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Perspective chapter: Internet of Things in Healthcare - New Trends, Challenges and Hurdles

*Luis Muñoz-Saavedra, Francisco Luna-Perejón,
Javier Civit-Masot and Elena Escobar-Linero*

Abstract

Applied to health field, Internet of Things (IoT) systems provides continuous and ubiquitous monitoring and assistance, allowing the creation of valuable tools for diagnosis, health empowerment, and personalized treatment, among others. Advances in these systems follow different approaches, such as the integration of new protocols and standards, combination with artificial intelligence algorithms, application of big data processing methodologies, among others. These new systems and applications also should face different challenges when applying this kind of technology into health areas, such as the management of personal data sensed, integration with electronic health records, make sensing devices comfortable to wear, and achieve an accurate acquisition of the sensed data. The objective of this chapter is to present the state of the art, indicating the most current IoT trends applied to the health field, their contributions, technologies applied, and challenges faced.

Keywords: IoT systems, healthcare, eHealth, telehealth, medical support

1. Introduction

In recent years, the set of technologies encompassed under the name of the Internet of Things has experienced its greatest evolution and is currently approaching the slope of enlightenment of the hype cycle according to Gartner [1]. It has been applied in numerous areas, notably changing and improving the way in which different tasks and activities, both business and personal, are approached in daily life. Devices such as home assistants, home automation devices, and activity monitors are used more and more widely, providing information and functionalities that can be used quickly and easily.

One of the fields where there is more expectation about the application of this set of technologies is that related to healthcare and telehealth. Currently, there are several problems inherent in the health field that can be addressed thanks to the remote communication offered by the IoT. Advances in telehealth allow medical consultations and follow-up of patients in remote and isolated places, or with the limited mobility [2]. On the other hand, they enable the interconnection between health centers and remote systems that monitor elderly or disabled people who live alone or

spend part of the time without company at all times, controlling vital signs or possible events such as falls that could endanger their lives [3].

Likewise, health services can be improved and optimized when health centers are provided with the capacity to integrate and interconnect devices that collect biomedical information with electronic health records [4]. Diagnosis, treatment, and follow-up in recovery from illnesses can be benefited in many cases by the continuous collection of these data [5], which complements the information obtained with specific observations that the medical professional can make during consultations, often limited in time. In addition, the data collected are a valuable source of information that can be used by Big Data and Artificial Intelligence applications to make new discoveries.

Although the advantages of these technologies applied to healthcare are clearly beneficial in many areas, there are also many aspects that make their implementation a challenging task. Due to the sensitive nature of the information, the technologies that must be implemented are those with characteristics that allow compliance with data privacy and security policies and standards [6]. On the other hand, they require health systems to have an appropriate infrastructure to accommodate these new technologies, as well as the adaptation of their protocols [7]. The training of health technicians, professionals, and patients to adapt them to these new systems is another relevant factor, and one that is related to usability and user experience [8].

Our purpose with this work is to analyze the evolution of IoT applied to healthcare and telehealth in recent years, the trends in application and what challenges currently exist. To address this objective, we will analyze the most relevant works in the recent years to draw conclusions about the global evolution of these technologies, check in more detail the problems they face, and identify whether there are standards, norms, or common complementary technologies to give a solution.

The rest of the article is divided as follows: In section two, the methodology of collection and analysis carried out are presented, detailing the aspects and characteristics on which we focus, in section three the results obtained are presented, and finally, the last section presents the conclusions.

2. Methodology

2.1 Search approach

The criteria established for the inclusion of studies in the analysis were that they had to be published in journals that appeared in the Journal Citation Reports (JCR) or in conferences included in prestigious journal editorials and digital libraries. The search engine used for the search engine was Google Scholar. The search was limited considering articles published in the last 5 completed years, that is, from January 2017 to December 2021 inclusive. The queries created to be used in the search engine consisted of the combinations of the term "IoT" with "healthcare," "ehealth," and "telehealth." The search for these terms was established to be carried out on the full text of each work, not only on the title and abstract. Since the purpose is to collect current advances and trends, we exclude from the analysis those articles with a scoping review nature. Similarly, we exclude studies that were written in a language other than English.

Regarding the results obtained after carrying out the search, the first three hundred were taken for each year in order of relevance, and one hundred for each of the

three keywords considered in combination with “IoT,” that is, “healthcare,” “telehealth,” and “ehealth.” It was established to do a sequential filtering on the set, checking on each result that it meets each of the established inclusion requirements; otherwise, it will be discarded from the final set of results to be considered in the analysis. In the first place, the character of a high-impact journal paper or publication presented at a conference contemplated in prestigious digital libraries was verified, for which those results that were books or book chapters were also discarded. Next, the discarding of articles that were not written in English was applied. We considered that, to have a meaningful sample of current trends, a sample of 25 results would be taken for each combination of keyword and year. The most cited articles were used as a selection criterion. On this sample, studies consisting of bibliographic reviews were discarded. This last-filtering process was carried out firstly by analyzing the title of each publication and secondly by analyzing the abstract. Additionally, it was observed whether any study was replicated in the set or belonged to the same authors and the purpose was the same, in which case the study with the latest publication date was discarded.

For the initial purpose of filtering, basic information about these works was collected, specifically the title of the article, abstract, authors, access link to the publication, the number of citations, and character of the document according to Google Scholar. All the analyses of the information and filtering process were carried out jointly by the authors and verified between them.

2.2 Extracted information

Once the filtering process was carried out, the next step was to extract the relevant information for the analysis of the current situation, limitations, challenges, solutions, and current trends of IoT applied to healthcare and telemedicine. Mainly, we focus on extracting the most used communication technologies to provide solutions or address current problems in this area of research. Other relevant characteristics extracted were the scope of application from the point of view of what aspect of healthcare is intended to address or what characteristics of the infrastructure are intended to be addressed in the study. Related to the field, we also extract information on the technological aspects of the solution provided. Additionally, the country of the institution that supports each investigation was taken, in order to identify those countries that have the greatest impact worldwide in IoT for ehealth and telehealth fields.

3. Results and discussion

3.1 Results obtained after filtering process

After the filtering process, 186 [9–194] results were obtained, 69 with healthcare and another 69 with ehealth. The article analysis screening process resulted in a greater elimination of works related to telehealth, obtaining 48 results. This is mainly associated with the fact that after analyzing the title and abstract, it was detected that several articles did not fit in the field of healthcare using IoT. However, the cause of the greatest impact on the screening of results was the nature of the scoping review of several studies. Around eight publications per keyword and year on average were removed for this reason. Analyzing by year, the appearance of reviews was greater in

the most recent years, discarding approximately 35 of 75 results of the year 2021. This reveals the progress of previous years and the current trend in analyzing the actual scope of IoT and limitations, which is consistent with the status of this area on hype-cycle curve.

3.2 Countries with contribution with higher impact

Figure 1 illustrates the percentage of publications according to the country of the institution of the corresponding author. In those cases in which the corresponding author was not reflected, the institution of the main author was taken as reference. The graph shows that the institutions with the greatest impact in recent years are India (19.3%) and China (13.4%). The rest of Asian countries (including those located in the Persian Gulf and Russia) contribute 25.8% to this statistic. Approximately 21% corresponds to institutions in European countries, approximately 6% to entities in Africa (mainly Egypt and Tunisia), and 4% to countries in Central and South America. The United States and Canada add 7.5% and Australia and New Zealand approximately 4.8%.

3.2.1 Analysis of scopes of higher impact

With the term “scope,” we refer to the topics on which each study focuses on contributing to the area of IoT systems applied to ehealth and telemedicine. After the analysis, we have found studies whose scope is related to the provision of a health service, proposing models, system designs, and/or implementations of a complete system or a component of an IoT system. On the other hand, scopes focused on improving some characteristic of IoT systems that are relevant when applied to healthcare have also been identified.

Figure 2 illustrates the scopes in the analysis. It can be seen that the majority of studies focus on providing solutions for the field of monitoring. The reader should know that a division has been made in this scope, distinguishing between studies that explicitly indicated or from which the character of real-time monitoring could be clearly inferred. The total number of studies that fit this domain was 83. These data

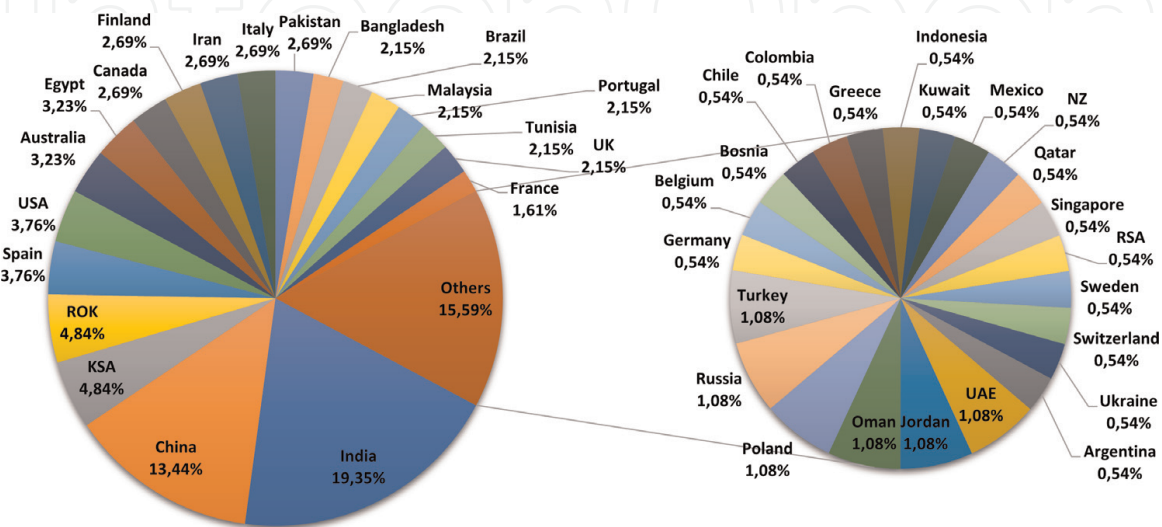


Figure 1. Publications with more impact per country (N = 186).

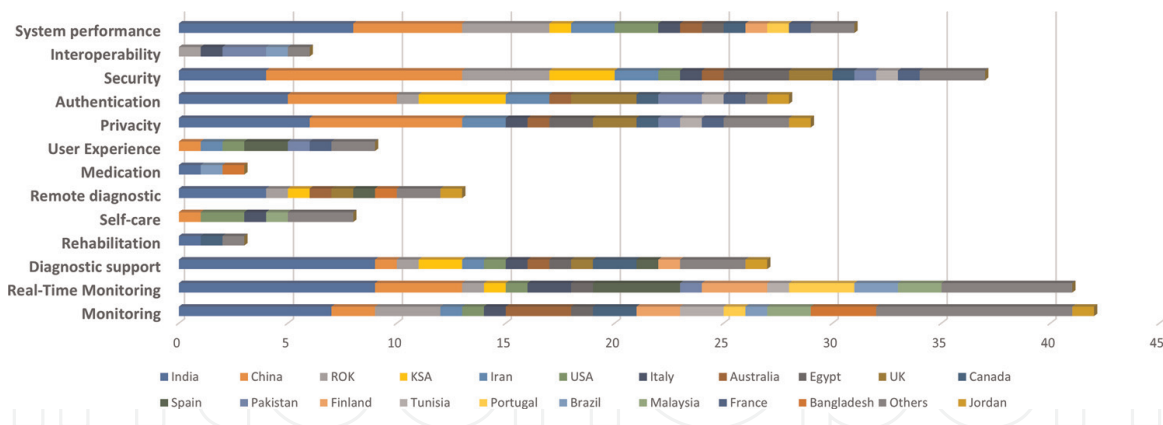


Figure 2.
 Scope of the studies considered in the analysis.

show that the main purpose of the application of IoT to healthcare is to monitor patients, ubiquitously or integrated into rooms, for better control of vital signs or physiological parameters. This result is consistent with the main use for which IoT systems are used. Continuing with the analysis focused on areas of application, the next most common are those related to diagnosis. The creation of models that help the medical professional to give a diagnosis stands out mainly Machine Learning models that can be integrated into the system, sometimes complemented with architectures equipped with resources to apply Fog computing, as well as with the decentralization of processing with computing at the edge, trend that is currently increasing with the optimization of hardware and AI frameworks for model integration and consumption reduction [195]. Additionally, the applications are not restricted to the field of healthcare in the personal context, but also in the workplace [196]. To a lesser extent, we also find the use of IoT to facilitate the remote diagnosis of the patient. This last result may be related to the existing limitations to provide appropriate resources to remote centers or isolated areas that allow establishing reliable connections with sufficient transmission quality. The least relevant areas currently are self-care and remote rehabilitation. The first of these two areas mentioned was the one that had the greatest impact at the beginning of the use of IoT for healthcare, currently being on the slope of enlightenment or plateau of productivity in the hype-cycle curve. The low frequency of appearance of rehabilitation as a field of study may be due to the difficulty in carrying out rehabilitation tasks remotely.

Focusing on areas related to the improvement of system features, studies focused on maintaining the security of the IoT system are more frequent, that is, on avoiding transmission failures, network hacks, or data corruption. Additionally, we find studies focused on providing encryption protocols to ensure the authenticity and privacy of the patient. These last two scopes are often intrinsically related to system security. These results reveal the great challenges that exist in the integration of IoT systems in the Electronic Health Records of health systems: to be able to relate the data to the patient without compromising their privacy, as well as to manage the enormous amount of information collected avoiding losses, falsification information, and other security breaches. Very close in relevance we find the improvement of the performance of the system, that is, looking for better response times in the transmission and processing of information. Again, it is a challenging topic, especially in combination with equipping the system with authentication, privacy, and security protocols, which slows down IoT systems, which must be addressed for this type of system to be useful in terms of practicality.

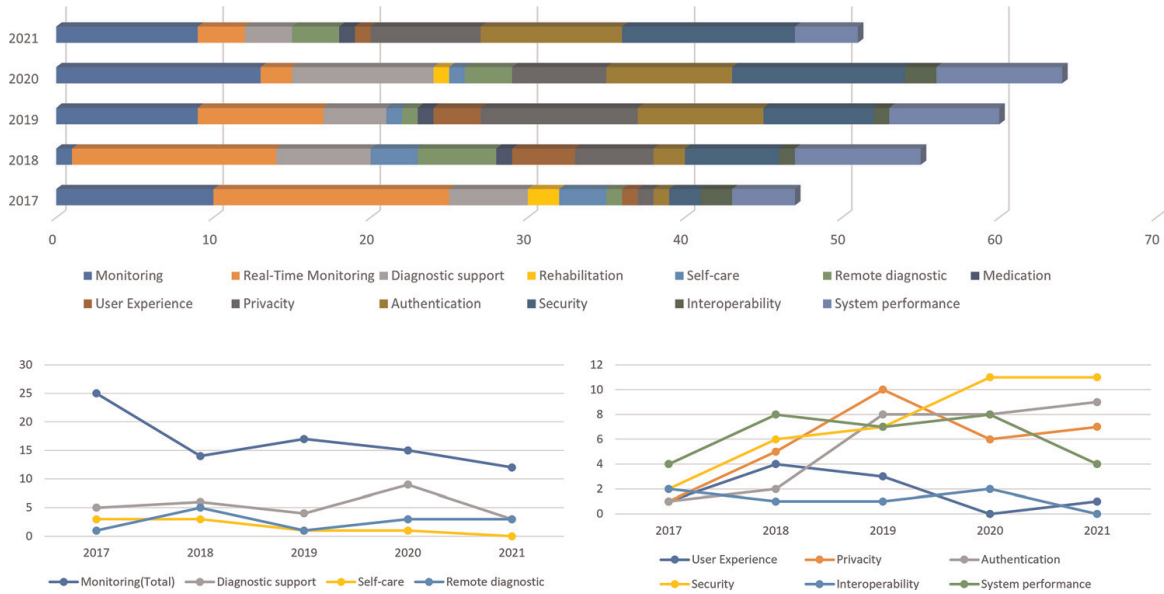


Figure 3. Scope trends. At top, classification grouped by year analyzed in the study. At left, scopes related to the system’s application approach. On the right, scopes focused on improving the characteristics of the IoT system.

In the results, we also observe that the studies related to the study of interoperability and the analysis of usability, user experience, and degree of acceptance have very little impact. These types of studies are not frequent, and yet, they address determining aspects in the adequacy of IoT systems to the health environment; its correct application depends on the fact that the implemented system is practical and perceived as useful. The little research on these issues may be the greatest limitation of these systems in the future.

Figure 3 shows the trend of these areas in the years considered for the analysis. Although a drop in the number of papers is perceived in 2021, this may be due to the fact that there has not yet been a stabilization in the number of citations on studies that contribute novelties to the field of research. Both graphs show how in recent years there has been a decrease in the impact of research aimed at providing solutions with IoT systems, and instead, there has been an increase in interest in research that focuses on improving some characteristics of the system architecture, mainly in security and privacy. This result again reveals indications of the situation of these systems in the hype-cycle curve, seeing reduced interest in deepen for new applications and consolidating their use by focusing on the greatest limitations that this set of technologies has, that is, aspects of security, privacy, and performance.

3.2.2 Interest in applied technologies

Paying attention to communication technologies, the charts in Figure 4 reveal a varied set of alternatives. In these graphs, only those studies that have used and revealed the technologies applied in the implementation of IoT systems are taken into consideration. As a result, 87 articles were considered. The charts highlight the use of Bluetooth technology, in both its older versions and BLE, and Wi-Fi. Despite being a technology adapted to IoT, the use of LoRa is not frequent. GSM and GPRS technologies continue to be used, mainly because they have a greater network infrastructure for these technologies and because they are more in line with the user profile that

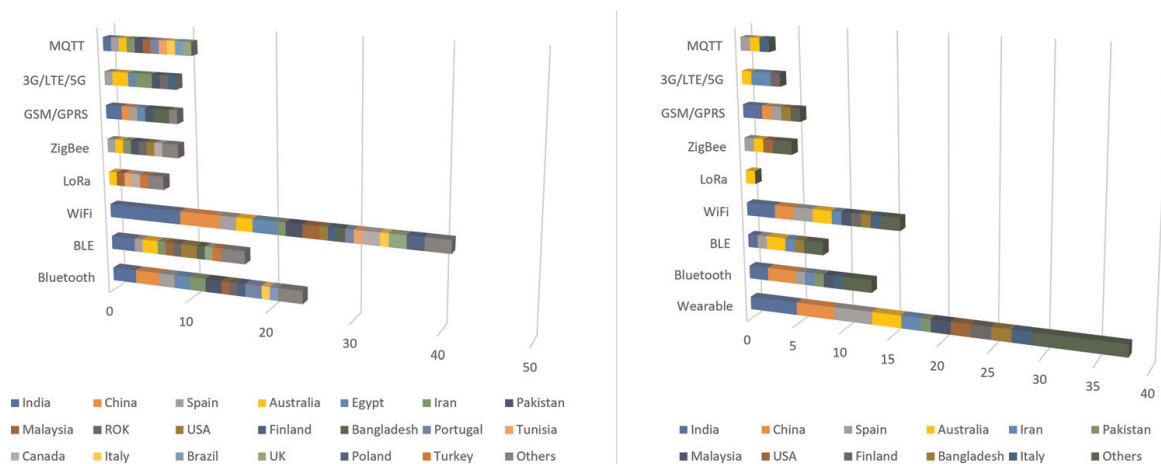


Figure 4. Most common communication technologies in studies that carry out an implementation of an IoT system ($N = 87$). Top-right chart considers only those studies whose sensing acquisition devices are wearable ($N = 36$).

these systems are aimed at, mainly older people or those who are not familiar with new technologies.

Among the studies that reveal the communication technologies used, only 36 focus on the use of systems with exclusively wearable devices for data acquisition. In these studies, a lower use of MQTT is revealed in favor of the use of technologies such as Zigbee. Wi-Fi technology is still the most frequently used; however, there is a remarkable decrease.

The most frequent technologies identified in the analyzed studies include Machine Learning and Deep Learning for the fields of monitoring and diagnostic support. In the fields of security, privacy, and authentication, the use of Blockchain stands out. On the other hand, Fog computing and edge computing are the technologies for which the greatest interest is shown in the field of performance improvement. This is one of the most current trends, driven by systems equipped with more specialized hardware processing units [197].

4. Conclusions

The results obtained from the analysis of impact studies in recent years regarding IoT in healthcare show that Asian and Middle Eastern countries contribute to this area to a greater extent, especially India and China. With regard to the areas with the greatest impact today, we find the application to monitoring as the greatest representative. However, this type of study has reduced its relevance in recent years and instead has grown interest in the integration of security, privacy, and authentication measures to IoT systems, which gives indications of the stabilization of IoT technologies, and there is a tendency to investigate the improvement of the most important weaknesses. Infrequent and low-impact study topics are the analysis of the perceived usefulness of these systems, as well as interoperability, which may imply limitations and obstacles in the future in the implementation and use of these systems. The most used communication technologies are Bluetooth and Wi-Fi, with a smaller representation of technologies such as LoRa, Zigbee, and mobile data transfer technologies. The design and implementation of systems exclusively equipped with wearable acquisition devices is reduced. Machine Learning, Blockchain as well as edge and fog computing are the most trending technologies.

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Conflict of interest

The authors declare no conflict of interest.


Author details

Luis Muñoz-Saavedra[†], Francisco Luna-Perejón^{*†}, Javier Civit-Masot[†]
and Elena Escobar-Linero[†]
University of Seville, Seville, Spain

*Address all correspondence to: fluna1@us.es

[†] These authors contributed equally.

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