# The Internet of Healthcare Things: A European Perspective and a Review of Ethical Concerns

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*Abstract*—The Internet of Things (IoT) is a disruptive technological paradigm that is at the center of the digital evolution by integrating physical and virtual worlds leading to the creation of extended interconnected ecosystems that are characterized as smart environments. The concept of the IoT has a broad range of applications in different industries including the healthcare sector. The Internet of Healthcare Things (IoHT), a branch of the IoT, is expected to bring promising benefits to all involved stakeholders and accelerate the revolution of the healthcare sector through a transition towards preventive and personalized medicine. The socio-economic challenges that the healthcare sector is facing further emphasize the need for a radical transformation of healthcare systems in both developed and developing countries with the role of pervasive technological innovations, such as IoHT, recognized as key to counteract the relevant challenges. Besides the number of potential opportunities that IoHT presents, there are fundamental ethical concerns that need to be considered and addressed in relation to the application of IoHT. This paper contributes to the discussion of the emerging topic of IoHT by providing an overview of the role and potential of IoHT, highlighting the characteristics of the current and future healthcare landscape, reporting on the up-to-date status of IoHT in Europe and reflecting upon existing research in the ethics of IoHT by incorporating additional ethical dimensions that have been ignored which can provide pathways for future research in the field.

*Keywords*—Ethics, Europe, healthcare, internet of things.

## I. INTRODUCTION

THE proliferation of technological innovations has given rise to the development of disruptive value creation paradigms with the most emergent being the IoT. The concept of the IoT is used to refer to an ecosystem of connected hardware, software and physical objects as well as social actors that supports data collection and exchange and enables timely communication and instant interaction. According to forecasts, the global market for IoT is expected to grow to $457.29 billion, and the number of connected devices is estimated to exceed 30 billion by 2020 making IoT the next industrial revolution [1].

In the coming years, the IoT will increasingly be seeing applications in various industries, such as retail, manufacturing, logistics, utilities, transportation, infrastructure and defense to name a few [1]. Such a broad application of the IoT is expected to bring manifold positive outcomes to a broad range of stakeholders, namely consumers, businesses and government and public authorities. In particular, consumers

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can benefit from more personalized products and services and at the same time improve their daily lives through access to information which will support better decision making. Businesses can offer customized and better products and services to their customers whilst enhancing their efficiency, productivity as well as collaboration with all parties in their value system. Governments and public authorities can obtain economic, social and environmental advantages by reducing expenditures, enhancing safety and security for their citizens and minimizing negative environmental impacts.

The healthcare sector is no exception to the overwhelming effect of the IoT as it is expected to be at the forefront of this disruptive paradigm. The IoHT is a branch of IoT and a concept that refers to the creation of an interconnected and interactive healthcare ecosystem. The IoHT is estimated to experience an explosive growth in the future. According to [2], the global IoHT market that will encompass medical devices systems and software, technology and services is estimated to grow from $41 billion in 2017 to $158 billion by 2022. By 2020, it is estimated that 646 million IoT devices will be used in the healthcare sector [1]. The widespread diffusion and implementation of the IoHT will transition the healthcare sector into a new era by supporting the creation of a patient-centered healthcare model that shifts from disjoined and reactive healthcare to coordinated and proactive healthcare delivery.

This paper discusses the overall role of IoHT, it reviews the status of IoHT in Europe and presents a conceptual framework of ethical considerations for the application of IoHT. Contributions to the ethical paradigm surrounding IoHT can provide a lens for future research in the field and influence the agenda for ethical policy implementation in IoHT.

## II. THE IoT IN HEALTHCARE

### A. The Emergence of IoHT

The IoHT is a fundamental driver for the digital transformation of healthcare and is expected to play a central role in the strategic agendas of health initiatives at worldwide level. The IoHT is used to refer to a connected infrastructure of healthcare devices and software applications which can communicate with various healthcare IT systems and enable real-time intervention solutions thus improving the overall delivery, affordability and reliability of healthcare services [3], [4]. In parallel with the concept of IoHT, the term Smart Health is used by the European Commission to also refer to innovative networked technology-driven healthcare solutions [5], [6]. The term Smart Health emphasizes the introduction of novel possibilities for the management of healthcare in the 21st

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century. The idea of the IoHT can be employed in different settings, both clinical and non-clinical [7], as well as in various locations, such as the healthcare provider's premises, the patient's home and the street [5], [6]. As IoHT can be used in a wide range of applications, namely clinical, consumer and research, it can encompass long-term monitoring, management of health and chronic illness and consumer-level health and well-being management [8].

### B. Opportunities for IoHT

The application of the IoHT is expected to support the creation of a highly interactive ecosystem among a broad range of stakeholders, such as patients, carers and healthcare providers. Such an ecosystem can provide significant opportunities for a mutual gain to all involved parties.

For patients, IoHT can provide several positive outcomes, namely improved drug and disease management, improved diagnosis and treatment, effective remote monitoring of chronic diseases and an enhanced overall patient experience [2]. IoHT brings the patient at the center of the healthcare system and aims to empower patients by encouraging them to adopt a more (pro)active role in the management of their healthcare status. In the context of healthcare a (pro)active approach suggests a two-dimensional relationship that involves both ends of the healthcare service, the healthcare providers and the healthcare recipients co-influencing the dynamics of healthcare provision. Such a proactive approach is an integral part in the realization of preventive healthcare practices that can facilitate better and timely healthcare decision making. Through the analysis of the IoHT data, it is likely to obtain a better understanding of the contributing factors to different diseases and the effectiveness and efficiency of various treatments thus supporting the advancement of the diagnosis, treatment and prevention of diseases and the promotion of healthier practices among broader populations [8], [9].

For healthcare service providers, IoHT can support the development of new business models and changes in work processes and at the same time lead to productivity improvements and cost containment [10]. Healthcare service providers globally are under the microscope facing a high level of scrutiny due to criticisms for poor quality in healthcare provision and are concurrently confronted with significant financial constraints in the allocated budgets and shortages in the human resource healthcare labor. All these exacerbating problems render the transformation of healthcare systems absolutely vital and urgent. For the alleviation of the challenges that healthcare systems are encountering, innovative technological solutions, such as the IoHT, are considered rather promising [11].

## III. THE HEALTHCARE CONTEXT & EUROPE

### A. The Environment of the Healthcare Sector

The healthcare sector is confronted with significant socio-economic challenges that call for a fundamental reform of the status quo of healthcare systems around the world. The most

pressing socio-economic challenges involve an ageing population as a consequence of the shifts in demographics resulting to a rise of chronic diseases and the spiraling costs of healthcare provision versus constrained financial budgets. On a global scale, healthcare expenditure is expected to grow from \$7.1 trillion in 2015 to \$8.7 trillion by 2020 and the percentage of people aged 65 and above is expected to double by 2050 [2].

Continuous medical advances have resulted in higher life expectancy which in conjunction with an increasing ageing population creates a significant need for long-term healthcare provision [12]. The chronic diseases, some of which are exacerbated by lifestyle, that are associated with an ageing population involve heart diseases, diabetes, lung and kidney disorders, Alzheimer, cancer and overweightness all of which are challenging and expensive to cure [13]. In addition, the supply of a labor intensive base that is required to meet the needs for long-term healthcare support is at stake. The shortage in healthcare labor is estimated to reach in Europe 20 million by 2025 [12], [14].

As a consequence of the increased complexity in healthcare demand, the conflicting challenges and the major constraints that the healthcare terrain is evidencing, a major shift in focus from disease treatment towards disease prevention is rendered crucial for healthcare systems in the developed world. This healthcare trend and repositioning is aligned with the concept of Predictive, Preventive, Personalized, Participatory and Precision (5P) medicine that provides opportunities to transform healthcare systems and empower patients [12]. In this strategic healthcare goal, the role of technological innovations is recognized as a catalyst. Consequently, advancements in pervasive digital technologies, such as the IoHT, Big Data, Robotics, Artificial Intelligence and High Performance Computing, have the potential to remedy the challenges the healthcare sector is facing and offer opportunities for radical changes in healthcare enabling new approaches to prevention, personalized medicine and access to integrated healthcare whilst supporting independent living [12].

### B. Healthcare Policies in Europe

To counteract the aforementioned challenges and develop more efficient and effective healthcare systems, governments at worldwide level have been placing innovative solutions at the heart of their strategic health policy agendas. Whilst IoHT-based services are in their nascent stage and relevant policies are still scarce, eHealth (electronic health) policies that set the broader framework for innovative healthcare strategies have long been a key goal in Europe.

In 2004, the European Commission (EC) launched the eHealth Action Plan which was the first formal commitment by its Member States to cooperate in the area of eHealth [15]. In 2012, the EC unveiled a second eHealth Action Plan covering the period 2012-2020 that aimed to address the barriers to the deployment of eHealth systems [16]. Two years later, in April 2014, the EC initiated a public consultation on mHealth (mobile health) for input from interested stakeholders

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to identify barriers and challenges related to the use of mHealth [17], [18]. The EC in its latest communication for the digital transformation of health and care acknowledges the role of technological advances, such as these in the field of IoT, and their potential for research purposes and for introducing personalized healthcare solutions [19].

### C. IoHT Initiatives in Europe

The EC is currently investing and exploring the possibilities of the IoT including its potential in the healthcare domain through certain initiatives and projects.

In 2016, the EC launched the IoT European Platform Initiative (IoT-EPI) under which seven research and innovation IoT projects are funded by the Horizon 2020 programme [20]. One of these projects is titled INTER-IoT running from 01/01/2016 to 31/12/2018 and will be tested in two application domains, port transportation and logistics and mobile health. One of the main objectives of INTER-IoT is the design and implementation of an Integrated Interoperable Open Platform for Mobile Health Monitoring (INTER-Health) that will support health monitoring at three different locations, namely at healthcare centers through the center's facilities, at home through a set of medical consumer devices, and in mobility based on body sensor networks [21].

An additional current large scale European project is ACTIVAGE (2017-2020), a Multi Centric Large Scale Pilot on Smart Living Environments, whose objective is to build the first European IoT ecosystem across nine deployment sites in seven European countries (Spain, France, Italy, Germany, Greece, Finland and United Kingdom) through the reuse and scale up of underlying open and proprietary IoT platforms, technologies and standards and the integration of new interfaces needed to provide interoperability across these heterogeneous platforms [12], [22]. The end goal of ACTIVAGE is to enable the deployment and operation of Active & Health Ageing IoT based solutions and services at large scale by supporting and extending the independent living of older population in their living environments and at the same time responding to the real needs of caregivers, service providers and public authorities [12], [22]. ACTIVAGE therefore aims to respond to the challenges arising from the sociodemographic trends that will prevail in the future.

## IV. ETHICAL CONSIDERATIONS FOR IoHT

The transmission and processing of sensitive, unstructured and dynamic data and the high degree of automation that form the basis of IoHT pose some fundamental ethical concerns and associated risks in the context of healthcare. Ethical concerns with IoHT may occur at three main levels, device, data and practice [8]. The first stems from inherent risks of Internet-enabled devices, the second concerns the sensitivity of health-related data and the third is associated with the impact on the delivery of healthcare [8]. The identified ethical concerns as these are classified at the three levels and a mapping of the relevant emerging implications are presented in Table I. The ethical dimensions concerning IoHT that are discussed here derive from a systematic literature review in six databases (Web of Science, SCOPUS, Global Health, Philpapers, PubMed and Google Scholar) between 2000 and 2016 [8]. Whilst there is some overlap among the concerns raised at the three levels, this classification can act as a useful organizing structure for future discussion on ethical design and deployment of IoHT [8].

TABLE I
IoHT ETHICAL CONCERNS AT DEVICE, DATA AND PRACTICE LEVELS (BASED ON [8])

| Level | Ethical Issues | Implications |
|---|---|---|
| Device | Personal Privacy | - Fear of loss of Protection of Physical Boundaries<br>- Fear of loss of Social Interaction that could lead to Social Isolation |
| | Obstructiveness, Stigma and Autonomy | - Disruption of patient's normal behavior or autonomous decision making due to monitoring<br>- Patient's social identity stigmatized by health condition<br>- Safety concerns due to imprecise/false entry of data by patients |
| Data | Informational Privacy | - Fear of loss of data control emphasizing the importance of transparency in the collection and processing of information |
| | Data Sharing and Autonomy | - High level of surveillance by healthcare providers in cases of abnormalities eliminating patient's self-determination |
| | Consent and the Uncertain Value of IoHT Data | - Lack of an explicit informed consent mechanism and inadequacy of single-instance consent approach in cases of repurposed data |
| | Ownership and Data Access | - Legislative frameworks covering the right to be forgotten and modify personal data<br>- Danger of misinterpretation of data due to limited experience or expertise<br>- Intellectual property rights in relation to beneficial outcomes emerging from the utilization of data |
| Practice | Social Isolation | - Diminish of interpersonal communication between healthcare providers and receivers |
| | Decontextualisation of Health and Well-being | - Health and Well-being interpreted as an objective measure eliminating the importance of contextual factors, such as the social, mental and emotional state of the patient |
| | 'Good' Care and User Well-being | - Fear of loss of trust and relational understanding between the healthcare provider and recipient resulting at the expense of in-practice excellence |
| | Risks of Non-professional Care | - Lack of medical, moral and legal deontology associated with informal carers emphasizes the ideal of patient self-responsibility |

This paper focuses on the ethical considerations emerging from the application of the IoHT. Such a disruptive technological paradigm entails a dynamic mode of healthcare delivery and a complex web of stakeholders whose role may evolve during the process of healthcare provision, thus raising a number of ethical dilemmas. Reflecting upon the points raised in the systematic review conducted by [8], conflicting requirements and further ethical dimensions are discussed in

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section 'A. Emerging Ethical Themes for the IoHT' that can contribute to future research in ethical paradigms for the application of the IoHT.

### A. Emerging Ethical Themes for the IoHT

The diminish of interpersonal communication among the key players involved in the delivery of healthcare in the IoHT ecosystem and the possibility of pervasive IT systems, such as robots, replacing healthcare professionals significantly reshapes the healthcare provider-recipient relationship and how healthcare provision is overall perceived as it is also stated in [23]. A 'dehumanization' of the healthcare support environment creates a major ethical tension. It will be useful to consider the specific contextual factors where pervasive technologies can be successfully and safely employed. Such a suitability assessment can be determined by the patient's health condition. Complicated health conditions are likely to raise safety alerts thereby emphasizing the need for a careful consideration of possible adverse effects that should be carefully monitored. As such it will be essential to identify the possible effects to different patient groups and particularly those groups that are likely to face the most challenging conditions, such as the elderly who are likely to experience a complicated combination of healthcare requirements. In complex health situations, the role of the surrounding human-centered environment is fundamental to support the healthcare process. Whilst informal carers are expected to be part of the IoHT paradigm to avoid any potential risks, it is essential to engage healthcare professionals and experts in critical stages of the healthcare process. Accordingly, a major priority will be to strictly determine the ethical boundaries of the decision-making and accountability and liability framework concerning the provision and management of healthcare. Although one of the main goals of IoHT is to enhance patient autonomy and self-determination, it is likely that certain patient groups, such as the older and disabled groups, will need the intervention of an intermediary agent to support their health, thus perplexing further the ethics around IoHT. Disabled people are a special group of interest for the IoHT, as according to statistics it refers to about 15% of the world population with 2-4% experiencing significant difficulties in their daily lives [24]. Furthermore, this figure is estimated to rise due to the ageing of the population and the rapid acceleration of chronic diseases [24].

A careful ethical consideration of decision-making, accountability and liability is very important in a complex multi-stakeholder setting where the boundaries of physical and virtual world are blended as in the case of the IoHT. The ethical boundaries need to be carefully considered in order to prevent exposure for both healthcare service healthcare providers and recipients to dangers and potential health damage.

## V. Conclusion

The IoT is characterized as the next industrial revolution and its disruptive technological paradigm is influencing a broad range of applications and diverse industries. The healthcare sector is expected to experience the impact of the IoT at a significant volume. As such, the sub-field of the IoHT has emerged which refers to the creation of a highly interactive ecosystem among a broad range of stakeholders, patients, carers and healthcare providers that aims to facilitate better and timely healthcare decision making. Consequently, IoHT can provide a mutual gain to all related parties allowing healthcare providers to function more competently and patients to receive better healthcare treatment and self-management.

The objectives that IoHT aims to achieve are in line with the targets that healthcare systems around the world are setting to overcome the socio-economic challenges that they are confronted with. The role of pervasive technological innovations, as is the case of the IoHT, is pivotal for the passage into the very much needed digital transformation and modernization of the healthcare sector. A wide level of IoHT adoption is expected to indicate a major shift in the focus of healthcare systems from disease treatment to disease prevention and lead to the development of personalized and preventive healthcare value systems. Nevertheless, the application of IoHT raises some fundamental ethical concerns.

This paper included a non-exhaustive review of ethical considerations related to IoHT providing some additional ethical perspectives that should be part of the IoHT ethical agenda. Within a complex, multi-stakeholder environment that IoHT operates, ethical frameworks need to specify the boundaries of decision making, accountability and liability for the various healthcare stakeholders involved in the healthcare process. These ethical boundaries are likely to vary for each patient group according to its personal condition and needs. It will be useful for future studies to explore these variabilities in the ethics of IoHT that are attached to different patient groups. The intention of this paper is to raise awareness of work in progress in the emerging area of the IoHT and indicate some possible ethical angles for future research in the field of ethical IoHT.

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