Internet of Medical Things applications

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The Internet of Things (IoT) have been adopted by several areas of the society, such as smart transportation systems, smart cities, smart agriculture, smart energy and smart healthcare. The healthcare is an area that takes a lot of benefits from IoT technology (composing the Internet of Medical Things (IoMT)), since low cost devices and sensors can be use to create medical assistance systems, reducing the deployment and maintenance costs, and at the same time, improving the patients and their family quality of life. However, only IoT is not able to support the complexity of e-health applications. For instance, sensors can generate large amount of data, and the IoT devices do not have enough computational capabilities to process and store these data. Thus, the cloud and fog technologies emerge to mitigate the IoT limitations, expanding the IoMT applications capacities. The cloud computing provides virtual unlimited computational resources, while the fog push the resources closest to the end users, reducing the data transfer latency. Therefore, the IoT, fog, and cloud computing integration provides a robust environment to e-health systems deployment, allowing a plenty of different types of IoMT applications. In this topic review, we present an overview of a systematic mapping with the goal to overview the current state-of-the-art in IoMT applications using IoT, fog and cloud infrastructures.

Keywords: Internet of things ; Internet of medical things

Introduction

According to a study performed by the World Health Organization (WHO)[1], we will have the largest number of older people in the history by 2020, and at first time, it will surpass the number of children up to five years old. The same study also says that the life expectation will reach 90 years by 2030, and up to 80% of the elderly population will live in low and middle income countries. The academic and business communities are devoting many efforts to develop new applications that promote quality of life, not only for this portion of the population but for all those need constant caring; services, such as vital signs monitoring, fall detection systems, heart attacks, among others, are increasingly in evidence [2]. The greater demand for long-term patient health care and the need of controlling health care expenditures require the efficient use of low-cost technologies in order to apply them in the best possible way.

Most of these e-health systems relies on Internet of Things (IoT) infrastructure (or specifically Internet of Medical Things (IoMT)). Smartphones and smart devices are very popular, and more cheap than medical specialized devices. With these IoT devices, it is possible to collect different vital signals, such as heart rate, body temperature, blood pressure, or still identify if the user has suffered some accident, such as fall, by using accelerometer sensor data. However, commonly the IoT devices do not provide good computational processing, long-term storage, neither guarantee of quality of service (QoS) due to their hardware capacity limitations. So, to mitigate this issue, IoT has two major allies to provide e-health applications with high availability and quality: cloud and fog computing.

As the cloud architectures were not designed to operate integrated to IoT, there are some transversal requirements that should be complied with, such as scalability, interoperability, flexibility, reliability, efficiency, availability, and security, as well as specific computation, storage and communication needs[3]. On the other hand, fog computing has emerged between the cloud and the IoT devices, providing data management and also communication services to facilitate the execution of relevant IoT applications through intermediary compute elements (fog nodes) [4].

In this paper, we provide an overview about IoMT applications in e-health systems, through a systematic mapping, focusing on the integrated infrastructure with IoT, fog and cloud, the methods used in the literature to evaluate them, and the main research challenges an opportunities in this area.

Methodology

We followed the methodology presented by [5] to conduct the systematic mapping. The Figure 1 shows the process steps and the respective outcomes. For details about the methodology, see [5].

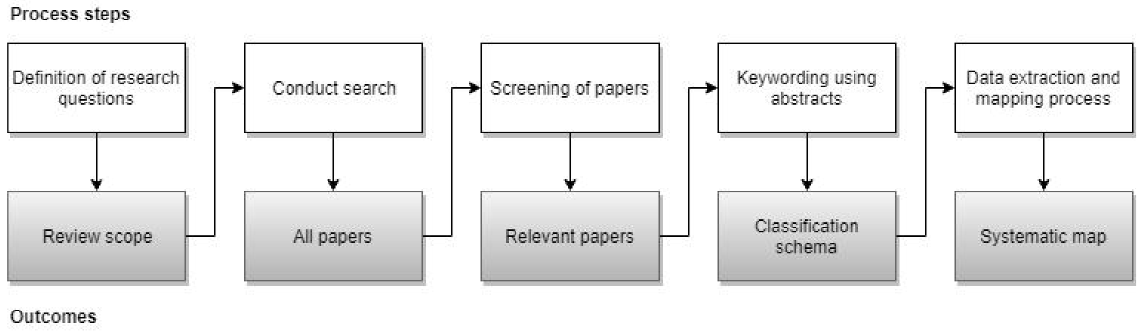

Figure 1. Systematic map schema from [5].

According to [5], the main goal of a systematic mapping "*is to provide an overview of a given research area, and identify the quantity and type of research available within it*". Often, a systematic map can also be used to map the frequencies of publication over time to see trends. Our goals are described as following four research questions (RQs):

- RQ 1: What is the current state-of-the-art in e-health applications using fog-to-cloud computing infrastructure?
- RQ 2: What are the most common e-health applications using fog-to-cloud computing infrastructure?
- RQ 3: What are the most common methods (simulation, modelling or prototype) used to evaluate e-health applications?
- RQ 4: What are the main challenges for implementing e-health applications that rely on fog-to-cloud computing?

According to [5], the primary studies *are identified by using search strings on scientific databases or browsing manually through relevant conference proceedings or journal publications*". In this work, we performed the primary studies identification by using search string on relevant databases. The search string used was: ("e-health" OR "ehealth" OR healthcare) AND ("cloud" OR "fog") AND ("Internet of things" OR "IoT"); and the scientific databases were: IEEE, ACM, and Springer. We retrieved 83 papers from IEEE, 1 from ACM and 81 from Springer.

As IoT, fog computing and cloud computing are very embracing terms, they are often used in abstracts but not necessary are addressed further in the paper. So the application of the inclusion and exclusion criteria is done manually, and in order to avoid bias, when doubt appeared, more than one researcher classified the paper. After the screening, we kept 38 papers from IEEE and 12 from Springer.

Considerations

It was observed the great usage of the cloud + IoT infrastructure configuration in 62% of the papers, but in the last two years, 2017 and 2018, there was a growing in researches with the integrated cloud + fog + IoT infrastructure. Through the systematic mapping it was also possible to identify the main IoMT applications that are being developed; the monitoring of patients in daily activities and monitoring of elderly people are the applications most used in the works. Regarding the elderly monitoring, there are several IoMT application types, ranging from common daily monitoring to more specific applications, such as the one proposed by [6] to avoid thermal shock in elderly people living in Japan. As a consequence of the mapping, it was found that the two most common target of monitoring used are Heart rate with 12 papers and Humidity and Room Temperature with 09 papers. 42% of the works found in this systematic mapping study used prototyping for proposal evaluation, 16% modeling, 14% simulation and another 28% did not evaluate the proposal.

To conclude the study, we presented some common research challenges and opportunities in IoMT application area, highlighting the IoT devices' limitations, the system availability, the standardization process and the data security.

This entire paper will be published soon in the Emerging Technologies in Biomedical Engineering and Sustainable TeleMedicine book.

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