An Overview of IoT and Healthcare

Gonçalo J. F. Carnaz[1] and Vitor Nogueira[1]

Departamento de Informática, Universidade de Évora,
Largo dos Colegiais 2, 7004-516 Évora,
d34707@alunos.uevora.pt
vbn@di.uevora.pt

Abstract This paper is an overview of some of the implications of IoT on the healthcare field. Due to the increasing of IoT solutions, healthcare cannot be outside of this paradigm. The contribution of this paper is to introduce directions to achieve a global connectivity between the Internet of Things (IoT) and the medical environments. The need to integrate all in a global environment is a huge challenge to all (from electrical engineers to data engineers).This revolution is redesigning the way we see healthcare, from the smallest sensor to the big data collected.

Keywords: Internet of Things, healthcare, medical environments, sensors.

1 Introduction

The first principle of IoT (Internet of Things) is to connect smart objects - things - to the Internet in a transparent way. This leads to an exchange of data between all things, and bring users information in a more secure way. Cisco Systems estimates that IoT will consist of 50 billion devices connected to the Internet by 2020 and it is predictable that many physical objects, like computers, sensor actuators, will be distributed with unique addresses and the ability to transfer data, from the common daily activities to restricted medical records, in a secure way.
This technology, named as Internet of Things (IoT), "provides an integration approach for all these physical objects that contain embedded technologies to be coherently connected and enables them to communicate and sense or interact with the physical world, and also among themselves" [19]. The Internet of Things (IoT) is a concept that's reflects a "connected set of anyone, anything, anytime, anyplace, any service, and any network" [16].
One of the most attractive applications fields for IoT is the Healthcare, giving to us the possibility of many medical applications such as remote health monitoring, fitness programs, chronic diseases, and elderly care[16]. The rest of the paper is organized as follows: in section 2 and section 3 we provide a brief synopsis about IoT and Healthcare. Section 4 describes the recent innovations related to healthcare technologies. One main problem that arises from IoT and Healthcare is the security, a matter discussed in section 5. This innovations brings a bunch of Services and Applications, that we describe in section 6.

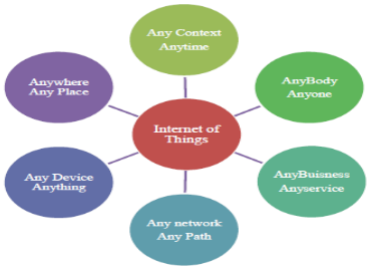
2 IoT

The term "Internet of Things" was disseminated by the research work of the Auto-ID Center at the Massachusetts Institute of Technology (MIT) in 1999 [17]. IoT includes two concepts: "Internet" and "Thing", where "Internet" refers to "The world-wide network of interconnected computer networks", based on a standard communication protocol, while "Thing" refers to "an object not precisely identifiable" [6]. These concepts mean that every object can be addressable by an IP (Internet Protocol), and can act in a smart space, like a healthcare environment. Another definition of IoT is "a self-configured dynamic global network infrastructure with standards and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities, and are seamlessly integrated into the information infrastructure" [3]. Indeed, IoT is the resulting global network interconnecting smart objects by means of extended Internet technologies, the set of supporting technologies necessary to realize such a vision (including e.g., RFIDs, sensor /actuators, machine-to-machine communication devices, etc.) and the ensemble of applications and services leveraging such technologies to open new business and market opportunities [13]. The fundamental characteristics of the IoT technology are summarized as following:

- a real-time solution in a global environment;
- mainly wireless solutions: indoor and outdoor environments;
- ability to remotely monitoring the environment and tracking objects.

According to these definitions, Figure 1 shows the dimensions of IoT.

Figure 1. Dimensions of IoT [10]



3 Healthcare

Healthcare is one of the main priorities for all governments, basically related to population growth, rural urbanization, declining birthrate, population aging, economic growth and social unbalanced resource utilization, some social problems

have become increasingly apparent in the healthcare field, some of these issues in healthcare that IoT may prevent, or can combat in a most effective way:

- health management level and the incapability of responding to emergency;
- serious shortage in medical staffs and institutional facilities especially in rural areas, lack of medical facilities, low level of treatment, inadequate healthcare system;
- Imperfect diseases prevention system cannot meet the national strategy requirements to safeguard the health of the citizen resulting in an heavy burden on economy, individuals, families and State;
- Inadequate disease prevention and early detection capability;

But there are some challenges, that IoT can help to solve:

- break geographic barriers, providing rapid clinical responses;
- medical consultation and communication links of medical images and video data;
- a unique ontology for all things among IoT-based healthcare.

There are a lot of applications in the healthcare field, including the possibility of using smartphone capabilities as a platform for monitoring of medical parameters that advise patients of medical issues.

4 Healthcare Technologies

The many uses of the systems and products that connect to the Internet of Things (IoT) are changing the healthcare field. Patients and providers both stand to benefit from IoT carving out a bigger presence in healthcare. Some uses of healthcare IoT are mobile medical applications or wearable devices that allow patients to capture their health data. Hospitals use IoT to keep tabs on the location of medical devices, personnel and patients. We list below some of tecnhologies that can be applied to IoT-based healthcare systems.

Cloud Computing The integration of cloud computing into IoT-based healthcare technologies should provide facilities with ubiquitous access to shared resources, offering services upon request over the network and executing operations to meet various needs, please refer to [4].

Grid Computing The concept of Grid Computing can be applied to IoT, because the non-invasive sensing and low-power wireless communication technologies has enabled continuous monitoring and processing of mobile patients using biomedical sensor nodes. These small wearable devices - limited in memory, energy, and computation and communication capabilities - are capable of continuously monitoring vital signs such as blood pressure, temperature, Electrocardiogram (ECG), Electromyogram (EMG), oxygen saturation.For more information about grid computing and IoT we recommend the reading of paper [11].

Big Data All data provided by medical sensors in the healthcare environment must be analysed, then tools must be created to increase the efficiency of relevant health diagnosis and monitoring methods and stages.[16]

Networks To support the physical infrastructure on the IoT-based healthcare must be defined for short-range communications, such as WPANs, WBANs, WLANs, 6LoWPANs and WSNs to long-range communications, e.g., any type of cellular network. For low-power medical sensor devices, the use the employment of ultra-wideband (UWB), BLE, NFC and RFID technologies can be applied, as well communications protocols [16].

Ambient Intelligence The application of ambient intelligence is an important part of IoT-based healthcare, because end users, clients, and customers in a healthcare network are humans (patients or health-conscious individuals). One of the fields is HCI (Human Computer Interation) [16].

Augmented Reality Augmented reality has brought about a significant change in the healthcare industry. There are different applications of this technology in the medical sector. Right from providing assistance during surgeries to improving medical training, augmented reality is all set to make a bigger impact in the coming years. Apart from saving patients' lives, existing processes in healthcare organizations can be made more efficient and precise with augmented reality. We will have a look at the numerous uses of this amazing technology in the healthcare industry[14].

Wearables As we may read in [16],"Patient engagement and population health improvements can be facilitated by embracing wearable medical devices as landmarks. This has three major benefits: connected information, target-oriented healthcare communities and gamication".

5 Healthcare Security

Connecting the IoT devices is transforming healthcare. But, security is a issue to clinical engineering and business technology. In addition, such smart devices may be connected to global information networks for their access anytime, anywhere. Therefore, the IoT healthcare domain may be a target for attackers. To facilitate the full adoption of the IoT in the healthcare domain, it is critical to identify and analyze distinct features of IoT security and privacy, including security requirements, vulnerabilities threat models, and countermeasures, from the healthcare perspective.

5.1 Security Requirements

Security requirements for IoT-based healthcare solutions are similar to those in standard communications scenarios. Therefore, to achieve secure services, there is a need to focus on the following security requirements [16].

- **Confidentiality** - ensures the inaccessibility of medical data for unauthorized users.
- **Integrity** - Maintains all data integrity during the transmission process of data between devices.
- **Authentication** - Authentication is verified between peers with which it is communicating.
- **Availability** - Availability of all IoT healthcare services (either local or global/cloud services) to authorized parties when needed even under denial-of-service attacks.
- **Data Freshness** - Data freshness includes data freshness and key freshness. Because each IoT healthcare network provides some time varying measurements, there is a need to ensure that each message is fresh [16].
- **Non-Repudiation** - Non-repudiation indicates that a node cannot deny sending a message sent earlier.
- **Authorization** - Authorization ensures that only authorized nodes are accessible for network services or resources.
- **Resiliency** - If some interconnected health devices are compromised, then a security scheme should still protect the network/device/information from any attack.
- **Fault Tolerance** - A security scheme should continue to provide respective security services even in the presence of a fault (e.g., a software glitch, a device compromise, or a device failure).
- **Self-Healing** - A medical device in an IoT healthcare network may fail or run out of energy. Then remaining or collaborating devices should enable a minimum level of security.
- **Secure booting** - When the device is powered at the first time, the authenticity and integrity of the software on the device is verified using cryptographically generated digital signatures. For more information, please read the white paper [23].
- **Interoperability** - when different things cooperate in order to provide the desired service, at the right time.
- **Privacy** - are a mandatory issue, because sensitive data are exchanged across the network.

5.2 Security Challenges

For IoT the need of security requirements, cannot be provided by the traditional security techniques and therefore IoT has to find new challenges to ensure security. In the following items we can find a list of features for IoT security.

- **Computational Limitations** IoT health devices are embedded with low-speed processors. The central processing unit (CPU) in such devices is not very powerful in terms of its speed. In addition, these devices are not designed to perform computationally expensive operations. That is, they simply act as a sensor or actuator. Therefore, obtaining a security solution that minimizes resource consumption and thus maximizes security performance is a challenging task.
- **Memory Limitations** Most IoT healthcare devices have low memory. Such devices are activated using an embedded operating system (OS), system software, and an application binary. Therefore, their memory may not be sufficient to execute complicated security protocols.
- **Energy Limitations** A typical IoT healthcare network includes small health devices of limited battery power (e.g., body temperature and BP sensors). Such devices conserve energy by switching on the power-saving mode when no sensor reading needs to be reported. In addition, they operate at a low CPU speed if there is nothing important to be processed.
- **Mobility** In general, healthcare devices are not static but mobile in nature. Such devices are connected to the Internet through IoT service providers. For example, a wearable body temperature sensor or a heart monitor may be connected to the Internet and notifies the concerned caregiver of the user's conditions.
- **Scalability** The number of IoT devices has increased gradually, and therefore more devices are getting connected to the global information network. Therefore, designing a highly scalable security scheme without compromising security requirements becomes a challenging task.
- **Communications Media** In general, health devices are connected to both local and global networks through a wide range of wireless links such as Zigbee, Z-Wave, Bluetooth, Bluetooth Low Energy, WiFi, GSM, WiMax, and 3G/4G. Wireless channel characteristics of these networks make traditional wired security schemes less appropriate. Therefore, it is difficult to find a comprehensive security protocol that can treat both wired and wireless channel characteristics equally.
- **The Multiplicity of Devices** Health devices within an IoT health network are diverse, ranging from PCs to low-end RFID tags. Such devices vary according to their capability in terms of their computation, power, memory, and embedded software. Therefore, the challenge lies in designing a security scheme that can accommodate even the simplest of devices.
- **A Dynamic Topology** Because the IoT-based healthcare network must be anywhere and anytime, a new topology that may be based on the existent ones, but a dynamic topology [16].
- **A Multi-Protocol Network** A health device may communicate with other devices inside the local network through a proprietary network protocol.
- **Data confidentiality** Because medical data are a sensitive subject, we need to build a stream access control or identity management system.

– **Trust mechanisms** To maintain communication between peers a trust negotiation mechanisms, negotiation language or object identity management system must be applied.

6 IoT Healthcare Services and Applications

Regarding IoT Healthcare Services and Applications, the range of fields can include: management of private health and fitness, care for pediatric, supervision of chronic diseases, elderly patients, among others. For a better understanding of this topic, this paper categorizes the discussion in two aspects: services and applications.

6.1 Healthcare Services

Ambient Assisted Living Ambient Assisted Living systems have a potential to meet the personal healthcare challenges and involve citizens in their healthcare. The AAL systems provide an ecosystem of medical sensors, computers, wireless networks and software applications for healthcare monitoring, a service that can be provided by IoT. That is, a separate IoT service is mandatory.

m-Health Things (m-IoT) The m-IoT is "defined as a new concept that matches the functionalities of m-health and IoT for a new and innovative future (4G health) applications" [12]. As shown in [15], m-health is mobile computing, medical sensors, and communications technologies for healthcare services. In theory, "m-IoT familiarizes a novel healthcare connectivity model that connects the 6LoWPAN with evolving 4G networks for future internet-based m-health services. Although m-IoT characteristically represents the IoT for healthcare services, it is worth mentioning that there exist some specific features intrinsic to the global mobility of participating entities" [15] [16].

Adverse Drug Reaction An adverse drug reaction is an injury from taking a medication, either a single dose of a drug or its prolonged administration or as a consequence of a combination of two or more drugs [9] [2]. Solutions to this issue can be found in the previous references.

Community Healthcare A service that may be provided by IoT is a network covering an area around a local community, a municipal hospital, a residential area, or a rural community, being a cooperative network structure. A cooperative IoT platform for rural healthcare monitoring has been proposed and found to be energy-eficient [20].

Wearable Device Access Various non intrusive sensors have been developed for a diverse range of medical applications [21], particular for WSN-based healthcare services. Such sensors are prospective enough to deliver the same services through the IoT. On the other hand, wearable devices can come with a set of desirable features appropriate for the IoT architecture.

Semantic Medical Access The use of semantics and ontologies to share large amounts of medical information and knowledge has been widely considered [1]. The wide potential of medical semantics and ontologies has received close attention from designers of IoT-based healthcare applications.

Indirect Emergency Healthcare There are some indirect emergency situations where healthcare issues are involved, including: adverse weather conditions, transport (aviation, ship, train, and vehicle) accidents, earthen sites collapse, among others. Therefore, a service called indirect emergency health care (IEH) can be offer a bundle of solutions such as information availability [16] [7].

Embedded Gateway Configuration A configured gateway service, by the name embedded gateway configuration (EGC) service, that connects networks nodes, where patients are connected, with the Internet, and all the medical equipment, requires some common integration features depending on the specific purpose of the deployed gateway [16].

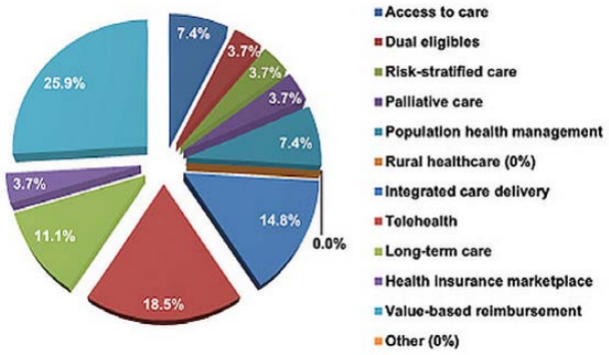
Embedded Context Prediction One of the main issues is the frameworks that all third-party developers may have to build with suitable mechanisms, that we called suitable mechanisms(ECP) service [16]. Such a framework is developed in[7] in the context of ubiquitous health care.

Early intervention/prevention Monitoring of human activities and well-being, like monitoring everyday activity and report it to hospital or family members. IoT may provide the way to monitoring all that activities with devices embedded.

6.2 Healthcare Applications

The following applications were selected by the incidence of population diseases, from published paper of DGS (Direcção Geral de Saúde - Portugal) [8], and the need of an urgent responses from the medical community. Another source for analysing the need of applications in medical environments is the HINtelligence report, 2015. This report provides the results in the chart of Figure 2, that we can analyse the needed areas of IoT applications, but in a high level view. Note that the following applications are based on the paper [8].

Figure 2. Top Healthcare development areas for 2015 (HINtelligence report, 2015).



Diabetes Prevention "The term "diabetes mellitus" describes a metabolic disorder of multiple aetiology characterized by chronic hyperglycemia with disturbances of carbohydrate, fat and protein metabolism resulting from defects in insulin secretion, insulin action, or both. The effects of diabetes mellitus include long–term damage, dysfunction and failure of various organs"[1]. Blood glucose monitoring can prevent all the risks that this disorder may bring to patients, monitoring individual patterns of blood glucose and helping patients to plan their meals, activities and medication times.

Electrocardiogram Monitoring According to report [18], 30% of all deaths are related to circulatory systems problems, like arrhythmias, myocardial ischemia, or prolonged QT intervals. Thus the importance of the monitoring of our vital signals by a electrocardiogram (ECG) - the electrical activity of the heart recorded by electrocardiography, includes the measurement of the heart rate and the determination of the rhythm as well as the diagnosis of arrhythmias, myocardial ischemia, and prolonged QT intervals. Indeed, IoT-based applications for ECG monitoring have the potential to give maximum information and deliver information to medical staff [5].

Blood Pressure Monitoring Blood Pressure Monitoring is a part of the prevention of circulatory systems problems, therefore, IoT-based applications can control remotely the communication between a health post and the health center [16].

Body Temperature Monitoring Homeostasis is how human body manages a multitude of highly complex interactions to maintain balance or return systems

[1] in http://www.who.int/diabetes/action$_o$*nline*/*basics*/*en*/*_online*

to functioning within a normal range, like body temperature. Monitoring of this variable is an essential part of healthcare services because body temperature is a decisive vital sign. Using a body temperature sensor that is embedded in a TelosB device allows retrieving body temperature variations and reporting to a temperature measurement system based on a home gateway over the IoT [16].

Oxygen Saturation Monitoring Blood oxygen saturation can be measure with a pulse oximetry, a non invasive and non-stop monitoring system. The integration of a pulse oximetry in a IoT-based application can support the oxygen saturation monitoring [10].

Rehabilitation System One of the main problems identified in the Portuguese population, is the population aging and the related medical issues, like the cerebrovascular accident, that leads patients to rehabilitation clinics. In [24], an ontology-based automating design method for IoT-based smart rehabilitation systems is proposed to mitigate the problems previously described.

Medication Management One of the main problems in public health and cause of huge financial burden is the medication poses. IoT ensure a new tool to resolve this issue [16].

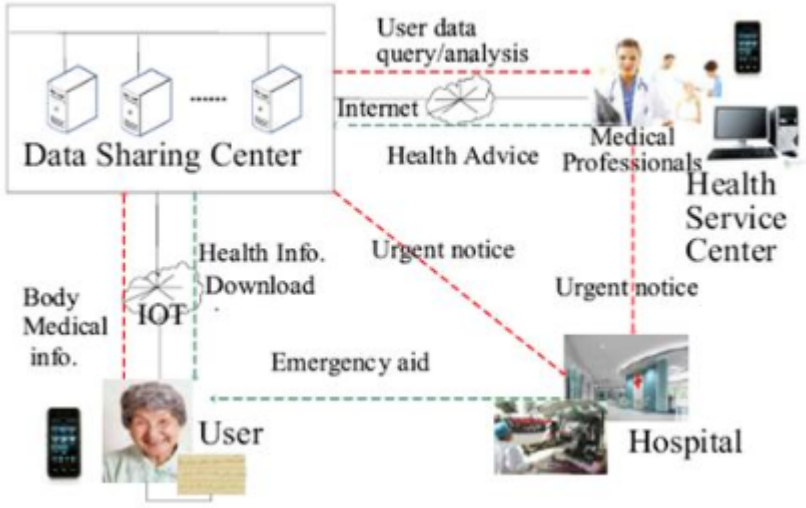
Wheelchair Management Smart wheelchairs with full automation for disabled people is a response from IoT, like the acceleration in pace of work [16].

An framework that can be applied to a real application is the Remote Monitoring and Management Platform of Healthcare Information (RMMP - HI) [22], this platform can provide monitoring and management of these lifestyle diseases so as to reach the purpose of prevention and early detection. Body medical sensors can register, delete and update data throughout a IoT based network, then collects human body medical information, and sends to a data sharing center that propagates data to medical staff or hospital facilities based on rules, such as urgent notice derived to an hospital.

7 Conclusion

The Internet of Things changed the healthcare industry, increasing efficiency, lowering costs and putting the focus back on better patient care. Meanwhile, the IoT is growing from building blocks of automation and machine-to-machine communication to the smallest sensors. We consider also how IoT can be used to increase healthcare and how IoT helps people and governments to improve daily activities in personal and public level. Although there are security issues in giving location information, we can give some permission to people in order to allow mechanisms to prevent people from abusing. Yet there are a lot of remaining

Figure 3. The framework of healthcare service [22].



works to be done in order to make the best use of this IoT technology. We need to grow these applications in the future until the desired level of health comes in society.

References

1. A. Burgun, G. Botti, M.F., Beux, P.L.: Sharing knowledge in medicine: Semantic and ontologic facets of medical concepts. In: Proc. IEEE Int. Conf. Syst., Man, Cybern. (SMC). pp. 300–305 (1999)
2. A. J. Jara, F. J. Belchi, A.F.A.J.S.M.A.Z.I., Gomez-Skarmeta, A.F.: A pharmaceutical intelligent information system to detect allergies and adverse drugs reactions based on Internet of Things. In: Proc. IEEE Int. Conf. Pervasive Comput. Commun. Workshops (PERCOM Workshops). pp. 809–812 (2010)
3. Commission, E.: Internet of things strategic research roadmap. http://www.internet-of-thingsresearch.eu/pdf/IoT_Cluster_Strategic_Research_Agenda_2009.pdf (2009), [Online; accessed 18-Jan-2016]
4. Council, C.S.C.: Impact of Cloud Computing on Healthcare (2012)
5. Dash, P.K.: Electrocardiogram monitoring. In: Indian J. Anaesthesia,vol. 46). pp. 251–260 (2002)
6. of the European communities, C.: Internet of things in 2020. http://www.umic.pt/images/stories/publicacoes2/Internet-of-Things_in_2020_EC-EPoSS_Workshop_Report_2008_v3.pdf (2010), [Online; accessed 18-Jan-2016]
7. G. Mantas, D.L., Komninos, N.: new framework for ubiquitous context-aware healthcare applications. In: Proc. 10th IEEE Int. Conf. Inf. Technol. Appl. Biomed. (ITAB). pp. 1–4 (2010)

8. GEORGE, F.: Causas de Morte em Portugal e Desafios na Prevenção. DGS (2012)
9. Group, I.E.W.: Guidance for industry-E6 good clinical practice: Consolidated guidance. In: U.S. Dept. Health Human Services, Food Drug Admin (1996)
10. H. A. Khattak, M.R., Sciascio, E.D.: CoAP-based healthcare sensor networks: A survey. In: Proc. 11th Int. Bhurban Conf. Appl. Sci. Technol. (IBCAST). pp. 499–503 (2014)
11. Hariharasudhan Viswanathan, E.K.L., Pompili, D.: Mobile Grid Computing for Data and Patient-centric Ubiquitous Healthcare. In: The First IEEE Workshop on Enabling Technologies for Smartphone and Internet of Things (ETSIoT) (2012)
12. Istepanian RS, Hu S, P.N.S.A.: The potential of Internet of m-health Things "m-IoT" for non-invasive glucose level sensing. In: Conf Proc IEEE Eng Med Biol Soc. (2011)
13. L. Atzori, A. Iera, G.M.: The Internet of Things: a survey," Computer Networks. vol. 54, pp. 2787–280 (2010)
14. medicalaugmentedreality.com, I.S. How augmented reality can bridge the gap in healthcare? http://www.augmentedrealitytrends.com/augmented-reality/healthcare-industry.html (2014), [Online; accessed 18-Jan-2016]
15. R. S. H. Istepanian, E.J., Zhang, Y.T.: Guest editorial introduction to the special section on m-health: Beyond seamless mobility and global wireless health-care connectivity. In: IEEE Trans. Inf. Technol. Biomed.,. pp. 405–414 (2004)
16. S. M. RIAZUL ISLAM, DAEHAN KWAK, M.H.K.M.H., KWAK, K.S.: The Internet of Things for Health Care:A Comprehensive Survey. In: IEEE Access (2015)
17. S. Sarma, D.L. Brock, K.A.: The networked physical world (2000)
18. da Saúde, D.G.: A Saúde dos Portugueses.Perspetiva 2015 (2015)
19. Tuan Nguyen Gia, Amir-Mohammad Rahmani, T.W.P.L., Tenhunen, H.: Fault Tolerant and Scalable IoT-based Architecture for Health Monitoring. In: IEEE Access (2015)
20. V. M. Rohokale, N.R.P., Prasad, R.: A cooperative Internet of Things (IoT) for rural healthcare monitoring and control. In: Proc. Int. Conf.Wireless Commun., Veh. Technol., Inf. Theory Aerosp. Electron. Syst. Technol. (Wireless VITAE),. pp. 1–6 (2011)
21. W.-Y. Chung, Y.D.L., Jung, S.J.: A cooperative Internet of Things (IoT) for rural healthcare monitoring and control. In: A wireless sensor network compatible wearable u-healthcare monitoring system using integrated ECG, accelerometer and SpO2. pp. 1529–1532 (2008)
22. W. Zhao, C.W., Nakahira, Y.: Medical Application On IoT. In: International Conference on Computer Theory and Applications (ICCTA). pp. 660–665 (2011)
23. windriver.com: White Paper:Security in the Internet of Things - Lessons from the Past for the Connected Future (2013)
24. Y. J. Fan, Y. H. Yin, L.D.X.Y.Z., Wu, F.: IoT-based smart rehabilitation system. In: IEEE Trans. Ind. Informat. pp. 1568–1577 (2014)