Journal of Biomedical Informatics 56 (2015) 265–272

Contents lists available at ScienceDirect

Journal of Biomedical Informatics

journal homepage: www.elsevier.com/locate/yjbin

Methodological Review

Mobile-health: A review of current state in 2015

Bruno M.C. Silva [a,1], Joel J.P.C. Rodrigues [a,b,*], Isabel de la Torre Díez [c,2], Miguel López-Coronado [c,2], Kashif Saleem [b,3]

[a] Instituto de Telecomunicações, University of Beira Interior, Rua Marquês d'Ávila e Bolama, 6201-001 Covilhã, Portugal
[b] Center of Excellence in Information Assurance (CoEIA), King Saud University, Riyadh, P.O.: 11362, BOX: 266, Riyadh, Saudi Arabia
[c] Department of Signal Theory and Communications, University of Valladolid, Paseo de Belén, 15, 47011 Valladolid, Spain

ARTICLE INFO

Article history:
Received 21 July 2014
28 May 2015
Accepted 3 June 2015
Available online 11 June 2015

Keywords:
e-Health
Health telematics
Healthcare
m-Health
Mobile health
Telemedicine

ABSTRACT

Health telematics is a growing up issue that is becoming a major improvement on patient lives, especially in elderly, disabled, and chronically ill. In recent years, information and communication technologies improvements, along with mobile Internet, offering anywhere and anytime connectivity, play a key role on modern healthcare solutions. In this context, mobile health (m-Health) delivers healthcare services, overcoming geographical, temporal, and even organizational barriers. M-Health solutions address emerging problems on health services, including, the increasing number of chronic diseases related to lifestyle, high costs of existing national health services, the need to empower patients and families to self-care and handle their own healthcare, and the need to provide direct access to health services, regardless of time and place. Then, this paper presents a comprehensive review of the state of the art on m-Health services and applications. It surveys the most significant research work and presents a deep analysis of the top and novel m-Health services and applications proposed by industry. A discussion considering the European Union and United States approaches addressing the m-Health paradigm and directives already published is also considered. Open and challenging issues on emerging m-Health solutions are proposed for further works.

1. Introduction

The introduction of mobile device (PDAs) in the 90s enabled physicians to easily download medical records, lab results, medical images, and drug information. Patients could be aware of their diagnostic, disease control, and monitoring with comfortable mobile devices that accompany them everywhere. According to [1], from 2010 to 2016 the global telemedicine market is expected to grow up to nearly 27.3 billion dollars. A key factor that contributes to this market investment is the increased remote monitoring of patients. Basically, telemedicine considers the use of medical information, also known as Electronic Health Records (EHRs) [2], exchanged via electronic communications improving the patients health status. In United States, the use of EHR technology is already widely adopted. It is estimated that 55% of medical professionals are using EHR platforms [3].

With the advent of mobile communications using smart mobile devices that support 3G and 4G mobile networks for data transport, mobile computing has been the main attraction of research and business communities. It offers numerous opportunities to create efficient mobile health (m-Health) solutions. M-Health is the new edge on healthcare innovation. It proposes to deliver healthcare anytime and anywhere, surpassing geographical, temporal, and even organizational barriers [4,5]. M-Health systems and its corresponding mobility functionalities have a strong impact on typical healthcare monitoring and alerting systems, clinical and administrative data collection, record maintenance, healthcare delivery programs, medical information awareness, detection and prevention systems, drug-counterfeiting, and theft [6]. Typical m-Health services architectures (presented in Fig. 1) use the Internet and Web services to provide an authentic pervasive interaction among doctors and patients. A physician or a patient can easily access the same medical record anytime and anywhere through his/her personal computer, tablet, or smartphone. The patient can contact the physician in case of an emergency, or even,

* Corresponding author at: Instituto de Telecomunicações, University of Beira Interior, Rua Marquês d'Ávila e Bolama, 6201-001 Covilhã, Portugal. Tel.: +351 275 242 081, +966 114696458; fax: +351 275 319 899, +966 114696452.
E-mail addresses: bruno.silva@it.ubi.pt (B.M.C. Silva), joeljr@ieee.org (J.J.P.C. Rodrigues), isator@tel.uva.es (I. de la Torre Díez), miglop@tel.uva.es (M. López-Coronado), ksaleem@ksu.edu.sa (K. Saleem).
[1] Tel.: +351 275 242 081; fax: +351 275 319 899.
[2] Tel.: +34 983423000x3703; fax: +34 983423667.
[3] Tel.: +966 114696458; fax: +966 114696452.

http://dx.doi.org/10.1016/j.jbi.2015.06.003
1532-0464/

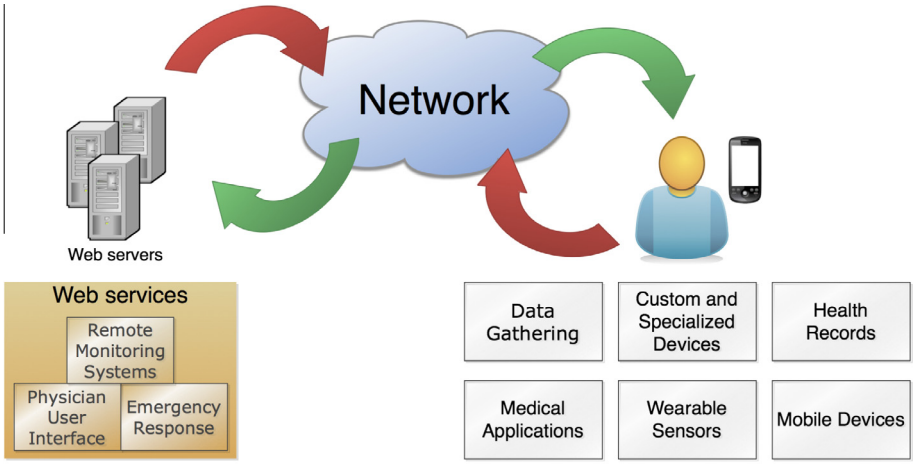

Fig. 1. Illustration of a typical architecture of m-Health services.

have access to medical registers or appointments regardless of time and place.

This paper presents a comprehensive review of the state of the art on m-Health services and applications. It surveys the most significant research work and presents a deep analysis of the top and novel m-Health services and applications available in mobile markets and healthcare industry.

The main contributions of this paper are the following:

- An extensive review of the state of the art on m-Health;
- A study of the developments/break-through on m-Health;
- An analysis of the top mobile health applications in mobile markets;
- A discussion about current and open issues on m-Health services and technologies.

The reminder of this paper is organized as follows. Section 2 elaborates on the current state of the art on e-Health systems and how health institutions and agents are embracing the information and communication technologies. Section 3 focuses on m-Health awareness and the use of m-Health services and applications. A discussion about current and open issues on m-Health technologies is presented in Section 4. Finally, the paper is concluded on Section 5.

2. Healthcare and e-Health systems: The road so far

Health telematics had becoming a great topic in terms of medical informatics and healthcare. Currently, hospitals and health systems are relying on information and communication technology (ICT) as a mean for improving quality, safety, and productivity of health care services. E-Health connects medical informatics, public health, and business through associated technologies, such as the Internet. However, it has been suffered from a slow start due to the low priority given by Hospitals and health systems to ICT in the 90s. Nonetheless, the need to produce a standard for hospital information systems was crucial. In 1987, the International Health Level Seven (HL7) organization [7] was founded and, in 1994, it was accredited by the American National Standards Institute (ANSI). Its name is a reference to the seventh layer of the ISO Open Systems Interconnection (OSI) Reference model also known as the application layer. Currently, the HL7 is adopted by ISO as a reference in terms of international standardization, publishing together several frameworks and related standards for exchange, integration, sharing, and retrieval of electronic health records (EHRs). In the beginning of the new century, between 1999 and 2002, e-Health services have finally awakened and rapidly increased. This growing was analog to the rapid evolution of ICT infrastructures and access to patient data. The Web 2.0 concept and the emerging Web 3.0 have offered to healthcare professionals conditions that never had been given before [8]. They also enabled a key element in healthcare systems, the emergence of EHRs or Personal Health Records (PHRs). Usually, healthcare providers keep and handle patient health records. However, it is becoming more common that patients also request access to those data. Medical records (or health records) allow medical doctors to easily access a patient information without needing to ask them in person. E-health systems are typically sustained on EHRs [9]. An EHR-system is basically a repository of information regarding the health records of patient/consumer in a computer form [10]. The deployment of a public EHR-system can offer several advantages to a public healthcare system, for example, lower and more efficient management costs, more efficient management of high-volume patient data, and centralized medical patient records [11].

In January 1st of 2015, the Centers for Medicare & Medicaid Services (CMS) from the U.S. Department of Health and Human Services (HHS), approved incentive payments for primary care that includes chronic care management (CCM) services. Such services, requires structured data recording using certified EHR technology [12]. These certified EHR technology must follow the regulations of the EHR incentive programs. These programs provide incentive payments to eligible professionals, hospitals, and critical access hospitals (CAHs), but only if they implement, upgrade and use certified EHR technology. This technology must be certified by the Office of the National Coordinator for Health Information Technology (ONC) under the Office of the Secretary for the U.S. Department of HHS [13]. These incentives, are a clear statement of intention, for a widely appliance of EHR services, exploring their advantages of reduced costs and improved the healthcare professionals productivity.

A large number of telemedicine and e-Health systems are being widely and successfully produced delivering health care through different communication technologies. In 2011, the World Health Organization (WHO) has identified a compendium of emerging health technologies, under development and already commercialized [14]. This report presents several health technologies that present the potential for being low-recourse solutions for unmet medical needs. Currently, the commercialized and most relevant