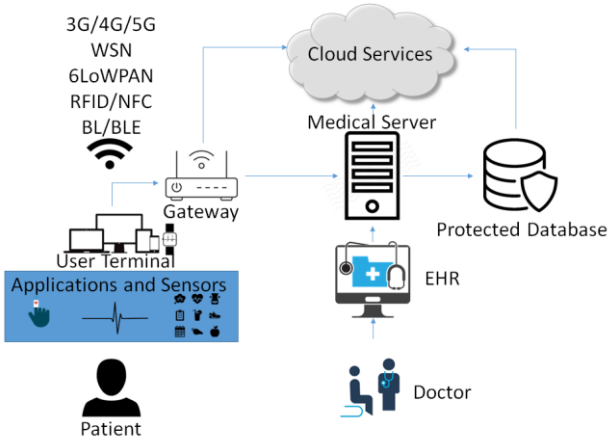

Figure 1: Illustration of an IoT-based solution for healthcare.

Globally, it is expected that IoT Healthcare Market rounds US$ 158.07 Billion by 2022 [4]. Moreover, Brazil is the 4th country with the highest number of Internet users [5]. According to Cisco, Brazil will represent 1/3 of the US$ 860M market that Latin America will represent for IoT. Tata Consultancy Services Limited mentions that Brazilian companies are going to invest US$ 79,9M more than other emergent countries, such as India and Mexico [6].

Considering the relevance of health services and applications within the context of IoT, this work aims to analyze the IoT on the healthcare vertical, in Brazil. This work focuses on IoT applications and services that attained the stage of a real prototype or are already available in the market. After a market and scientific publications outlook it will be discussed the stage of development of this technology in Brazil.

The remainder of this paper is organized as follows. A brief review of IoT for healthcare is elaborated in Section 2. Section 3 shows real products available in the IoT market for healthcare in Brazil. A discussion considering research solutions and products is presented in Section 4. Finally, the paper is concluded on Section 5.

2. Related Work

This section reviews the related literature published in the last few years on IoT for healthcare in Brazil.

Remote healthcare monitoring - Remote healthcare monitoring can be defined as a solution that

can collect and transmit physiologic data from patients remotely. Its basic architecture includes user interfaces (using smartphones, computers, or tablets), data collectors (any kind of biosensors), and Internet connectivity [3].

In [7], the author discussed about a network structure used for patients monitoring in rural and low population density areas, which is based on IoT technology. The collected data reaches the closest healthcare facility where it will be processed and presented to healthcare providers. It enables healthcare providers to analyze data from their patients in remote areas and, if necessary, it requests emergency medical assistance to the location.

The prototype proposed in [8] monitors patients remotely. The supervisor system receives preprocessed data and presents the collected data in a simple and cohesive manner. With low-cost technologies, the system showed great benefits for users' quality of life.

A low-cost embedded system developed to measure blood pressure is described in [9]. The data collected is stored and presented in a Webpage, hosted at the device itself. This information is available to healthcare providers through the Internet.

A data communication protocol integrating IoT technologies, mobile computing, and cloud storage is presented in [10]. This work aims to acquire, transmit, store, and deliver on-demand visualization of biomedical signals.

EcoHealth is a middleware platform for IoT capable of support a connection between patients, doctors, and devices [11]. This Web-based platform enables the data management, to simplify and to standardize the development of IoT applications minimizing compatibility and interoperability problems between heterogeneous devices.

Healthcare Solutions using Smartphones – It considers any application designed for smartphones or tablets, which helps physicians in patients diagnose, finding drug references, providing medical education, and clinical communication. Two examples of these applications are presented below.

A project aiming to evaluate portable and mobile devices able to access medical facilities information is discussed in [12]. In [13], text messages are automatically sent to a patient 24 hours before the scheduled appointment, as a reminder for an appointment with a doctor.

Ambient Assisted Living – Ambient assisted living (AAL) is a service that uses ICT technologies, including IoT, to provide healthcare for elderly and incapacitated individuals. AAL solutions proposes to extend the users' independent life in their place of living in a convenient and safely way. A common use of AAL is the connection between the user and smart objects, such as body and motion sensors. Providing greater autonomy to the user, AAL solutions increase the individuals' confidence and stimulate a more active life [3].

A cloud-based IoT software infrastructure for AAL is described in [14]. M-hub is a middleware service for mobile devices. It automatically discovers several smart objects through short-range, using wireless personal area networks (WPANs), and connects them to the Internet.

An approach for fall detection for elderly people is described and evaluated in [15]. It is a non-intrusive system used to analyze activities, such as running, walking, sitting down, standing up, laying down, and falling. Paradigms of artificial intelligence were applied to classify the movements.

Wearables – Wearable technologies can be defined as sensorial devices capable of capture physiological patient's signals, such as body temperature, heart rate, blood pressure, etc., integrated in regular clothes [16].

Vital signs monitoring system is proposed in [17]. A set of sensors attached to the patient's clothes is connected to a microcontroller allowing supervision. The monitoring system is designed to be used by elderly patients in rest homes. A system capable of monitoring the user's physical activities is proposed in [18].

3. Available Solutions Proposed by Industry

This section presents some Brazilian IoT-based healthcare solutions found in the market. "*Dev Tecnologia*" includes a cloud platform for device management and connectivity that may be included in the end-to-end IoT solutions offered by the company [19]. "*Gemed Oncologia*" allows remote access to electronic health records via smartphones and tablets and also notifies appointments in advance to the patient [20]. "Arkmeds" automates many routine inspections using a management tool accessed through the Web or mobile devices [21]. SensorWeb remotely monitors temperature and sends it to secure servers that can be safely accessed through the Web or mobile devices [22]. "MCare" offers a wristband that notifies parents anytime their children get lost [23]. A complete management portal for clinical and population data is offered by Sisqualis, using the new Google Cloud [24]. Bionexo offers a series of digital solutions, which allows real-time management of health supplies using Amazon Web Services [25]. Carenet presents a platform, which processes data (generated by wearable, health applications, and healthcare devices) and turns it into information that can be accessed through mobile devices [26]. Hi Technologies offers a product called Tele-ECG. This system is capable of store ECG (Electrocardiogram) data on a server, allowing physicians to easily access the ECG data through the Internet [27].

At first, it is possible to notice that Brazil has several IoT solutions for healthcare. However, these solutions do not include yet the IoT potential for healthcare. Next section discusses these problems with detail.

4. Discussion and Comparative Analysis

This section presents the technological solutions presented in the literature and discussion.

Table I summarizes the more relevant IoT-based solutions for healthcare founded in the related literature

from Brazil. The most important topics considered in this analysis are the following: security mechanisms, Web standards and protocols, communications protocols, and hardware platform or operating system (OS).

Table I – Summary of the IoT-based Healthcare solutions in Brazil based on the related literature.

Reference	Security Mechanisms	Web Standards and Protocols	Communication Protocols	Hardware Platform or OS
[15]	-	HTTP	-	RFID
[16]	-	-	XBee® Pro S2	Arduino
[17]	-	-	IEEE 802.11 b/g/n	Arduino
[18]	ECDH, SSL	HTTP, TCP/IP	Bluetooth, WiFi	Android and Arduino
[19]	SSL	XLS, CDMA and WiFi	GSM, GPRS, CDMA and WiFi	Computer
[20]	-	-	DDS,MR-UDP, S2PA	M-Hub, SDDL
[21]	SSL	SFTP	-	Android, Raspberry Pi
[22]	-	REST	-	-
[23]	-	HTTP	Bluetooth, 3G/4G. WiFi	Android
[24]	-	SOAP, XML	-	-
[25]	-	TCP/IP	ZigBee, Bluetooth, WiFi	Smartphone
[26]	JAAS	RESTful APIs	-	Arduino

The first aspect to analyze is security and privacy due to the sensitive patient`s data. However, most related works fails to approach this topic [15, 16, 17, 20, 22, 23, 24, 25]. There are some works using Secure Socket Layer (SSL), Elliptic Curve Cryptography (ECDH), and Java Authentication and Authorization Service (JAAS) to encrypt data, which is a good start. However, most of the studies analyzed in this paper do not mention any kind of security mechanism (e.g., data encryption).

Another important aspect presented in Table I, is the used platform. As may be seen in this table, most of the projects are in an early stage of development using hardware prototyping platforms, such as Arduino or Raspberry Pi. For smartphone applications, it is possible to note that developed Apps are just for Android OS.

Regarding Web standards and communication protocols, all the presented works are using traditional technologies, such as HTTP, REST, XBee, Bluetooth, ZigBee, LTE, or IEEE 802.11. None of the founded related work uses any cloud integration, which may imply low scalability, flexibility, and data storage capacity.

After analyzing the related literature, it was possible to observe that, in terms of products, the contributions available are far from the market reality.

Similar to the solutions presented in Session 3, some companies are offering remote healthcare monitoring systems, as may be seen in [21, 27]. Therefore, it is possible to conclude that research studies, which is focusing IoT for healthcare and AAL, are in the right way.

For cloud integration, there are some companies working on that, such as those mentioned in [19, 24, 25]. However, none of the publications decided to use any kind of cloud integration.

Wearable devices are also being developed in Brazil [22]. Therefore, it is also a good opportunity to start a new business based on them [14, 15, 17].

Smartphones and tablet applications are being developed as a management tool in the market, and they are also aligned with scientific publications.

5. Conclusion

Healthcare is considered one of the most important industry sectors for IoT-based applications. The Brazilian community takes great interest on this new technology that is expected to grow significantly within the next years.

Due to the relevance of the technology, Brazilian researchers started to study and explore its potential. This paper presented the IoT for healthcare solutions that are being studied, experimented/tested, and developed in the Brazilian scenario.

Analyzing the found data, it is possible to perceive that the technology is being developed; however, much work should be done to increase the current scenario. Security and privacy, quality of service, and quality of experience on these technologies continue being a big challenge. In addition, from the market perspective, there are just a few services and products already developed. So, a long path should be done.

It is expected that these obtained results will be extremely useful for researchers, healthcare providers, and technology professionals that want to develop IoT-based solutions for healthcare, aiming to explore the topic and improving the technology's scenario in Brazil.

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References

[1] Santos BP *et al*. Internet das Coisas: da Teoria à Prática. In: 34th Simpósio Brasileiro de Redes de Computadores e Sistemas Distribuídos; 2016 May 30 Jun 03; Salvador, Brazil. 2016. p. 329.

[2] Perera C, Liu CH, Jayawardena S, Chen M. A Survey on IoE From Industrial Market Perspective. IEEE Access [internet]. 2013 [cited 2017 April 4]; 2:1660-1679. Available from: http://ieeexplore.iee.org/document/7004894/.

[3] Kabir H, Hossain M, Kwak K. The Internet of Things for Health Care: A Comprehensive Survey. IEEE Access [internet]. 2015 June 1 [cited 2017 April 4]; 3:678-708. Available from: http://ieeexplore.iee.org/document7113786/.

[4] Markets and Markets [internet]. 2017 [cited 2017 April 6]. Available from: http://www.marketsandmarkets.com/PressReleases/iot-healthcare.asp

[5] Internet World Stats [internet]. 2017 [cited 2017 April 6]. Available from: http://www.internetworldstats.com/top20.htm

[6] Freund FF. Novos negócios baseados em Internet das Coisas. Revista FAE [internet]. 2016 [cited 2017 April 13]; 1(2):7-25. Available from: https://revistafae.fae.edu/revistafae/article/view/402.

[7] Serafim E. Uma Estrutura de Rede Baseada em Tecnologia IoT para Atendimento Médico em Áreas Urbanas e Rurais [dissertação]. Campo Limpo Paulista: Faculdade Campo Limpo Paulista; 2014.

[8] Lima RC. Wireless Sensor Networks application on remote Healthcare Monitoring. Revista Interdisciplinar de Tecnologias e Educação [internet]. 2016 [cited 2017 April 12]; 2 (1). Available from: http://sinte.btv.ifsp.edu.br/index.php/SInTe/article/view/178.

[9] Dantas ECS. Hardware embarcado de baixo custo para medição de pressão arterial com recursos de Internet das Coisas [dissertação]. João Pessoa: Instituto Federal de Educação, Ciência e Tecnologia da Paraíba; 2016.

[10] Machado FM, Koehler IM, Ferreira MS, Sovierzoski MA. An mHealth Remote Monitor System Approach Applied to MCC Using ECG Signal in an Android Application. Advances in Intelligent Systems and Computing [internet]. 2016 [cited in April 14]; 445:43-49. Available from: http://link.springer.com/chapter/10.1007/978-3-319-31307-8_5.

[11] Murakami A, Kobayashi LO, Tachinardi U, Gutierrez MA, Furuie SS, Pires FA. Acesso a informações médicas através do uso de sistemas de computação móvel. In: Congresso Brasileiro de Informática na Saúde; 2004 Nov 7-10; Ribeirão Preto, Brazil. 2004.

[12] Gomes B, Muniz L, Silva F, Rios LT, Endler M. A Comprehensive Cloud-based IoT Software Infrastructure for Ambient Assisted Living. In: International Conference on Cloud Computing Technologies and Applications; 2015 June 2-4; Marrakesh, Morocco. 2015.

[13] Mano LY. Explorando tecnologias de IoT no contexto de Health Smart Home: uma abordagem para detecção de quedas em pessoas idosas. Journal on Advances in Theoretical and Applied Informatics [internet]. 2016 August [cited 2017 April 23]; 2(1): 46-57. Available from: http://revista.univem.edu.br/jadi/article/view/1667.

[14] Oliveira GA. Um Modelo para Gerenciamento de Históricos de Contextos Fisiológicos [dissertação]. São Leopoldo: Universidade do Vale do Rio dos Sinos; 2016.

[15] Rios, TS, Bezerra, RMS. WHMS4: Um Modelo Integrado para Monitoramento Remoto de Saúde. In: 10ª Conferencia Ibérica de Sistemas y Tecnologías de Información; 2015 June 17-20; Águeda, Portugal. 2015.

[16] Costa TM, Salomao PL, Martha AS, Pisa IT, Sigulem D. The impact of short message service text messages sent as appointment reminders to patients' cell phones at outpatient clinics in Sao Paulo, Brazil. Int J Med Inform [internet]. 2010 Sep 26 [cited 2017 May 2]; 79(1):65-70. Available from: https://www.ncbi.nlm.nih.gov/pubmed/19783204.

[17] Portocarrero JMT, Souza WL, Demarzo MMP, Prado AF. SIAF: Um Sistema de Informação de Atividade Física. In: X Workshop de Informática Médica; 2010 Jul 23; Belo Horizonte, Brazil. 2010.

[18] Maia P, Batista T, Cavalcante E. A web platform for interconnecting body sensors and improving health care. Procedia Computer Science [internet]. 2014 [cited 2017 May 2]; 40:135–142. Available from: http://www.sciencedirect.com/science/article/pii/S1877050914014082.

[19] Dev Tecnologia: end-to-end Solutions [internet]. 2017 [cited 2017 May 5]. Available from: http://devtecnologia.com.br/

[20] Gemed Oncologia: Oncology Clinics Management System [internet]. 2017 [cited 2017 May 10]. Available from: http://www.interprocess.com.br/gemed/gemed-oncologia/

[21] Arkmeds Management Tool [internet]. 2017 [cited 2017 May 5]. Available from: http://arkmeds.com/

[22] SensorWeb: measurement everywhere [internet]. 2017 [cited 2017 May 5]. Available from: http://www.sensorweb.com.br/

[23] MCare Smart Wistband [internet]. 2017 [cited 2017 May 5]. Available from: https://www.mcare.net.br/

[24] Sisqualis Health Information Interoperability Solutions [internet]. 2017 [cited 2017 May 5]. Available from: https://sisqualis.com.br/saude/#interop/

[25] Bionexo Online Supply Management [internet]. 2017 [cited 2017 May 5]. Available from: http://beta.bionexo.com/br/

[26] Carenet: Digital Health Data Platform [internet]. 2017 [cited 2017 May 5]. Available from: http://www.carenet.com.br/

[27] Hi Technologies: Tele-ECG [internet]. 2017 [cited 2017 May 5]. Available from: http://hitechnologies.com.br/site/pt/portfolio/tele-ecg/