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Health Internet of Things: Metrics and methods for efficient data transfer

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ABSTRACT

The rapid development of modern Information and Communication Technologies (ICTs) in recent years and their introduction into people's daily lives worldwide, has led to new circumstances at all levels of the social environment. In health care in particular, sensors and data links offer potential for constant monitoring of patient's symptoms and needs, in real time, enabling physicians to diagnose and monitor health problems wherever the patient is, either at home or outdoors. However, the use of Internet of Things concepts in the health domain does not come without extra data and therefore a data transfer cost overheads. To deal with these overheads, novel metrics, and methods are introduced in an attempt to maximize the capabilities and widen acceptance/usage provided by the Internet of Things. Without losing its generality, the method discussed is experimentally evaluated in the paradigm of the Health domain. The focus is on the need for an overview of available data formats and transmission methods and selection of the optimal combination, which can result to reduction/minimization of costs. An analytic methodology is presented backed with theoretical metrics and evaluated experimentally.

1. Introduction

During the recent years mobile devices have been embraced by everyone, thus creating a huge market that is expected to evolve even more in the years to come. One of the many fields of their application is the medical domain [1], as they are considered to be a great means of improving provided healthcare. An increasing number of healthcare professionals utilize applications that enable remote monitoring or healthcare management. Moreover, many consumers already take advantage of m-health applications to improve and assist their own health [2]. Mobile applications solutions are widely accepted because they are easy to use. This is the reason why already numerous applications are available, which target different health issues and groups of people.

The oncoming development will integrate the existing individual applications, equipment and expertise in the field of medical informatics under the "umbrella" of *Internet of Things* (IoTs) [3]. The basic idea of this concept is the ability of many objects around us to interact and cooperate with each other in order to achieve common goals [4] towards pervasive healthcare. These smart objects will be able to identify and connect with others, therefore enabling people to communicate and exchange information with items used in their everyday lives or related to their health, by merely touching them, using properly equipped mobile devices. Secure healthcare services will supplement the process by receiving and reclaiming the resulting data or by ensuring optimal establishment of communication channels between patients, healthcare givers and anyone else involved in the process.

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Frequently, in mobile medical applications, the need arises for the patient to monitor and therefore measure his/her own vital signs after the physician's order or inducement and send this data to the physician on a regular basis. A frequent example are the cases of chronic diseases. There are many medicine related procedures that utilize mobile applications to facilitate the parties involved [5]. Many works study the ways mobile applications assist medicine, but they all assume that people involved have access to internet connection and unlimited resources to dispose [6,7]. However, this is not always true, as nowadays, the cost of Internet use has been reduced significantly for cable cases, but it is not yet trivial and constitutes an important factor that limits its universal spread, especially in mobile devices.

In this paper, we present a methodology to measure and evaluate network consumption of connecting devices which communicate with other applications and exchange health oriented data. We present metrics and methods to perform simulation experiments to evaluate IoT network usage and the cost that it induces, taking into consideration that Internet is used both at PCs and increasingly from mobiles – smartphones. We show that it is possible to maximize today's data transfer technologies to enable Health IoT. In particular, given the health vital signs data needed to be monitored, the proposed solution detects the most appropriate data transfer technology to be used, depending on the volume and type of encoded data to be sent.

Analytically presented in [8], when implementing healthcare Internet of Things solutions there are several design consideration. The most important consideration about the wide area network are the type of transmission used, i.e. the data rate, and coverage [8], which both imply cost effectiveness fine-tuning needs depending on the technology adopted. Different WAN networking technologies for the home and the patient imply different data rates, coverage and therefore cost rate options. In this study, we introduce a methodology and study all possible popular communication scenarios for long range – WAN transmission of health data. Such data may be sent by patients/home personal area network [8] to the clinic physicians or private doctor or caregiver using either broadband land lines or alternative mobile long-range transmission technologies, e.g. 3G, SMS, MMS. The different scenarios aim to show to the readership and the researchers how to apply our methodology to enable systematic studies of network usage in the implementation of Internet of Things at home for patients. Minimizing costs and at any case keeping them calculated can be crucial in implementing IoT for health at patient's home or when patient is outdoors on a walk or at his/her work [8]. Our approach is independent and fully extensible to include *any type of vital sign* and the ones given are provided for experimental purposes only and do not narrow the generality of the approach.

The rest of the paper is organized as follows: Section 2 discusses related work and technologies involved in the evolution of the Internet of Things. Section 3 describes the evaluated network connection architectures. Section 4 presents a review of data transfer costs. Section 5 introduces the methodology, we propose and defines novel metrics. Section 6 presents the experimental setup and evaluation of the simulation outcomes. Finally, Section 7 concludes the paper and gives ideas for further research.

2. Related work and technologies

2.1. Medical information systems

Internet has broaden the scope of medical information systems and led to the development of distributed and interoperable information sources and services. In the same time, the need for standards became crucial. Medical information systems may include medical imaging storage and transmission systems, nursing information systems, laboratory information systems, pharmacy information systems, and so on. To treat patients, medical personnel can use different information systems in accordance to their needs, in order to diagnose and run tests, like blood tests, urine sampling, computed tomography scans, X-ray, and so. A medical information system produces all kinds of medical information in various formats, including texts, numbers, pictures, static, dynamic images, etc. This heterogeneous information can then be integrated without the need of medical personnel. According to a patient ID, name, or other basic data, the information can be indexed by, for medical use upon request [10].

2.2. Mobile health applications

In different specialties and health issues, we often see use of individual mobile health applications, developed to serve specific purposes [22]. The need for such applications is apparent in every major online market for mobile applications including Android Market, Apple Store and Samsung Apps. Applications which assist Cardiology measure blood pressure [11], applications for Diabetes record blood glucose [12], for Obesity, they record calories and diet [5], for Dementia they use GPS to monitor the patient [6,7] and applications for chronic diseases target mobile phones with sensors and detect tachycardia or respiratory infections [9]. Additionally, smartphones and handheld devices (PDA's) are often used by health personnel within hospitals [13] in combination with technologies like Bluetooth and WI–FI. The key aim of these systems is to facilitate doctors and nurses throughout the hospital, using a typical smartphone [14,15].

An example, in Orthopaedics, is the integrated system that was developed for recording, monitoring and studying patients with Open Tibia Fractures [16]. The authors participated in the development of the system, which is based on web and mobile applications. Primary goal was the creation of a system that contains most of the scientifically validated data elements, reducing this way omission and improving consistency, by standardising the reporting language among medical