The Art of Advanced Healthcare Applications in Big Data and IoT Systems

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Abstract. The goal of this chapter is to analyze existing solutions for selfaware Internet of Things. It will highlight, from a research perspective, the performance and limitations of existing architectures, services and applications specialized on healthcare. The chapter will offer to scientists from academia and designers from industry an overview of the current status of the evolution of applications based on Internet of Things and Big Data. It will also highlight the existing problems and benefits of the IoT for disabled people or people suffering from diseases and the research challenges found in this area. *abstract* environment.

Keywords: Internet of Things, Big Data, Analytics, Healthcare, Body Sensor Networks

1 Introduction

Nowadays, a massive amount of data is being generated and stored in the cloud. One of the main promises of analytics is data reduction with the primary function to support processing with the help of the existing infrastructure. The motivation of this chapter direction comes from data being generated from a variety of sources, such as healthcare industry, communication, messaging networks, mobile sensors and many others, rather than a new storage mechanism. Data reduction techniques for Big Data have three perspectives: descriptive analytics, predictive analytics and prescriptive analytics. In the pay-as-you-go cloud environment, the storage can be very expensive.

The perspective of this chapter is represented by: monitoring, analysis and control of environments, based on collected data from a network of sensors.

The Internet of Things (IoT) is a paradigm where every object can be identified and has sensing, networking and processing capabilities. The objects can communicate with each other or with other devices or services available over the Internet.[1] Those objects will be ubiquitous and context-aware.

The objective of this chapter is to highlight the current status of the evolution, trends and research on Internet of Things applied in e-Health by examine

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the literature. In order to achieve our objective, a comprehensive review of the literature, that included conference papers, books and journal articles, was performed.

This chapter is organized as follows: in section 2 we do a deep dive on the role of IoT in e-Health, followed by an overview of the Big Data systems prepared for the healthcare applications in section 3. We present existing healthcare applications in section 4. In the final section we will present our conclusions.

2 IoT solutions for e-Health Systems

2.1 Introduction

The exact meaning of e-Health term varies with the source. There is not a single consensus definition. Some benefits of e-Health extend from established telemedicine systems, others are only practical using a machine-to-machine (M2M) model and assume that patients have access to broadband service.

The World Health Organization defines e-Health as: E-health is the transfer of health resources and health care by electronic means. It encompasses three main areas: The delivery of health information, for health professionals and health consumers, through the Internet and telecommunications. Using the power of IT and e-commerce to improve public health services, e.g. through the education and training of health workers. The use of e-commerce and e-business practices in health systems management. E-health provides a new method for using health resources - such as information, money, and medicines - and in time should help to improve efficient use of these resources. The Internet also provides a new medium for information dissemination, and for interaction and collaboration among institutions, health professionals, health providers and the public.[2]

Technology and Health are the two main coordinates when defining the e-Health term. The Internet and all the electronic devices are most commonly used to dissipate the information about health services or other information regarding this area.

Based on the Internet of Things paradigm we have a lot of new opportunities that are reshaping the e-Health concept on a daily basis.

The applications for e-Health will thrive in the next future using IoT for home and assisted-living environment. There is a noticeable interest for developing the monitoring systems dedicated to elderly or post trauma patients, including video and voice options. The systems allow the identification of falls and send notification to the medical personnel without any human intervention, by monitoring the automated movement. Since the traditional movement monitoring systems are infested with false alarms, a more accurate response can be obtained by a combination of voice and video verification in case of any notification or alarm.

Another reading that provide important information for physicians is the monitoring of blood pressure. Also, the remote monitoring of the patients to get readings for the blood glucose, pulse oximetry or hart monitoring is a strong

source of important information, especially since the measurements reflects the patcients condition on daily basis, under normal conditions, without the stress implied by the visit to the physicians office.

The most important thing is that e-Health means human interactions. This translates into a more dynamic situation: a technical support can be called to solve some issues by phone and more important if reported to the location, the devices on the patient are mobile and this means that the health-care services will be moved from hospital environment to a patcients context.

The patcients health and fitness information can be remotely monitored by e-Health applications and when critical conditions are detected, alarms are triggered. Also the e-Health applications can provide remote control of certain medical treatments or monitor of some parameters.

2.2 Context

The IoT can improve peoples live and health through automation and augumentation. Its capabilities can save peoples time, money and improve decision making.

The main technical and managerial challenges in IoT development [10] highlighted by the reviewed literature are:

- Data management challenge
- Data mining challenge
- Privacy challenge
- Security challenge
- Chaos challenge

Data management challenge All the devices or sensors are generating a big amount of data that must be stored and processed

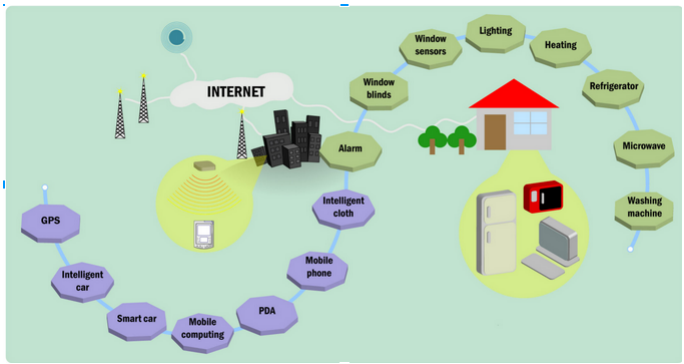

Fig. 1. Illustration of data acquisition equipment in IoT [3]

The data generated by IoT has different characteristics compared with general big data because of the different devices that generates data, different types of data collected, of which the most classical characteristics include heterogeneity, variety, unstructured feature, noise, and high redundancy.

Although the current IoT data is not the dominant part of big data, by 2030, the quantity of sensors will reach one trillion and then the IoT data will be the most important part of big data, according to the forecast of HP. A report from Intel pointed out that big data in IoT has three features that conform to the big data paradigm:

- abundant terminals generating masses of data;
- data generated by IoT is usually semi-structured or unstructured;
- data of IoT is useful only when it is analyzed.

The architecture of data centers are not prepared to deal with the heterogeneous nature and big volume of personal an enterprise data. [11]

Data mining challenge In order to use the big amount of data (discrete data or stream data) stored from all kind of devices, the use of data mining tools becomes a necessity.

Data need to be tamed and understood using computer and mathematical models. Traditional data mining techniques are not directly applicable to unstructured images and video data. Coupled with the need for the advanced data mining tools to mine streaming data from sensor networks and image and video data, there is a shortage of competent data analysts. McKinsey Global Institute estimated that the United States needs 140,000 to 190,000 more workers with analytical skills and 1.5 million managers and analysts with analytical skills to make business decisions based on the analysis of big data. [10][23]

Privacy challenge Because more and more personal devices - smart health equipment and smart car emergency services provide a vast amount of data on IoT users location and movements, health conditions, and purchasing preferences - become traceable through Internet of Things, threats to personal privacy become a problem.

The ownership of the data collected from smart objects must be clearly established and the smart objects and reading devices from the Internet of Things should each be equiped with privacy policies.[19]

Protecting privacy is often counter-productive to service providers in this scenario, as data generated by the IoT is key to improving the quality of peoples lives and decreasing service providers costs by streamlining operations. The IoT is likely to improve the quality of peoples lives. According to the 2014 TRUSTe Internet of Things Privacy Index, only 22% of Internet users agreed that the benefits of smart devices outweighed any privacy concerns [21].

Security challenge Because most of the Internet of Things devices are typically wireless and may be located in public places, the communication should be encrypted. However, many IoT devices are not powerful enough to support robust encryption. [18][19][20]

In addition to an encrypted communication, identity management and unique identifiers are another important components of any security model.

Those are some essentials requirements for the IoT success.

Chaos challenge The evolution of IoT technologies (chips, sensors, wireless technologies, etc.) is in a hyper- accelerated innovation cycle that is much faster than the typical consumer product innovation cycle.

There are still competing standards, insufficient security, privacy issues, complex communications, and proliferating numbers of poorly tested devices. If not designed carefully, multi-purpose devices and collaborative applications can turn our lives into chaos.

In an unconnected world, a small error or mistake does not bring down a system. However, in a hyper-connected world, an error in one part of a system can cause disorder throughout. Smart home applications and medical monitoring and control systems consist of interconnected sensors and communication devices and controllers. If a sensor of a medical monitoring and control system malfunctions, the controller may receive an incorrect signal, which may prove fatal to the patient. It is not difficult to imagine smart home kits such as thermostats and residential power meters breaking down or being attacked by hackers, creating unexpected safety problems. The Internet bandwidth can get saturated with data traffic of proliferating devices, creating system-wide performance problems. A single device may have an insignificant problem, but for the system as a whole, the chain reactions of other connected devices can become disastrous.

To prevent chaos in the hyper-connected IoT world, businesses need to make every effort to reduce the complexity of connected systems, enhance the security and standardization of applications, and guarantee the safety and privacy of users anytime, anywhere, on any device.

2.3 IoT for e-Health systems

"The Internet meets the physical world" is the new phase of the Internet evolution brought forth by the IoT, and the todays few billions of endpoint will exponentially grow in numbers, and this will lead eventually to some scalability issues.

Starting from the traditional Internet who connected computers, the outcome will be now improved by the IoT powered e-Health solutions who will connect people, information, processes, devices and the context. The previously passive and not connected intelligent devices will be connected by the IoT and this connection will bring forth a huge amount of information that can and will be used for algorithms bases actionable decisions. This new information will be

based on strict evidence and will strongly impact the health-care services and the way these services are provided.

We all know that the health-care system of today is struggling to provide viable solutions for population. Through the many opportunities brought by the Internet of Things for e-Health, the wellness of the population will increase and the strain points of the health-care system will be reduced in time. The proactive monitoring of the patients, preventive medicine, follow-up care and permanent care disease management are only few of the most promising use of the connected e-Health cases.

The opportunities, changes and complexities of e-Health enabled by the IoT is significant and can be characterised by:

- number of devices interconnected
- number of type of devices, applications and processes that are interacting
- number of devices that will generate information
- number of decision making points
- number of entry points into the system

The IoT devices could be categorized into two major classes:

- the current smart phones, tablets, and laptops (see **Fig.2**)
- a set of interconnected sensors (ex. Smart Cities, Manufacturing Automation, etc.) (see **Fig.3**)

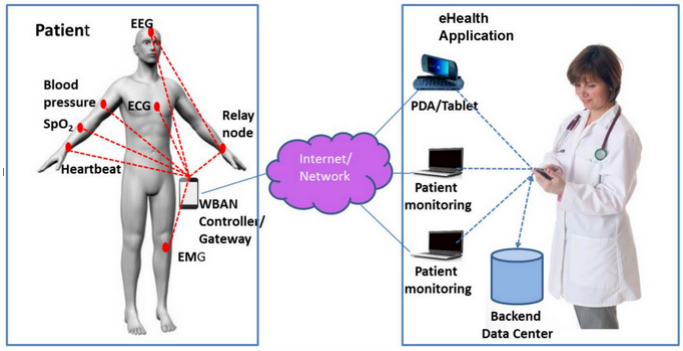

Fig. 2. Conceptual layout of the ASSET testbed - example of IoT architecture [25]

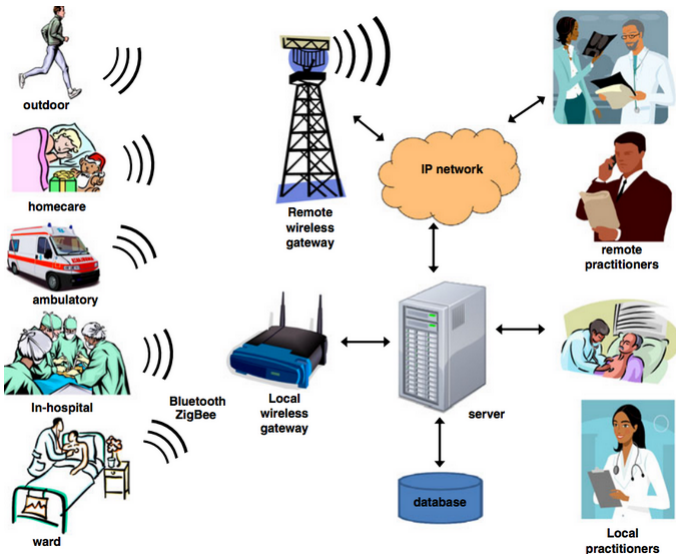

Fig. 3. Typical architecture of wireless sensor networks in health-care applications [26]

Based on how the devices are connected to the patient we can classify them into:

- implantable
- wearable

Those devices could be connected on a need basis, always connected or unconnected.

Based on how the device is connected to the network, the devices can be classified into:

- wired
- wireless
- non-connected

Based on the data generated, the devices can be classified into:

- real-time streaming (ex. patient monitoring)
- discrete data sources (oximeter - generates data at predefined intervals)
- one-time data source (ex. MRI scanner)

Considering the pacient needs, a pacient monitoring system could track data for a long term trend in medical condition or only for its treatment period. The monitoring system could also send data to a precessing element every x hours and even accept a delay of few seconds. The total loss of data for an entire measurement period where that period is a very small fraction of the total

collection time would be of little consequence. In contrast, a device that actively monitors a serious, life-threatening condition that requires specific action to be taken with a given time period or where a single-occurrence is of importance would impose tight requirements on the collection and dissemination of the data. In that case, it would not be acceptable to delay or lose a single packet of data.

Based on how the device is used, we can have devices used by:

- a single person - dedicated
- a limited group of people - shared with a limited group
- a group of people - shareable with a wider population.

The main challenge of an e-Health system based on an IoT architecture is to support this wide range of device types in a variety of care needs and settings.

"Prevention must become a cornerstone of the health-care system rather than an afterthought. This shift requires a fundamental change in the way individuals perceive and access the system as well as the way care is delivered. The system must support clinical preventive services and community-based wellness approaches at the federal, state, and local levels. With a national culture of wellness, chronic disease and obesity will be better managed and, more importantly, reduced." [27]

3 Big Data Platforms for Healthcare Applications

As we can see, IoT is an important source of big data. Big data could come form medical care, traffic, agriculture, industry, etc.

According to the processes of data acquisition and transmission in IoT we can devide the IoTs network architecture into three layers:

- the sensing layer
- the network layer
- the application layer

3.1 Ayasdi

Ayasdi is an enterprise software company that sells big data analytics technology to organizations looking to analyze high-dimensional, high volume data sets. Organizations and companies have deployed Ayasdi's software across a variety of use cases including the development of clinical pathways for hospitals, fraud detection, trading strategies, oil and gas well development, drug development and national security applications.[7]

4 Healthcare Applications: a brief overview

Nowadays, the domain of the application areas based on an IoT architecture is limited only by our imagination.

In the next future, the applications for IoT will grow relentlessly due to the huge variety of the objects and the fact that it is not only an important source of big data, but also a major market for big data applications.

Healthcare and medical data are evolving and continuously growing complex data, based on a huge amount of various information values. The unlimited potential for storing of Big data will lead to dramatically increased storing, processing, querying, and analyzing medical data. Healthcare and medical data are evolving and continuously growing complex data.

Aetna Life Insurance Company took a sample comprising of 102 patients from a total of thousand patients in order to complete an experiment designed to predict the recovery in of patients diagnosed with metabolic syndrome. On a period of three consecutive years 600,000 laboratory test results was scanned during an independent experiment and 180,000 claims using a series of detections tests results of patients with metabolic syndrome.

Furthermore, the final results were compiled into a high personalized treatment plan assessing the risk factors and the recommended treatment plan for the patients. Based on this, doctors may decrease morbidity by 50% in the next 10 years assisting and helping patients to lose weight by five pounds, or advising patients to reduce the total triglyceride in their bodies if the sugar content in their bodies is over 20. [3]

The Mount Sinai Medical Center in the U.S. utilizes technologies of Ayasdi, a big data company, to analyze all genetic sequences of Escherichia Coli, including over one million DNA variants, to investigate why bacterial strains resist antibiotics. Ayasdis uses topological data analysis, a brand-new mathematic research method, to understand data characteristics. [3]

HealthVault of Microsoft, launched in 2007, is an excellent application of medical big data launched in 2007. HealthVault is available as a Web Service and mobile app for iOS and Windows Phone, can tap into a huge array of medical-grade devices and apps, such as glucose monitors and blood pressure cuffs, to automatically import data into one location. Its goal is to manage individual health information in individual and family medical devices. In addition, it can be integrated with a third-party application with the software development kit (SDK) and open interface.[3],[4]

Security in healthcare applications of sensor networks is a major concern. Since healthcare applications of sensor networks are almost similar to WSN application environment, most of the security issues are also similar and hence comparable. [5]

The security issues can be related to system security and information security. Authors in [6] classified the threats and attacks into two major categories:

- **passive** - it may occur while routing the data packets in the system
- **active** - those type of threats are more harmful, criminal minded people may find the location of the user by eavesdropping. This may lead to life threatening situation.

5 Conclusions

The objective of this chapter is to highlight the current status of the evolution, trends and research on Internet of Things applied in e-Health by examine the literature.

The objective of this research report is to highlight the current status of the evolution, trends and research on Internet of Things applied in healthcare by examine the literature.

IoT and Big data analytics have the power to transform the way healthcare performs nowadays. Using this power healthcare organisations and industry can gain insight informations from data repositories and make informed decisions, not suppositions.

IoT requires real time data analysis services which can cope with huge amounts of data. These services raise new challenges from the Big Data point of view: we claim that fully distributed frameworks are required to achieve scalability.

Issues like security, privacy and standards for IoT and Big data analytics should also be considered. Applications in healthcare and data analytics have the potential to become more mainstream and accelerate their maturing process.

The normal trend of sensor device design is that they have little external security features and hence prone to physical tempering. This increases the vulnerability of the devices and poses tougher security challenges.

In the table above we present the attacks which can occur in any health-care system using wireless sensor networks.

Attack assumptions	The risks to WBAN	Security requirements
Computational capabilities	Data modification Impersonation	Data integrality Authentication
Listening capabilities	Eavesdropping	Encryption
Broadcast capabilities	Replaying	Freshness protection

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