Smart hospitals in smart cities

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SMART HOSPITALS IN SMART CITIES

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ABSTRACT

The Internet of Things (IoT)has contributed to the beginning of the era of Smart Cities, Smart Schools, Smart Homes and then Smart Hospitals. Smart cities are able to reduce maintenance costs by optimizing energy consumption, to improve citizens' safety, to monitor and control municipal functions like parking, traffic, lighting, and overall satisfaction of all residents.

At the same time, in this increasingly wireless and connected world, also many hospitals and healthcare facilities are connecting to Internet of Things, devices to enhance security, safety, operational efficiency and the patient and resident experience.

One of the issues to be addressed is that hospitals are still not very smart. The problem is not so much the diffusion of technologies, rather then to make sure that those already present, that are almost always isolated can dialogue with those of recent development and thus create new generation of infrastructures. For example, any hospital has security systems, the evolutionary leap is to enrich all this with new platforms to create an integrated and reactive system.

Another issue is also connecting the Smart City with the Smart Hospital in order to maintain the care also after the check out, to accompany the patient after the discharge from the hospital in his/her journey back home and throughout all the period of convalescence.

In this sense it is very important to have a connection between IoT, Cities infrastructures and new diffused Hospitals infrastructure in the cities.

The article, starting from the description of two examples of European University Smart Hospitals (Careggi Smart Hospital in Florence, Rovereto Hospitaland the Karolinska Hospital in Stockholm), analyzes the potentiality of the new technologies embedded in Smart Hospital, and identifies the main strategies to connect the Smart Hospitals with the Smart Cities.

Keywords: Internet of Things (IoT), Smart Hospitals, Smart Cities.

Technological innovation in Hospital buildings

In 1999, at the Massachusetts Institute of technology, the British technologist Kevin Aston coined the term "Internet of Things – IoT" as system able to "connect devices such as everyday consumer objects and industrial/commercial equipment onto the network, enabling information gathering and management of these devices via software to increase efficiency, enable new services or achieve other health, safety or environmental benefits".

Internet of things (IoT) startsthe beginning of the 4thindustry technological revolution and it represents a network connecting any items with internet with the aim to implement information

1 Corresponding author

exchange and communication, furthermore to implement intelligent recognition, positioning, tracking, monitoring and management, by means of radiofrequency identification (RFID), infraredsensors, GPS, laser scanners and other information sensing equipment, according to conventional protocol (Gu, JingJing; Chen, SongCan; Zhuang, YI).

Digital and smart technologies are now an integral part of our everyday life and often hidden in the objects that we use, in the functions that help us to live better, to work, to have free time and so on.Even cities are now becoming more and more smart, integrating technologies for energy management, including those from renewable sources, for the smart mobility, the use of big data for monitoring traffic or the level of pollution or for preventing natural disasters.This global technological evolution allows today to use the potential of digital communication technologies also in terms of Health 4.0, with the aim of increasing people's health, information security, sustainability of medical care and use of enabling technologies related to online health.

The 4.0 Hospital is an integral part of the Smart City, thanks to the advanced and capillary sanitary networks that allow the communication and data from the hospital building to the city up to enter in our homes. So the Smart Hospital allowsto monitor remotely the health status of long-term patients (for examples telemedicine). This allows not only to make the health supply more widespread and to improve its quality but also to have a saving of current levels of expenditure.For what concerns specifically IoT in Health Care, three different settings are usually considered: - Acute care (hospitals), - Community-based care (home setting) and Long-term care (nursing homes).IoTs can be used to collect patient and other data in these settings, and aggregate data using analytics and then reporting the information to caregivers and or take some action, (Laplante, Philipp; Kassab, Mohammad; Laplante, Nancy; Voas, Jeffrey). Following the concept of the patient-centred or people-centred, the aim is that in the future the patients will be supposed to come up with a plan that works for them, together with their healthcare staff. So the patient is not any more a passive part of the treatment, rather is will be included as partner, (Barsaum, Peter; Berg, Paul; Hagman, Andreas; Scandurra, Isabella).

What defines a Smart Hospital?Smart hospital, based on technology of IoT and constructed with the vector of various application service systems, is a new kind of hospital in which are integrated the function of diagnosis, treatment, management and decision with intelligent systems of ICT. The features of IoT, such as comprehensive perception, reliable transmission, intelligent processing and so on provides technique support platform for the construction and implementation of smart hospital (Lei, Yu; Yang, Lu; Xiao, Juan Zhu).

An hospital building is Smart not only when all the aspects related to patient care, logistics, tracking of personnel and users, tracing of medicines, intelligent care devices, etc. are smart, but also everything related to spaces, architecture andbuilding installations are Smart.What are the main technological innovations that make an hospital smart?Some of the key technologies involved in Smart Hospitals are:

1.Internet Technologythat represents the engine that make the system fully functional, through use of wireless communication, IrDA (InfraredData Association), Buetooth, WIFI (wirelessFidelity), UWB (untrawideband), Zigbee, and so on.

2. RFID Technology: RFID (Radio-Frequency Identification) is "a technology for the automatic identification and/or the storage of information related to objects, animals or people (automatic identifying and data capture, AIDC) based on the data storage capacity of particular electronic labels, called tags (or even transponders or electronic or proximity keys), and on their ability to respond to remote interrogation by specific fixed or portable devices, called readers (or even interrogators)", (Wikipedia).

- Rfid technology, applied to the care system allows: the traceability of personnel and patients to locating them, the traceability of medical instruments and miscellaneous material to make logistics more efficient with the effect of saving costs and time, increasing safety for the pa-

tients. For example providing each employee with an identification tag on radio frequencies, it is possible to precisely manage the accessibility of everyone to areas of its own competence, prohibiting at the same time its access where it is not allowed.Another use is the use of RFID technology in hospitals is to track workwear. Tracing the garments entails advantages both in the management of laundry operations and in the phase of order and reordering of materials.

- Rfid technology, applied to hospital building allows: to have the story about the maintenance operations of the plants and of the structural components of the building. This is important to make efficient programmed maintenance. Rfid applied to the buildings allows to know the origin of construction materials and furniture, to guarantee the use of sustainable materials, without toxic substances.

3. Sensor Network Technology that is the core of IoT and it can cooperatewith RFID systems to better track the status of things, i.e.their location, temperature, movements, etc. Sensornetworks consist of a certain number (which can be veryhigh) of sensing nodes communicating in a wirelessmultichip fashion. Usually nodes report the results of theirsensing to a small number (in most cases, only one) ofspecial nodes called sinks. With the continuousdevelopment of science and technology, the traditionalsensors are in the procedure of microminiaturization,intellectualization, and beingnetworked (Atzori, Iera, Morabito).

- Sensor Network Technology applied to care system offers various forms of personalized care, monitoring personal health conditions also by remote way as well as enhancing patient safety. It allows assistive home monitoring system forpatients, incorporating medical datacaptured via different biosensors embedded into the patient's physical surrounding (Holzinger, Martina).

- Sensor Network Technology applied to hospital buildings allows several applications, such as environmental monitoring, control energy saving,plant monitoring, lighting, fire protection, access control, heating and air conditioning, anti-intrusion, video surveillance, security. It consists of electronic devices designed to monitor and control the different sub-systems of a buildings.

Several research projects developed prototypes of pressure sensitive floor elements allowing the detection of falls without additional technology being worn by the patient. While early systems distributed pressure sensitive floor tiles at specific locations within the environment (Holzinger, Martina).

4. Embedded Technology:IoT is an embedded system based oninternet. Just because more and more intelligent terminalproducts have the requirements to network, it hasten theproduction of IoT concept (Xiaohui, Liu).

5. Blockchain:another recent system that makes up the IoT is the technology of the blockchain. This technology derives from bitcoin technology, and itallows to read large volumes of heterogeneous data coming from nanocomponents, mobile devices, app and internet of things. The true disruptive innovation is undoubtedly the use of the blockchain system applied for the first time to the exchange of medical data that summarize the clinical history of a patient in an encrypted, sequential and accessible to everyone way.

6. Software and BIM: another advantage is the use of the BIM (Building Information Modeling) methodologies that allow, through the mapping of the hospital building, to manage and control the hospital management and maintenance planning process. BIMallows managingthe activities and roles of the different operators involved in the various stages of the design process, through the exchange and sharing of complex data and multidisciplinary knowledge. One of the main objective is to guarantee the saving of energy consumption by developing design models capable of simulating alternative conditions, measuring the impact of different technological choices and helping the decision about the collocation of various spaces and functions. Energy efficiency is one of the strategic objectives on which these models are focused, both for the purposes of cost containment and environmental compatibility.

Through the implementation of smart hospital, it canimplement the application system based

on digitalenvironment to promote the implementation process insmart diagnosis, smart treatment, smart management,smart decision and smart service.Each citizen can therefore be connected to an adaptive and intelligent infrastructure that through blockchain, IoT, wearable devices and networks, can inform people about their state of health through sensors and notifications and will contribute to raising the expectation of a healthy life from the physical and mental point of view.

ICT Technologies application in existing Hospitals: the cases of Careggi Hospital in Florence and Rovereto Hospital

Integrated data management in an existing hospitalbuilding that moving to become "smart" representan opportunity to improve healthcare services offer.

In particular,the possibility for every citizenof accessing to healthcare information in a virtual way allows improving the efficiencyof the referring healthcare system. Healthcare companies are acquiring information systems capable of retrieving data from internal and/or external databases with the aim of managing many data about the patient's care path.

According to the indications of the EU eHealth Action Plan, the University Hospital of Careggi in Florence (AOUC), starting from 2013, utilizes a platform named "Careggi Smart Hospital", defined as "a platform for the development of new applications to simplify the life of hospital users through the use of technology ".Through multi-channel access solutions with app, web and Totem, the platform offers to citizen the possibility to access at all digital health services. The system can be used in a public or a private mode (customizable according privacy characteristics that each user chose) and it allows managingmany data about different services like booking services, analysis of reports, payments, control of therapeutic pathways and information on care services about the hospital area. The platform allows also having a map of spaces of the entire university hospital campus thatconsistof 50 buildings covering more than 250,000 square meters.

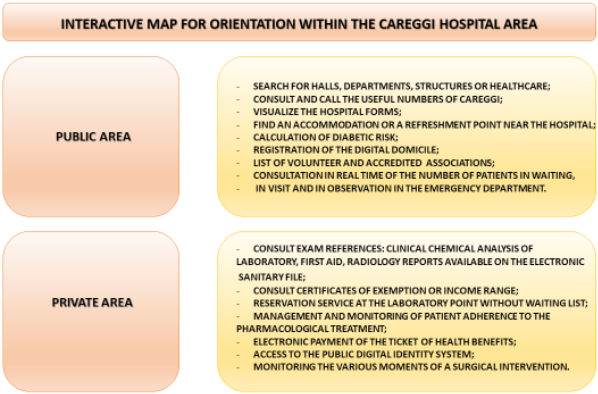

Figure 1: Interactive map for orientation within the Careggi Hospital Area

The Smart application retrieves in a real-time data from the various systems used in the hospital. In particular, the system of Careggi Smart Hospitalcollects data from operational-management databases with the aim to define a framework of coded information simplified for users. The wayfinding module of the App is a "search engine" that allows the user to find buildings, paths, activities, people and functions in over 15,000 environments (rooms) in the Careggi

Hospital area.The App is based on the Computerized System of Structural Consistency Analysis (S.A.C.S. ©) that manages a series of information summarized in:organizational, structural and plant data, relating to all 52 buildings belonging to the Careggi Hospital. SACS is a suite of software that, on the scale of the single room (room), manages data related to the health organization, to the personnel, plant and technology types as well as functions strictly related to the management of space and equipment maintenance, locating information on the structural dimensional consistencies of buildings and their territorial structure. Careggi Smart Hospital offers a view of the system on information concerning certain characteristics, such as personnel, the use of environments and the homogeneous clusters related to the types of care present in the pavilions or in portions (blocks).

Thanks to the smart app it is possible to carry out targeted research, such as the location of medical personnel (and their institutional references in order to be able to contacted them), the location of areas of health activities identifying the building and floor and, through the interface with the plans, it is possible to identify the routes to perform in order to achieve the function, based on the user's location.

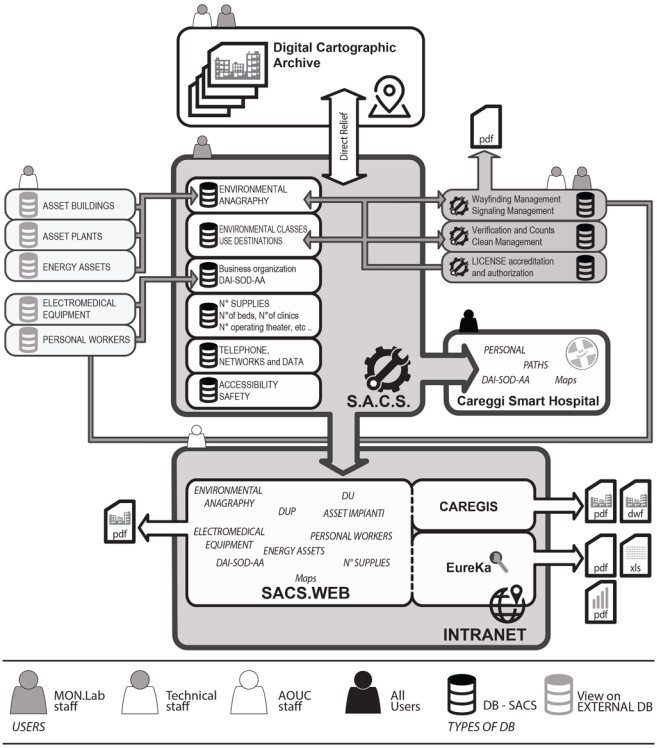

Figure 2: Saacs Concept Configuration

Another interesting system is "I-Locate", a software developed in Rovereto Hospital (Italy). The project involved 24 European institutions with the aim of creating a portal for geographic data related to indoor environments, and an interoperable platform able to support different technologies of "indoor location". The Rovereto Hospital was identified as the optimal facility for experimentation. In fact, the idea was to experiment this software in medium-sized hospital

in order to produce replicable and diffusive results in other large-scale hospitals. The software was tested in other hospital environmentsuch as the Utrecht hospital in the Netherlands, the MITERA hospital in Athens, the St James hospital in Malta and the Alba Iulia hospital in Romania.The system, based on IoT architecture, is composed of a QR code, a wi-fi or bluetooth signal and it allows tracking placement and availability of medical supplies in real time. In addition, it is possibleto attach to object information's about, for example, instructions for the use orthe expiration of maintenance.

It will be up to the Hospital Manager to choose which data and information'sto upload on the internet portal.

New Smart Hospitals

In the previous paragraph, is described technologies of last generation that fit into existing hospital buildings. The design of the new Hospital 4.0 must take into account new paradigms and new models that exceed traditional hospital models. Conventional typological schemes such as hospitals with vertical, horizontal, monobloc, campus etc. are now exhausted models of Hospital. The hospital, first conceived as a closed system, will tend to open up to the city until reaching the patient's home, to be permeable, dematerialized and more and more integrated with highly complex technologies. The hospital changes because the approach to the disease is changing. Starting from the reactive approach to the disease, we move on to the prevention-based approach, on the medicine based on the predictive genome, on personalized medicine etc.These new methods proposed for the provision of health services require the study of architectural layouts of the hospital building as flexible as possible and able to adapt to the evolution of the technology itself.

The Smart Hospital is the place where only those patients who need high-intensity care will be called because the local network will be structured in such a way as to guarantee the services of ordinary care in a path of continuous dialogue between local social and health centers and the patient's home. Through the use of sensors, medical devices, complex devices for diagnostics and the most sophisticated equipment for the operating room, Hospital 4.0 is seen as a place designed to accommodate not only people but also many robots that will perform various functions, from operating room, distribution of drugs, meals, transport of goods.

Through the use of various electro-medical devices, able to connect to the network by sending parameters that can feed in real time the wealth of clinical information of each patient, the Smart Hospital can also be defined as a "hub", a place of convergence and subsequent redistribution of a whole series of information that can be used by general practitioners, operators in the districts and caregivers in the private houses, with the aim to manage the care plan dedicated to each patient.

A good example of a new Smart Hospital aimed to establish this "hub" system is the New Karolinska in Solna, Stockholm in Sweden, a new university hospital whose construction started in 2010 was recently completed (December 2017). The Hospital covers 320,000 square meters and it has 8,000 rooms and 35 operating theatres.

The information and communication technology (ICT) of this hospital presents a high standard in terms of infrastructure, systems, applications and equipment. ICT Procurement Projects covered ICT infrastructure, AV Solutions and Equipment, Patient Notification System and Messaging Service System.

An interesting example of the use of robotics in the New Karolinska Hospital is represented by the JIT cabinets, robots that take care of the distribution of the sanitary material.

The system is based on the "just-in-time" principle and aims to facilitate ground service for healthcare staff. In the JIT cabinets, there is all the equipment and materials that are needed. The staff can find them easily in several places on every floor close to the main corridors, help-

ing to answer easily to the users' need in the hospital. Virtually all transport takes place using these robot trucks, automated guided vehicles (AGV), which have their own lifts and will carry out around 1,600 transports per day.

The entire New Karolinska in Solna, Stockholm is interconnected with a pneumatic dispatch system that is a total of seven kilometers long. The new pneumatic tube system that have seen the collaboration between architects, researchers and technicians, has a much more modern design than the old pneumatic tube systems. This system smooths the logistics in order to send medication and blood samples between different units. The material, with the exception of biological materials and flammable substance, can be sent and move with a speed of more than 20 km/h.

Together with the remote - controlled AGVs, the pneumatic tube system helps to minimize the storage at the care units. The carrier that holds the materials has a component in it that lets the system know where it should go, a so-called RFID tag. This is the same technical component that is used, for example, to tag wild animals and track them, and it is used in the hospital AGV robots.

Caring, Privacy and Safety are defined as the most important requirements for IoT in Healthcare applications (Laplante, Kassab, Voas). The fact that "caring" was identified as an important quality in IoT for healthcare reinforces the belief that, in planning IoT healthcare applications, there is a strong need for domain expertise and deep inter-professional collaboration (in this case nurses and engineers). Both nurses and engineers will have to assist with technological insights, feasibility of use and application and understanding of IoT for the benefit of patients, families and providers. In addition, the challenge of the future of Internet of Things is precisely the resolution of the difficulties of communication between such different fields, for example between clinical engineering and computer science or better between hospital construction and clinical engineering.

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