

# Internet of Things Application in the Healthcare Sector

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**Abstract-** The healthcare system implies a multi-factorial and multi-disciplinary approach because of the complexity of the entity itself. Internet of things (IoT) provides flexible and personalized solutions at a low costs. A literature review of application of IoT in the healthcare sector, with a particular focus on the operating room, has been performed.

**Index Terms-** Internet of things, Healthcare, Operating room, Monitoring, Efficiency

## I. BACKGROUND

The IEEE Community defines the IoT as: "... a self-configuring and adaptive system consisting of networks of sensors and smart objects whose purpose is to interconnect "all" things, including every day and industrial objects, in such a way as to make them intelligent, programmable and more capable of interacting with humans"[1].

In addition, non-private hospitals represents complex system to manage, characterized by enormous and urgent needs and limited resources [2], [3]. Internet of things provides solution at lower costs [4].

## II. LITERATURE REVIEW

A literature review has been performed according to the following steps: (i) identification of the keywords and their combination; (ii) selection of a source database; (iii) results analysis. In a first selection on key words (i), the extraction was for: "internet of things", "operating room application", "healthcare", whereas the second one was composed by the following: "hospital", "artificial intelligence", "distributed computer system", "privacy". The searches were done separately for each keyword applied to the journals' abstracts, title and keywords in each specific search engine. In the second step search (ii), two different abstracts and citations databases of peer-reviewed literature has been selected: Scopus and Science Direct. At the end of this phase 25 articles have been collected.

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After a first evaluation of the abstracts, 22 studies have been considered. The collected papers were systematized in terms of: names of the authors, year of publication, journal title, objective, approach and characteristics. During the third step (iii), a new systematic analysis of core specifics has been performed. The present paper provides the state of the art in the healthcare application of Internet of Things IoT. Table I reports the results of this analysis.

TABLE I  
State of the art in the healthcare application of IoT

Field of Application	IoT	Healthcare	Operating Room	Total
Hospital	4	2	3	9
Artificial Intelligence	3	2	2	7
Distributed computer system	3	2	1	6
Total	10	6	6	22

According to Figure 1, the topic was first covered in 2008, but nearly no significant paper appeared until 2012. Starting from 2015 an increasing interest in this field was evident, in fact the number of articles fast increased to reach us to maximum at 2016 and 2017. The authors reported also the data of 2018 which is still in progress.

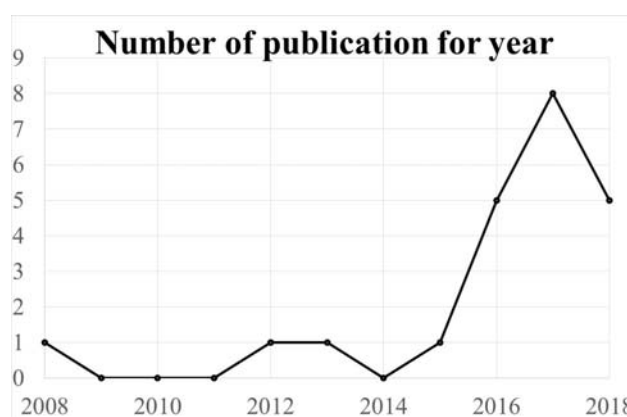


Fig. 1. Publications for year

Reference [5] focused on three main areas of IoT intervention in the healthcare:

- clinical care: sensors will help hospitalized patients for a continuous monitoring and the doctors reducing the time

spent for the moving between patients to reveal their health status. In addition IoT “will help them for rapid intervention in an emergency and will enable them to cooperate with international hospitals to track a patient's condition”.

- home care: for a continuous monitoring especially for the chronic patients.

- healthcare assistance: “Wireless body sensors can be used as well as in personal care in order to maintain health and fitness”.

Accordingly to ref. [5] the application of IoT in the healthcare sector has been conducted by the authors focusing on three main areas: operating room, monitoring and tracking, fog computing, privacy.

#### A. Operating room

Reference [4] shows how the application of IoT in the operating room can help with the reliability of the data and consequently of the Key Performance Indicators (KPI). In the hospital subject of the study the surgical session planning will be assigned accordingly to three parameters: KPI, surgical waiting list and a sustainability corrective factor. The use of Internet of Things (IoT) could help the data caption in real time and with an efficient allocation of the surgical slot.

Reference [6] reports how IoT can be used to improve the technical skills of the young orthopaedics. One of the most important activity involves “navigating through varying soft and hard tissues by hand, and, most importantly, understanding how medical instruments respond under these conditions”. The students time to learn is limited and the resources are limited (e.g. high cost of cadaver parts, etc). IoT gives the opportunity, through the data extraction after the training section, to the teachers to determine if the students learn a subjective skill. Without those data the residents would not have quantifiable numbers to guide them.

Reference [7] makes a point on the anesthesia record which should be accurately and comprehensively captured a patient’s anesthetic experience in a succinct format. Human errors are very frequent. IoT should: Improve cost containment, better operations management, reimbursement increase, Improved quality of care, higher safety, translational research and last but not least, better documentation. The authors suggest to implement a system which is not a stand-alone one.

Reference [8] reported two main field of IoT application: govern drugs along with the supply chain from the manufacturer to the consumer and to govern the movement of things in the operating theatre. The first application has been created to avoid counterfeit drugs and to recall drugs and it has been implemented through the 2D bar-code. The second example relates to an operating room monitoring tracking which has been implemented for patient safety: more precise documentation and less surgical-related complications (e.g. retained external objects in the abdominal cavity) In fact surgical towels were tagged with RFID tags. A direct consequence is that the safety of the

surgical procedure can be increased as well as the work-flow optimized.

#### B. Monitoring and tracking

IoT in combination with artificial intelligence, big data, decision making, information and communication technology (ICT) can be used in the smart city to the deployment of disease diagnosis [9]. In addition, “important challenges, including privacy, pilot studies and real project and communication between data managers and medical staffs, have been discussed”.

Reference [10] shows how IoT can support with the efficacy of the clinical treatment. The authors performed a real-time free flap monitoring based on an implanted Doppler system and “internet of things” (IoT)/wireless Wi-Fi. Through the IoT they achieved greater total survival rate (94.7% versus 89.5%).

Reference [11] introduces the opportunity to use IoT to localize the position of patients/medical staff/devices in real time. In addition this a low cost solution and it can be used to achieve the optimization of care delivery. Similarly, ref. [12] introduces the Passive RFID Tag Antenna-Based Sensors and Systems achieve the high efficacy of monitoring the asset and the people. In addition it can improve the communication, the safety and the localization.

Reference [13] shows a Real-time Locating Systems (RTLS) also well known as real-time location systems as a location aware systems. RTLS systems are primarily used for the object tracking placed indoor and can be used for patient admittance in an emergency department. In fact a database and a mobile application have been developed on the base of the Internet of Things allowing the fully digital archiving patient records. The authors developed a RTLS system based on the Infra Red (IR) system with anchors where the location of the patient is acquired using IR tags.

Reference [14] implemented an e-Health technologies system in an emergency room inside an hospital for the medical information transmission.

Reference [15] shows how IoT can help to better locate the patient and the physicians in order to manage in an efficient way personnel and resources. The proposed solution is based on readily available RF transceivers and microcontrollers and wearable sensor system which can facilitate locating users (e.g., patients or doctors) or objects (e.g., medical devices) in a building.

Reference [16] relates on how IoT can cover medical error issues and can also improve patient safety and quality. A categorization of the human errors has been reported. IoT is a valid instrument to implement human perception, decision-making and knowledge. A direct consequence is patient safety improvement.

Reference [17] reported different examples of smart items equipped with sensors appropriately placed around patients and the work environment of caregivers, thus monitoring different vital signs of human health and managing the work process of caregivers. This analysis was first performed by a German project named “Optimaler Einsatz von Smart-Items Technologien in der Stationären Pflege” which involved

healthcare specialists and IT professionals to model reference processes for practice-oriented cloud applications in the healthcare domain.

### C. Fog computing

Reference [18] focuses on the different healthcare application use cases presented in the literature and on the benefits which are derived from the implementation of that system. In addition an important analysis was conducted in order to face the privacy requirements in fact a list of recommended research and development actions is presented.

Reference [19] shows how “The needs for real-time response and ever increasing data demands novel solutions” will find a solution through the “Edge computing (fogs, cloudlets, micro datacenters, and mobile edge computing)”. This solution gains a real time response and it is near to end cloud services. It includes technologies such as Fog computing, Mobile Edge Computing, Cloudlet and Microdata center. Interesting application in the healthcare sector are reported where a real time monitoring of the frailty patient is required.

### D. Privacy

The privacy aspect for Wireless sensor has been solved in ref. [20] through a solution comprising of Identity, Route and Location (IRL) privacy algorithm and data privacy mechanism, that collectively provides protection against privacy disclosure attacks such as eavesdropping and hop-by-hop trace back attacks.

Reference [21] provides how some smart plug system are vulnerable and through four launched attack they demonstrated that it's possible to obtain the authentication credentials from the users. In addition guidelines have been presented.

In Figure 2 is reported the main field of research of the IoT application in the healthcare sector. As we can notice “Monitoring and tracking” is the principal one.

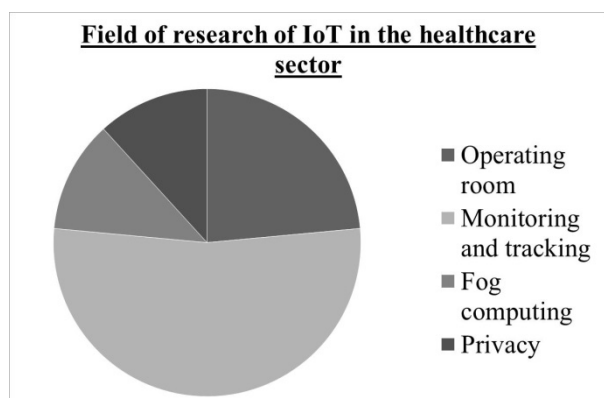


Fig. 2. Field of research of IoT in the healthcare sector

## III. RESULTS AND CONCLUSION

The major advantages of the application of IoT in the healthcare sector are:

- Lower costs
- Monitoring of the patients in real time. This means less unnecessary visits to doctor, and less hospital stays and re-admissions thanks to efficient data collection and management better patient experience.
- Being connected to the health care system through the Internet of things, patients get more engaged in their treatment, and doctors improve diagnosis accuracy since they have all the necessary patient data at hand, better management of drugs and medicine adherence, IoT solutions allow hospital staff to spend less time searching for drugs, track supplies and medicine, and track hygiene practices in hospitals and effectively prevent hospital infections.
- Reduced errors and waste, Using IoT for data collection and workflow automation is an excellent way to cut down on waste (such as unnecessary tests and expensive imaging), reduce system costs and minimize errors (especially the ones related to human factor).
- Improved Outcomes of Treatment, Healthcare solutions that are connected through cloud computing and use big data, can provide caregivers with the ability to access real time data which can be used to make informed decisions and to provide evidence-based treatments.
- OR utilization performance has been widely used as a measure for many health-care organizations. Given many potential factors that would impact the utilization, the identification of the most important factors that impact the utilization will assist the decision-making process of OR management.

The IoT application in the healthcare sector involves also some critical point such as the privacy aspect. Reference [22] discusses about the topic of the convenience of the IoT application and the authors focused the attention on three critical points: gossiping technology, personalization and the disempowered smartphone user.

Accordingly to the literature review on the topic of IoT in health care, the authors believe that more studies are needed in order to better understand possible application.

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