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Methodology Article

Incorporating the Internet of Things in the Modern Hospital: Attempting a "Taxonomy" of Pertinent Equipment and Services

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Abstract: The Internet of Things (IoT) is not new, but it is attracting increasing attention recently. The concept of the Internet of Things entails the use of electronic devices that capture, monitor and transmit data, are connected to a cloud, enabling them to automatically trigger meaningful "events". The modern Hospital is the most complex and representative system created by the human society and in its present stage of development, the Internet of Things is able to lend itself, to serve the radical transformation of Health-care and of its "temple", the 21st Century Hospital. It is the purpose of this paper, to attempt a first elementary approach, to categorize the numerous and multifarious equipment and materials employed and to sort the services needed and offered, in the diverse Departments of the modern Hospital, under the light of the disrupting influence of the emerging IoT. The most important Hospital Departments and Services (Emergency, Surgery, Radiotherapy, ICU, Medical Imaging, Bio-Signals, IVD-Laboratories, Cell-therapies etc.), are presented in this preliminary "road-map approach", in combination with innovative, already existing and emerging, Health-care supporting IoT applications.

Keywords: IoT, Health-Care, Hospital, Telemedicine

1. Introduction

The Internet of Things is a hot topic in the real-world, where various appliances are being connected to a network, in order to communicate with other devices. Interesting applications appear gradually in the Health-care sector, in many different forms and levels of complexity, from Emergency and ICU monitoring systems to on-line Blood-units inventory-software, become connected and the hospital can benefit from reduced costs and time-savings.

The purpose of this paper is to attempt an elementary "road-map approach", to categorize the numerous and multifarious equipment and materials employed in Medical Practice and to sort the services needed and offered, in the diverse Departments of the modern Hospital, under the light of the disrupting influence of the emerging IoT.

Hospitals use hundreds of electronic devices, such as IV pumps, physiological monitors and vital signs monitors. However, according to our own empirical statistics in various Hospitals and from published estimations [1], less than 25% of them are currently connected to any kind of network. Connecting hospital devices that have worked independently improves the efficiency of data collection and the nurses could spend more time on direct patient care. Clinical Decision Support helps Physicians with diagnosis and decision-making tasks, and Clinical surveillance systems could review large volumes of clinical data, reducing, both, patient risks and the cost of data collection. Further, networked Medical Devices will play a large role in Healthcare outside the hospital, especially in Home-care and patients' self-inspection.

The working-group of this ongoing project consists of 5 post-graduate students supervised by their Biomedical Engineering Professor. This collective project constitutes also, a new and more creative alternative approach, to the traditional semester exams. In a first approach, the Hospital is roughly divided into in five major areas.

a) The Emergency and the Outpatient Departments.
b) The Imaging and the Radiotherapy Departments.
c) The Surgical Departments, the Intensive Care Units (ICU, CCU, NICU etc.) and the Nursing Wards.
d) The in vitro Diagnostics, the Transfusion Medicine and the Cell Therapy Laboratories and Units.
e) The various Supporting Facilities (e.g. Sterilization, Laundry, Personnel and Patients Food-services, E/M Engineering Facilities, Warehouse etc.).

Table 1 displays a rough estimation of the difficulty degree to optimize the existing solutions in each Department or Service, that depends naturally on the specific Hospital under consideration, the Medical Specialties accommo-dated in a specific Facility, the specific Country, its level of Social-Services and Health-Insurance etc.

Table 1. *A rough estimation of the expected difficulty degree to upgrade via IoT, the existing solutions in each Department or Service: Low +, Medium ++, High +++.*

Assigned Department	Heterogeneity & Scalability of the Devices	Low Energy Data exchange & Tracking	Self-organization Interoperability & Security
Emergency Outpatient	+ + +	+	+ +
Imaging, RT	+ +	+	+ + +
Surgery ICU Wards	+ + +	+ +	+ + +
IVD-Labs Cell Therapy	+ + +	+ +	+ + +
Supporting Facilities	+ + +	+ + +	+ + +

The difficulty (or complexity) degree refers to the following three major aspects, of combining Biomedical Equipment, already existing Hospital Infrastructure and IoT technology [2].
a) Heterogeneity and Scalability of the Devices.
b) Low-energy data exchange and tracking.
c) Self-organization capability for IoT devices, Inter-operability and Security.

Figure 1 displays an abstractive, however, indicative for the future "technology roadmap" of the Internet of Things. In the following paragraphs we shall attempt to focus on the existing Hospital technologies and the perspectives of the emerging or at least promising IoT-related innovations, in each of the mentioned above Hospital areas and Services.

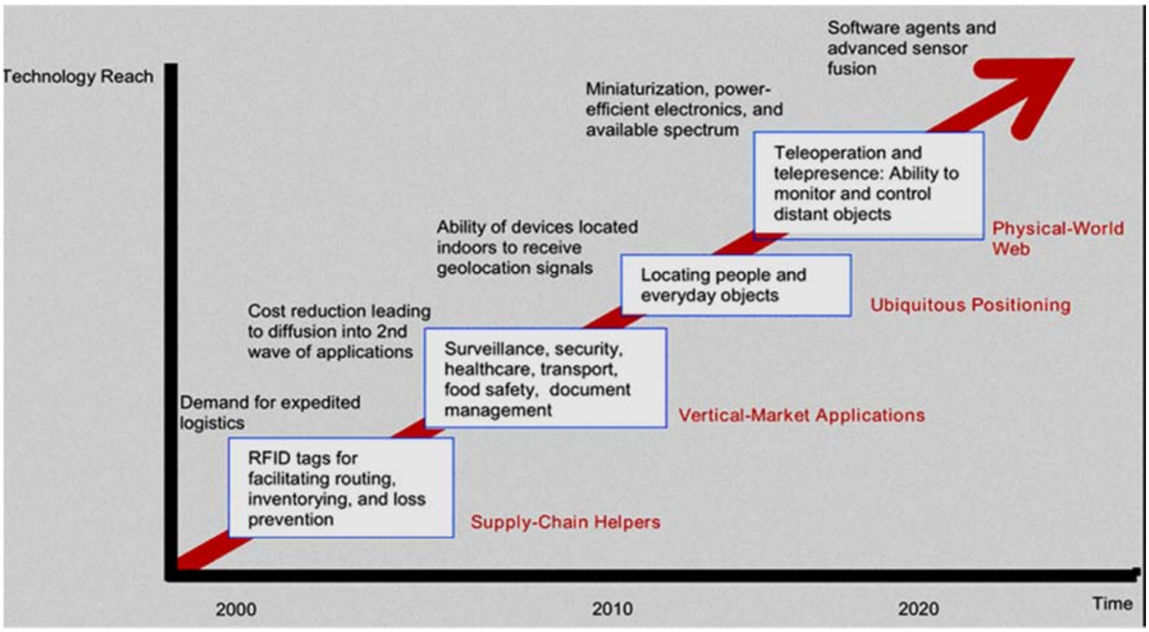

Figure 1. *A technology roadmap of the Internet of Things, SRI Consulting Business Intelligence, National Intelligence Council [5].*

2. The Emergency and Outpatient Departments

The Emergency Department and the Outpatient Departments of the modern Hospital constitute its two major interfaces to the Society. They have some similarities, however, there are major differences, concerning the urgency of the procedures, the triage of the patients and their follow-up, after discharge [3], [4].

2.1. The Emergency Department (ED)

The Emergency Department (ED) includes schematically following sequence of acting:
a) Receiving of an Emergency call or another kind of notification, of an in-coming emergency patient.
b) An "IoT-device" can accelerate the identification and the registration of the patient, by transmitting a first standard message, including for instance an ID-string a social security number and eventually, a codified

preliminary short-description, based for instance on one or two WHO ICD-10 assumed codes, over the IoT-device IP, during the transportation.

The second cardinal step is the "triage", based on:

a) The collection of in Vitro diagnostic (IVD) data, either on site by employing Point of Care Testing (PoCT) or transmitted from central Lab over the Autoanalyzer IP.
b) The collection of relevant electrical and non-electrical Biosignals, acquired on site, digitized and transmitted wirelessly and simultaneously to the patient-record, to a Decision Supporting Module (DSM), accelerating the triage-procedure and finally to the ED-records.
c) In between Medical Imaging (US, CT, MRI, PET etc.) examinations are performed on site or elsewhere, and the data are transmitted wirelessly to the Radiology Information System (RIS) and to the Picture Archiving and Communication system (PACS), contributing to the final Diagnosis and the appropriate treatment, of the ED-patient.

The IoT devices are useful, because they are able to participate fast and actively to the "reconstruction" of the distributed parts of the patient's record, and provide in a limited time-interval, to provide a more complete medical history of the patient, facilitating a rush progress of the acute patient's treatment.

2.2. The Outpatient Department

The Outpatient Department (Ambulatorium) offers usually more comfort, privacy and a little bit more time for the patients, however, the complexity and the severity of the procedures leading to a correct Diagnosis and Treatment is not much less pressing, compared to ED. Therefore, the employment of the IoT will bring all the advantages mentioned previously, providing more time and lower cost.

However, and additional advantage that can be provided in the very near future, will be the practically full automation of the Continuity of Care record and the advantages brought, by the use of semantically enriched XML; it will reduce the paper-work load and will "create" more time for the physician and the nurse, to be spent for the patients, making medical practice, a little bit more reasonable.

Synopsizing, we could remark that, as far as, the technical aspects are taken into consideration:

a) The crucial aspects related, to the difficulty degree of this transformation, the ED and the Outpatient Department (OUT) posses a high heterogeneity and scalability degree, due to the multiplicity of the ED-and OUT-devices, ranging from numerous minor devices, such as pumps, disposable catheters, O_2-saturation monitors etc, to medium-sized monitors and ventilators, up to expensive Imaging Systems and Anesthesia Machines.
b) As far as Self-organization, Interoperability and Security are concerned, the tasks to be performed can be analyzed in standardized steps and the combination of this approach, with Semantics lead to a rather acceptable quality.
c) Finally, the Low Energy Data exchange and Tracking, is easily provided in the present hi-tec environment, which is not the case, in home-care or patient's shelf-inspection settings.

3. The Imaging and the Radiotherapy Departments

The "Medical Imaging IoT" can be traced back over 20 years ago, since the concept of connecting and monitoring medical imaging equipment, via remote servers over the Internet is not new. It has been the corner-stone of the remote servicing capabilities that medical imaging vendors started to offer many years ago. Remote connectivity [6] has allowed for efficiency in equipment maintenance and support functions to a service model, adopting proactive and preventative service. Most Medical Imaging customers acquire remote services by vendors that allow for, early symptoms spotting of an approaching breakdown, minimizing, thus, downtime.

Concerning the major "Medical Imaging manufacturers", they are taking major steps towards the "next generation" of the Internet of "Medical Imaging Things".

a) GE Healthcare intents to connect 500,000 Imaging Machines, on the new GE Health Cloud, as announced at 101st RSNA, on Nov. 29th 2015, to help clinicians deliver better outcomes [7].
b) Siemens Healthcare is based on its developed remote monitoring of equipment technology (Lifenet and Siemens Remote Services, Microsoft Azure), and has made significant progress, in developing the "Teamplay" IoT platform for Medical Imaging [8].
c) Philips Healthcare's "HealthSuite" Digital Platform forms the base of its Medical imaging IoT strategy [9].
d) Finally, Toshiba intends to Collaborate with GE on a common Industrial IoT Pilot Project [10].

Today, a huge amount of Radiology Data are acquired, providing the opportunity to analyze images and associated clinical data, far more sophisticated and accurate, to improve diagnosis.

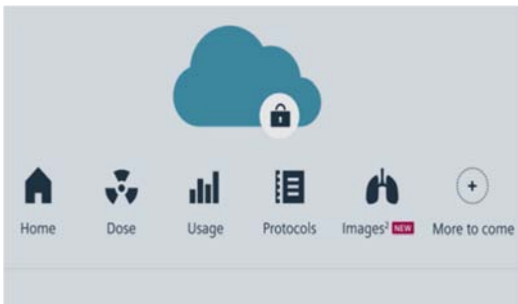

Figure 2. *The IoT cloud ecosystem of Siemens Healthcare "Teamplay" that will be open for third party, healthcare provider and academic institution app development [8].*

The IoT could contribute essentially, to the automation of the evaluation of the accumulated data and their processing, to reach more accurate individualized Diagnosis. Further, appropriate arrays of IoT-devices (cyber-actuators) could involve Radiology more actively in Epidemiological studies, by re-evaluating big amounts of Anonymized data, from around the world and by "comparing" within them, details of Medical Images, associated or assumed to be associated, with specific diseases.

The employment of the IoT, for automated recognition of Regions of Interest (RoIs), combined with the employment of mathematical methods and algorithms, driven by "machine intelligence", will be soon able to "view" and quantify the inner depths of the human body.

We can capture deeper data and we can also gain much more contextual data, for example in Oncology, where the richness of data plays a major role, both, in R&D and in treatment. Dense networks of IoT, re-evaluating different RoIs, driven by data-science methods and executed with iterative methods, could eventually lead us to trigger the emergence, of presently latent clinical information and, thus, to the acquisition of new medical knowledge. We could soon advance our ability to recognize early signs of bodily deterioration and try to link them with macroscopic patients' conditions change.

Radiology can produce really "BIG" data; however, we need to discover heuristic methods, by "merging" the potential of Imaging, Mathematics and IoT related grids (or arrays), into a new, almost "robotic" technique. The traditional leader companies in Radiology have already made, as we have shown previously, their own initial preparations, to combine all the necessary aspects of Medical Imaging with the emerging IoT.

Concerning Radiation Therapy, the present and emerging applications of IoT are mostly focused on the precision and the accuracy of the delivered Energy- dose, delivered to the Patient. Equipment connectivity and interoperability was a first priority in Radiotherapy and since 2013, Varian Medical Systems and Siemens Healthcare, are now using Varian software to plan and manage radiotherapy treatments, delivered on a Siemens medical linear accelerator [11].

These two companies have developed and deployed an interface that connects Varian's ARIA oncology information system with Siemens' Oncor and Primus accelerators and imaging systems. This step – as part of the company's "Agenda 2013" sector initiative – demonstrates once again Siemens Healthcare's role as a strong partner for imaging systems in radiation oncology [11]. However, appropriate IoT-devices, allow for the real-time follow-up of critical parameters, as for instance values of Temperature, of Vacuum, of RF-power, Current etc. and the recordings of therapeutic and scattered Energy-doses.

Radio Frequency IDentification (RFID), the "ancestor" of IoT-devices, already support Radiotherapy for a decade, as for instance for:

a) Implantable in-vivo Dosimetry, employing a dosimeter unit and a wireless RFID communication system [12].
b) Breast locating device including an RFID transponder as a diagnostic instrument, for examining a female breast [13].
c) Methods for Radiotherapy patient identification using surface imaging etc. [14].

There is no doubt that during the next few years, IoT-devices will replace RFID, in their supporting functions, resulting in further accuracy and precision in RT. Syno-psizing, we could remark that, as far as, the technical aspects are taken into consideration:

a) The aspects related, to the difficulty degree of this transformation, Medical Imaging and Radiotherapy the ED and the Outpatient Department (OUT) posses a medium heterogeneity and scalability degree.
b) The Low Energy Data exchange and Tracking, is easily provided in the Radiology and RT environment.
c) As far as Self-organization, Interoperability and Security are concerned, the tasks to be performed constitute still the main obstacle, to achieve a really disrupting influence of IoT, in these two fields.

4. Surgical Departments Intensive Care Units and the Nursing Wards

The importance of data in delivering efficient and effective health-care is obvious. Sensor technologies are making the creation of new data easier, however, tracking activities, pills and hospital-beds need to be communicated, aggregated, and analyzed. The Internet of Things promises to turn any object into a source of information about that object. This creates a new way to differentiate products and services and a new source of value. Admitting a patient for acute-care treatment, unleashes an avalanche of new data:

a) Current vital signs.
b) Patient's medical history.
c) Reviewing treatment options.

All these data may reach to a diagnosis and to a recommended course of treatment.

The two major common aspects of ICU, Surgery and Nursing Wards are to employ the emerging IoT Technologies, in order to optimize:

a) The care provided in Emergency situations, in the Operating Room and in the Wards.
b) The safety of the patients during their hospitalization since the hospital environment "kills" by accident, over 50,000 people every year, only in the US [15].

The main reason is that still today, a huge number of medical equipment operates independently and there is no way yet to acquire and process the provided data and information.

Figure 3. *An aspect of the Medical Device Complexity Problem in an ICU [15].*

Nevertheless, several providers are developing and offer systems that wirelessly link the sensors measuring electrical and non electrical Biosignals, in the ED, in the ICU and in the Operating Rooms. These systems aim:

a) To reduce the monitoring burden with algorithms spotting correlations between various Biosignals.
b) To sort out real changes in a condition that requires immediate action.

Therefore, beyond sensors creating data, Artificial Intelligence tools are needed:

a) That can analyze the vast amount of acquired data.
b) That is able to identify meaningful interrelations, so that better clinical decisions are made and, thus, the right treatment is provided.

An advanced example, is the *"da Vinci OnSite"*, a service that allows for, the da Vinci Surgery Technical Assistance Team (dVSTAT®), to remotely monitor the system status for real-time diagnostic feedback. OnSite utilizes any existing 10/100/1000 Mb Ethernet connection/port or 802.11 b or g-wireless network in the OR that has access to the internet and can be configured to the specifications provided by an organization's IT department.

Figure 4. *Remote monitoring of the da Vinci Surgical System can provide potential benefits that maximize patient throughput [16].*

The IoT is indispensable in Surgery, in the ICUs and in the Wards, offering monitoring services. The Heterogeneity and the Scalability of the Devices is extremely multifaceted and thus, connectivity becomes a difficult and costly task, however, necessary for a lean and less risky operation. Self-organization, Interoperability and Security constitute as well a major challenge, due to the necessity to incorporate Clinical Decision Making modules, increasing the reliability of the monitoring outcomes. Finally, Low Energy Data exchange and Tracking is still implementable, however, the multifarious systems and devices accumulated in these Departments, increases the necessary effort, to avoid induced electronic noise and mutual interactions, between them.

5. In Vitro Diagnostics Laboratories Transfusion Medicine and Cell Therapy

The traditional in vitro Diagnostics (IVD) Laboratories have more or less pioneered in the introduction of Computers and later of Networks in Laboratory practice. Therefore, a description of the established systems will be omitted and we shall proceed directly to the emerging IoT applications of IVD Point of Care Testing (PoCT) and the emerging possibility of networking of hundreds of millions of stand-alone IVD-PoCT equipment in the modern Hospital, Medical Practice and at Home…

PoCT is defined as any analytical test performed for a patient by a healthcare professional, outside the conventional laboratory/clinical setting. Recent years have seen a rapid growth in the use of PoCT, largely as a result of technological advances, such as:

a) New developments in solid phase chemistry.
b) Integration of micro-processors, resulting in equipment miniaturization.

Consequently, the latest PoCT devices are generally more reliable and less prone to error than previous generations.

Information is provided, in internationally recognized Guidelines (Fig. 5), on the employment of Point of Care Testing in vitro diagnostics devices, including:

a) The importance of identifying a clinical need before a decision is made to introduce a PoCT service.
b) The clinical governance issues, relating to the setting up and management of PoCT.
c) The need for local hospital pathology laboratory involvement, in all aspects of a PoCT service.
d) The needs for training, updating and monitoring, of all staff involved in the PoCT service.

The implementation of PoCT should be the effective response to a valid and continuing clinical need. The outcome of the clinical need for PoCT depends on:

a) Which groups of patients need testing, what test(s) need to be performed, and how the service currently provided meet the needs.

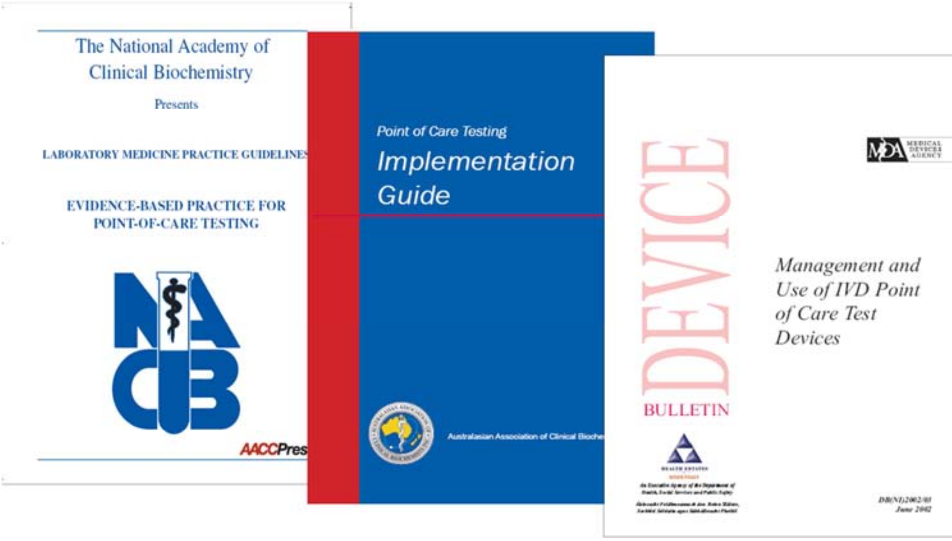

Figure 5. *Selected internationally recognized guidelines.*

b) Whether the access to a laboratory service, is difficult for patients with conditions, requiring frequent monitoring.
c) Whether PoCT will enable more rapid and effective Diagnosis and/or Treatment, as well as, measurable clinical and economic benefit.

Potential sites for point of care testing in hospital include:

a) Out-patient departments.
b) Accident and Emergency departments.
c) ICU/CCU.
d) Operating theatres.
e) Special units (coagulation, renal, liver, diabetic etc.).
f) Other hospital wards etc.

On the other hand, potential sites in Primary care include:

a) GP surgeries.
b) Community clinics.
c) Health centers.
d) Industrial medical centers.
e) Pharmacies.
f) Home-care and self-testing of patients.

The most frequently used PoCT devices categories are:

1) Non-instrumental disposable systems or devices, as:
   a) Test strips for a single analyte.
   b) Sophisticated multi-analyte reagent procedural-control strips, like urinalysis test strips, rapid test kits for infectious disease markers etc.
2) "Palm-held" devices, such as Blood-Glucose or Warfarin (INR) meters.
3) Finally, desk-top analyzers, such as Blood-Gas or Cardiac Enzyme analyzers.

The need for affordable mobile PoCT platforms, with high sensitivity, specificity, and rapid turn-around time and, last but not least, universal connectivity and interoperability, is the basis of the emerging IoT employment in the IVD-PoCT, based on:

a) Already existing cellular Technology adapted to the specific needs of each PoCT method.
b) Already existing and widely applied in the IVD-PoCT and in Transfusions Medicine RFID-Technology.
c) The emerging IoT Connectivity Technology [17].

"Particle" CEO Zach Supalla says: "The Internet of Things isn't (yet) a big business, and the concept favors lots of small-scale devices, rather than a handful of hits. Certifying, provisioning, and managing data plans for all of these devices is a tall order for wireless carriers, who are used to selling Smartphones by the million" [17].

The IoT is already used, for example in an Intelligent Intravenous Transfusion System [18]. The primary architecture and the principle of intravenous transfusion device are based on the IoT, particularly the medical monitoring platform, the intelligent perception unit, and the Infusion monitoring service. The system is giving the flow chart of the main program and the critical code for a five-liquid speed-measuring method. This system can satisfy the requirements for monitoring and managing centrally, the infusion process.

The Mayo Clinic has announced a partnership with GE Ventures to launch a new company, Vitruvian Networks, an independent platform company committed to accelerating cell and gene therapies through new, state-of-the-art, cloud-ready software systems and manufacturing systems. According to the release, Vitruvian Networks will be dedicated to helping combat cancer and other diseases, by offering systems that will expedite patient access to personalized therapies [19].

Vitruvian's platform will serve, as a network coordinator, for therapeutic companies, helping them bring the Internet of Things (IoT) to cell and gene therapies. The goal is to provide effective and safe treatment for cancer and other diseases.

The Heterogeneity and the Scalability of the IVD-PoCT Devices is very complicated, as well as, Self-organization, Interoperability and Security, due to the different physical and chemical principles, behind the employed equipment. Only low Energy Data exchange and Tracking is of moderate complexity.

6. Supporting Facilities and Networks of the Modern Hospital

This paragraph addresses the usually disregarded non-Clinical Hospital Services, such as Cleaning-Disinfection, Sterilization, Incineration, Electromechanical Networks, Hospital Clothing & Gear, Pharmacy etc. and the proposed IoT-related solutions are realistic and well-documented. The designed IoT-based Information-system, for the "non- directly Clinical" Hospital Services include presently:

a) Cleaning Disinfection and Asepsis.
b) In-Hospital Sterilization Services and Outsourcing.
c) Hospital Incineration of Bioactive wastes.
d) Electro-mechanical Networks: Water, Power Supply, Heating, Air Conditioning etc.
e) Hospital Patient and Personnel Food Services.
f) Hospital protective clothing-gear Management.
g) Pharmacy: Medicaments, Reagents and Disposables.

The non-Clinical Hospital Services have an important influence on the safe and smooth Hospital operation. The optimization of the function of these Facilities and the associated Services, require modern ICT- and gradually also IoT-technology installed in the Hospital. However, the functional-managerial aspects of the Hospital operation are not always up-to-date and sometimes are not present at all.

Seven important functional-managerial services/aspects of a modern Hospital are presently included in our system.

6.1. Cleaning Disinfection and Asepsis

The cleanliness of healthcare premises is an important component in the provision of clean-safe care. The system is based mainly on an "Infection Control Guidance Model" [20] for staff with cleaning responsibilities, including:

a) The Health and Safety training.
b) The definition of Cleaning Responsibilities.
c) The Work Planning and Scheduling.
d) The appropriate Technical Method Statements.
e) The emerging new Cleaning Technologies.
f) The Measurement of Cleanliness and the associated Reporting, based not only on a visual assessment, but on objective measuring tools, such as Adenosine Triphosphate (ATP) monitors.

This Guidance Model defines the main components of the "Flowchart" of the designed system and software. The installation of an IoT-based network of mobile and connected "probes", could report continuously the state of Disinfection and Asepsis, in all Units.

6.2. In-Hospital Sterilization Services and Outsourcing

The "CDC-2008: Guideline for Disinfection and Sterilization in Healthcare Facilities" and its evidence-based recommendations on cleaning and disinfecting healthcare-environment was adopted; more specific [20]:

a) The first cleaning and the removing of organic and inorganic materials, the chemical disinfectants (formaldehyde, hydrogen peroxide etc.).
b) The choice of disinfectant concentrations and of exposure times.
c) The sterilization methods (steam sterilization, ethylene oxide, hydrogen-peroxide gas plasma etc.).
d) The factors affecting the efficacy of disinfection and of sterilization.
e) The process management (sterilization cycle validation, physical facilities upholding, cleaning- packaging-loading-storage cycle etc.).
f) The sterilization monitoring (mechanical, chemical, and biological indicators).
g) The appropriate reuse of single-use medical devices.
h) The question of outsourcing-logistics.

An adverse-events reporting process, constitute the main components of the system. An IoT-based network of inter-connected "probes" could continuously monitor the efficiency and the efficacy of the Sterilization procedures.

6.3. Hospital Incineration of Bioactive Wastes

a) Medical waste incineration involves the burning of wastes produced by hospitals, veterinary facilities and medical research facilities. These wastes include, both, infectious "red-bag" medical wastes, as well as, non-infectious, general housekeeping wastes. The emission factors depend on whether both types of these wastes are combusted or only just infectious wastes [21].
b) Three main types of incinerators are used, most frequently the controlled air type and rarely the excess air, and rotary kiln types. Hospital waste may be identified as 'specific hospital waste' and 'other hospital waste'. Specific hospital waste includes human anatomic remains and organ parts, waste contaminated with bacteria, viruses and fungi, and larger quantities of blood [22].
c) Incineration of hospital wastes has been banned in some European countries, including Greece, and there is generally a move towards larger, centralized facilities. Therefore, our designed system is supporting the logistics of an "incineration outsourcing procedure" [23].

The RFID-tagging of "bulky"-packages of bioactive wastes helps the sorting and the tracking of them. More sophisticated IoT-sensors might reduce the risks of "mixed waste", probably containing extremely toxic materials [24].

6.4. Electro-mechanical Networks: Water, Power-Supply, Heating, Air Conditioning etc

The extremely complicated and multifarious Hospital Electro-mechanical Networks can be managed easier and in a smooth and not extremely expensive way, by employing the BACnet (Building Automation and Control NETworks) approach. BACnet is an ASHRAE 135-2012 Standard Data Communication Protocol that enables interoperability between different building systems and devices in building automation and control applications [25]. "Interoperability" has a variety of meanings, from simple information exchange, to deeper integration, to complete and complex interoperation, between component, devices and systems. BACnet provides the means for many kinds of basic and complex "interoperations", taking place by using Standardized Techniques.

BACnet does not replace the need for Display Data Channels (DDC) or Control Logic and offers a flexible range of networking options including, the use of Ethernet or IP-centric Infrastructure. The BACnet protocol defines a number of Services that are used to communicate between building devices and a number of Objects that are acted upon by the services and it may be considered as an IoT-system. Taking advantage of the mentioned BACnet Services and Objects, the design of the Electro-mechanical Hospital Networks (Water and Power Supply, Heating, Air Conditioning etc.) and their corresponding ICT-interfaces, becomes smoother and simpler. The emerging IoT "devices" are still expensive, but the prices tend to fall [26].

6.5. Hospital Patient and Personnel Food Services

Hospital Patient and Personnel Food Services sound trivial, but they are not. Everyone who was a patient or a staff-member understands it… Million cases of food-borne illness occur annually, costing billions of dollars worldwide, even in Hospitals. Many instances of food-borne illnesses are preventable and there is the potential to reduce the incidences, the cost and the burden of illness, associated with unsafe food. Food-borne illnesses constitute a public-health issue [27].

Unsafe food can cause many acute and life long diseases, and in some instances death. Vulnerable persons, such as the Hospital in-patients, elderly, young, children and infants, pregnant women and the immunocompromised people, are at higher risk [28]. The designed system gives priority in risk minimization, along with the other technical-managerial aspects of running a Hospital food-service. RFID-tagging and "smarter" IoT-devices may control better Temperature, Moisture etc. parameters [29].

6.6. Hospital protective Clothing & Gear Management

The Hospital (or the Outsourced) Laundry's purpose is to provide an adequate supply of clean linen to its users. Clean linen should be delivered in such a way, as to minimize microbial contamination from surface contact and air borne deposition. Soiled linen is handled in such a way, as to minimize microbial contamination into the environment and protect Laundry employees from body substance pathogens. Laundry's employees must participate in relevant continuing education, health-care textile items should be standardized (e.g. physical appearance, number of acceptable repairs etc.) and the equipment should be maintained to ensure that hygienically clean linen is delivered, according to jointly established standards. Each washing device should be controlled for starting pH (10.5-11.5), hot water temperature (65-80°C) and ending pH (5.5-6.5), at least once monthly [30].

Clean linen should be transported and stored so, as to minimize microbial contamination, linen transport carts should be sanitized in the cart washer, after being emptied of soiled linen and prior to being filled with clean linen and be covered for storage [31], [32].

Plant Facilities should be planned, equipped and ventilated so as to minimize contamination. A Surgical Pack Room should be operated for surgery-linen inspection and packing. A network of interconnected IoT-devices could easily and continuously monitor the entire procedure.

6.7. Pharmacy: Medicaments, Reagents & Disposables

Appropriate Medication in the hospital-setting, is a Multi disciplinary responsibility that includes:

a) Selection and formulary management by a multi-disciplinary committee.
b) Prescribing by the physician.
c) Procurement, storage, medication order review, and preparation and dispensing by the pharmacy Department.
d) Medication administration by nurses or other health care professionals.
e) Monitoring the effect of medicines on the patient by all members of the health care team.

The designed Hospital Pharmacy management system is supervising and documenting, the Medicine, Reagents and Disposable purchasing and allocation procedures, taking into account an option of an RFID/IoT-based tagging of Medicaments, Reagents & Disposables [33]-[39].

7. Concluding Remarks

The Internet of Things hardware must become smaller and cheaper to achieve "Ubiquity". The reason for the relative high-costs, associated wit IoT-technology is that in cellular telephony and in almost all emerging hi-tec industrial branches, a significant portion of the hardware cost is due to Industrial Property Rights (IPR) that is Fees, commonly known as "Royalties".

Every time an IoT-device is sold, the manufacturer for instance of device's cellular modules and/or other patented parts, has to pay a licensing fee (Royalty) to the holders of a number of relevant Patents, as for example 3G and LTE (Long-Term Evolution). LTE is a standard for high-speed wireless communication for mobile phones and data terminals. A few dollars IoT-device is much more difficult to absorb these fees, than a Smartphone or a Tablet [17].

For this reason, it is imperative, when planning of long-term and wide-range IoT-projects, to take carefully into account the "Innovation Trail", as shown in Figure 6 and the related Patent-costs.

The major advantages of the Internet of Things in Hospitals and other Healthcare organizations should include [40]:

a) Decreased Costs because Health-care providers could take advantage of the connectivity optimization of the existing healthcare solutions.

b) Improved Outcomes of Treatment, through cloud computing or other virtual infrastructure that gives caregivers the ability to access real time information.
c) Improved Disease Management, due to the fact that patients may be monitored on a really continuous basis.
d) Reduced Medical errors, due to the accurate collection of data and automated workflows, combined with data driven decisions.
e) Enhanced Patient Experience, since the connectivity of the Health-care system, through the Internet of Things, enables the covering of the patients' needs.
f) Enhanced Management of Drugs with IoT processes and devices, enabling cost minimization and increased medication compliance.

However, there are also some disadvantages, related to the IoT in Hospitals and other forms of Health-care. The IoT is still expensive, since high cost is usually associated with high technology. Finally, the IoT requires more time to adapt, could increase over-dependency on technology and, last but not least, it is still vulnerable to network hackers...

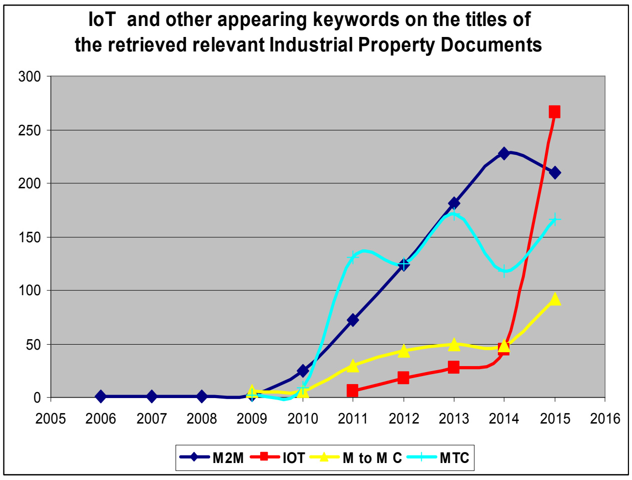

Figure 6. *Example of an IoT-related Industrial Property Docs mapping (2005-2015) that presents the increasing trends of filing, in the above mentioned subject-matter.*

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