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# OPPORTUNITIES AND DEVELOPMENT OF E-HEALTH IN AFRICA: GABON CASE

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23/08/2017

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(M. Sc. Thesis)

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## ABSTRACT

E-Health refers to the use of Information and Communication Technologies so as to collect, analyze, manage and share health information in better way in order to improve healthcare services. Nowadays, e-Health is attracted and widely used in developed countries around the world. This has shown that, using e-Health can offer suitable, sustainable and challenging solutions to health system by providing significant benefits. From different experiences, it appears that African countries may also fruitfully use e-Health technologies to improve the quality of their health services. This thesis discusses the main opportunities and development of e-Health system for African countries based on the characteristics, technologies and tools used in storing, managing and processing Big Data. Gabon, as a developing country was chosen as a case study where the main challenges of e-Health were investigated and a sample of e-Health website was implemented. Considering the whole health condition in Gabon, these innovative health solutions can be profitable by establishing legal frameworks and functional strategies in the purpose of providing financially affordable, reliable and more effective healthcare services. In this regard, much endeavors remain to be done in the field of healthcare provisions for both private sector and the government as policy maker should be more active in taking actions for implementing e-Health technologies.

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# AFRIKA'DA E-SAĞLIĞIN GELİŞİMİ VE FIRSATLAR: GABON ÖRNEĞİ

(Yüksek Lisans Tezi)

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## ÖZET

E-Sağlık, sağlık hizmetlerinin iyileştirilmesi amacıyla sağlık bilgilerini daha iyi bir şekilde toplamak, analiz etmek, yönetmek ve paylaşmak için Bilgi ve İletişim Teknolojilerinin kullanılması anlamına gelmektedir. Günümüzde e-Sağiık, dünyanın dört bir yanındaki gelişmiş ülkelerin dikkatini çekmekte ve bu ülkelerde yaygın bir şekilde kullanılmaktadır. Bu deneyimler, e-Sağlık'ın uygulamalarının önemli ölçüde yararlar sağlayarak, sağlık sistemleri için uygun, sürdürülebilir ve zorlu çözümler sunabildiğini göstermiştir. Farklı deneyimlerden hareketle, Afrika ülkelerinin de sağlık hizmetlerinin kalitesini iyileştirme için e-Sağlık teknolojilerini uygulamalarını verimli bir şekilde kullanabilecekleri görülmektedir. Bu tezde, büyük verilerin depolanması, yönetilmesi ve işlenmesinde kullanılan özelliklere, teknolojilere ve araçlara dayalı olarak Afrika ülkelerinde e-Sağlık sistemlerinin gelişimini ve bu alandaki başlıca fırsatları ele almaktadır. Tezde, e-Sağlık uygulamalarında aşılması gereken zorlukların ele alındığı durum çalışmasında gelişmekte olan bir Afrika ülkesi olarak Gabon seçilmiş ve bu amaçla bir örnek e-Sağlık web sitesi yapılmıştır. Gabon'daki genel sağlık durumu göz önüne alındığında, bu yenilikçi e-Sağlık çözümleri, mali açıdan uygun maliyetli, güvenilir ve daha etkili sağlık hizmetleri sunmak amacıyla yasal çerçeve ve fonksiyonel stratejiler oluşturarak başarılabilir. Bu bağlamda, sağlık hizmetlerinin karşılanmasında hem özel sektörün hem de politika yapıcı olarak hükümetin çok çaba harcaması ve bilgi teknolojilerinin uygulanması için daha aktif hareket etmeleri gerekmektedir.

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## SYMBOLS AND ABBREVIATIONS

The symbols and abbreviations used in this study are presented below along with explanations.

| Abbreviation | Explanation |
|---|---|
| **ACE** | Africa Coast to Europe |
| **CAB** | Central Africa Backbone |
| **CAMA** | Context-Aware Mobile Approach |
| **CNAMGS** | Caisse National de l'Assurance Maladie et de Garantie Sociale |
| **CSS** | Cascading Style Sheets |
| **DMP** | Dossier Medical Personnel |
| **DRS** | Direction Regional de la Sante |
| **E-Health** | Electronic Health |
| **E-Learning** | Electronic Learning |
| **HER** | Electronic Health Record |
| **GDP** | Gross Domestic Product |
| **HDFS** | Hadoop Distributed File System |
| **HDI** | Human Development Index |
| **HIS** | Health Information System |
| **HL7** | Health Level Seven |
| **HTML** | Hypertext Markup Language |
| **ICT** | Information and Communication Technology |
| **ITU** | International Telecommunication Union |
| **IEEE** | Institute of Electronic and Electronic Engineers |
| **NoSQL** | Not Only SQL |
| **MDG** | Millennium Development Goals |
| **M-Health** | Mobile Health |
| **MS Sante** | Secure Health Messaging |
| **PAHO** | Pan American Health Organisation |
| **PHP** | Hypertext Preprocessor |
| **PSGE** | Plan Strategique Gabon Emergent |
| **RDBMSs** | Relational Database Management Systems |

| Abbreviation | Explanation |
|---|---|
| **RPPS** | Health Professional Sharing Directory |
| **SOD** | Security Oriented Design |
| **UN** | United Nations |
| **WHO** | World Health Organisation |

# 1. INTRODUCTION

In Africa, Health Information Systems (HIS) have seen significant improvements, but there still are serious gaps, and much remains to be done to improve their quality and opportunities towards people and economy. Few countries have sufficiently effective HIS to fully manage the Millennium Development Goals (MDG) launched by the United Nations (UN). HIS have been chronically under-invested in the collection, analysis, dissemination and use of data. Even when they are available, data are often outdated and unreliable [1].

In recent years, the Gabonese government has made many efforts to revitalize the health system, notably through the multiplication of health centers and the improvement of health services with the new social protection scheme of the Caisse Nationale d'Assurance Maladie et de Garantie Sociale (CNAMGS). Despite its improvements, Gabon as well as many African countries is faced with a number of problems inherent to the poor quality of care services due to the lack of access to health information characterized by the lack of an efficient and reliable digital database and the dysfunctions of the information system, contribute negatively to the improvement of the health of Gabonese populations [2].

Today, the solutions to these problems exist and can be applied to the opportunities created by the appropriate conditions to the installation and dissemination of e-Health system in Gabon in order to contribute to the strengthening of the HIS, while promoting a better quality of care for patients.

The usage of e-Health is more and more profitable for many countries. Indeed, e-Health aims at supporting the healthcare system to help the professionals of this sector. According to some experiments from Norway or South Africa, it can improve care services towards patients as clients and then facilitate the work of physicians, nurses etc. At the beginning, investing in affordable e-Health applications may be expensive for countries but it will produce benefits if the system is well implemented in terms of rapidity, efficiency, quality of service and reduction of costs [3]. Such innovative technology in healthcare, allows for example to limit the mobility of disabled individuals and to care about them at distance. Obviously e-Health is a proof

of technological revolution in the healthcare's sector. Dealing with advantages of e-Health, several authors publish reviews upon this issue.

For example, in 2013 the Institute of Electronic and Electronic Engineers (IEEE) published a literature treating the Brazilian primary healthcare system based on the Context-Aware Mobile Approach (CAMA). It focuses on infrastructural support to provide value added to e-Health applications to become faster, safer and enables the reliability for both patients and medical staff [4].

In terms of advantages, in Japan for instance, regarding the fact that population is aging rapidly, and the diseases from aging increase, Government sets up the usage of e-Health in order to control this phenomenon and then reduce healthcare expenditures from the treatments. Thus, a platform based on the “Reduction of Days Spent for Treatments” and health insurance systems have been established. It connects aged people at home to medical institutions by transmitting vital data via telecommunications networks. As result, the users are treated in shorter days maintaining their lifestyle this allowing the reduction of costs not only for medicals centers but also for the patients. If Japan continues to use e-Health in the future by making improvements, it will reduce its expenditures of 1.5% of average per year according to the forecasts made by the University of Hyogo [5].

Moreover, with a view to recognizing the need to adapt to the ICT tools in order to improve healthcare services, France has settled e-Health services to meet the special needs of French patients. Indeed, in 2013, it was found in France that about 3.1 million people have difficulty accessing a general practitioner, and nearly 15 million people suffer from chronic diseases that require specialized and adequate care [6]. In addition, considering the increasing of the cost of healthcare, France has chosen e-Health through the setting up of Telemedicine and the Dossier Medical Personnel (DMP) in order to take over the management of patients and to provide remote services such as examinations, treatment or monitoring. Thus, these two ICT tools support the traditional means of providing care with the objective of supporting the emergence of digital health technologies in order to improve access to healthcare for all, while ensuring respect for patient rights. Furthermore, it should be made clear that the technologies cited above have made possible the development of the public

works management of information systems in the health and medico-social sector, which is a crucial device in the use of e-Health. Added to this, there are the secure healthcare messaging (MS Sante), the health professional sharing directory (RPPS), the health professional card (CPS) in the goal to ensure the safety and confidentiality of patients data.

Similarly, the needs of telemedicine development in the German health sector have proved to be crucial for improving the performance of the ambulatory sector, biological laboratories, by developing tele-monitoring and tele-rehabilitation centers and applications for management of patients with chronic diseases, cerebral vascular accidents, diabetes and heart failure. In view of the foregoing, in 2013, two hundred and seventy (270) projects were counted to meet these medical needs of German patients, but only two (2) flagship projects were able to integrate the official health organizations, namely the project SCHWESTER AGNES which consists of making home visits thanks to a nurse tele-assisted by a doctor. The second is TEMPIS project which supports patients with ischemic stroke by solving the problem of lack of neurologists in 15 regional hospitals that are connected to two university centers specialized in neurology in order to carry out the treatment of Thrombolytic as soon as possible [7].

As another advantage, we can also quote the “Security Oriented Design (SOD)” created especially towards elderly people to reinforce the actions of e-Health and related systems. In fact, with the development of this item, patients can view their records online via web and mobile client’s devices without need to go to the hospital each time. It also allows scheduling patients appointments and then to manage patient data as for example tests, prescriptions and visiting records [8]. Despite of these improvements, much remains to be done to use all the potentials of this particular technology already largely experienced in some countries like the United States and some others.

In addition, some developing countries have also experimented with telemedicine technology in recent years with the aim of designing a low-cost tele-consultation and tele-education platform to improve the accessibility and equity of healthcare towards patients living in medically isolated areas using lower cost infrastructure and free

online software. It is in this sense that Togo has designed this system which has permitted to consult patients at a distance through tele-radiology, tele-echography and tele-endoscopy between expert sites and isolated sites that is to say the regional hospital CHR Tsevie in Togo, the university hospitals CHU campus of Lome and Trousseau of Tours in France. Thus, due to a high-speed connection and remote control software, tele-echography, tele-radiology and tele-endoscopy sessions were carried out successfully [9]. As in the case of Togo, South Africa is also considered a pioneer in e-Health through the use of m-Health in Africa. Indeed, in Cape Town and Durban, South Africa, the Cell-Life project backed by Vodacom, has developed software and data management systems so healthcare professionals can use their mobile phones to monitor HIV treatment and identify potential health problems before they become life threatening. Data includes symptoms, compliance with drug regimes, ability to pay for transport to clinics and nutrition. A central database stores the information for access by healthcare professionals for their caseload about 100 patients each [10].

The development of ICTs offers real opportunities to take the challenges up in terms of relational, demographic, economic, scientific and especially medical matters. As particular case, Gabon is not an exception in this realm of developing technologies by regarding the telecommunications architecture. Meanwhile, internet should be a significant potential to develop certain health programs through e-Health in order to ease more the health services in the country by optimizing better the needs and the current records of health system at the same time.

This work is essentially based on the opportunity and development of e-Health in Africa sampling the case of Gabon. Indeed, as regards to the deficiencies encountered in Gabon health system in terms of the lack of health information access characterized by various errors in diagnosis and medical reports from physicians enabling inefficient health care services. The lack of patient self-education about the health information concerning some diseases such as malaria, tuberculosis, diabetes, or even infant and mother mortality is also a great reason for which this paper has the purpose to proposing an e-Health platform to bring some solutions to these problems.

This thesis is divided into five main chapters. The first chapter presents the overview of health system in Africa and more particularly in Gabon by showing the solutions adopted by certain countries for improving their health organization. The second chapter displays the opportunities and challenges of adopting e-Heath in Gabon by highlighting the technologies, strategies and benefits to which it is related to. The third chapter focuses on the characteristics, technologies and tools used in big data for storing, managing and processing huge volume of data in e-Health system. The fourth chapter discusses about the system design and implementation by showing some requirements in terms of access control, interoperability, security, and the overall architecture with samples of system implementations. The final chapter is relating to the eventual proposals of e-Health for Gabon and the benefits of this kind of health technology both for population healthcare and national economy.

# 2. OVERVIEW OF E-HEALTH IN GABON

E-Health is defined as the use of Information and Communication Technologies (ICTs) for health. It includes the treating patients, conducting research, educating health workforce, tracking diseases and monitoring public health [11]. E-Health is divided then, into three major areas such as *"Electronic health record"* focused on the storing, managing and transmission of data. The second one is related to *"e-Prescribing"* referring to clinical information system consisting for clinicians especially to make their decision and then to communicate the suitable medication prescriptions to their patients. The last one is *" Smart Home"* allowing simplifying health care services from a distance [12]. It is used for specific residence equipped with technology that allows monitoring and then provides independence and the maintenance of good health towards patients.

According to the World Health Organization (WHO) this concept is defined as "the cost-effective and secured use ICT in support of health and health-related fields, including health-care services, health surveillance, health literature, health education, knowledge and research" [3]. In other words, it takes into account the main aspects of health by using modern technologies in the goal to improve health-care services.

## 2.1. The Goals of E-Health

The main purposes of e-Health is to increase access and efficiency to health care by assuring remote consultation and remote monitoring for people living in rural areas who have limited ability to reach appropriate health centers like Libreville, Port-Gentil and Lambarene (Gabon). Table 2.1. shows different goals of e-Health.

Table 2.1. Goals of e-health

| Goals | Meaning |
|---|---|
| Increase access and efficiency to health care | Assuring the ability to bring healthcare services to patients in distant zones via an improved quality of health services by using accordingly and efficiently the health budget |
| Increase health staff capacity | Improving the quality of health care services to patients through the provision of better health information |

Table 2.1. (continued) Goals of e-health

| Goals | Meaning |
|---|---|
| Better outcome for patients | Accessing to better health services on time no matter the area with a reduction of health care costs by ensuring a better quality of patients' health records. |
| Increase access to health knowledge | Accessing more rapidly and efficiently to information stored in EHR to the benefit of medical staffs and patients. |
| Increase health system performance | Enabling safety, efficiency and quality of health services through a good distribution of health information into the health system. |
| Increase patient participation and self-management of health | Enabling patients to get greater autonomy for managing themselves as needed. |
| Improve decision and policy making process | Enabling health system performance |
| Reduce costs of health care | Through certain e-Health technologies like remote monitoring the most costly care interventions are reduced to facilitate health care access to patients |

## 2.2. Core Components of E-Health

According to Pan American Health Organization (PAHO) and WHO, the Figure 2.1. shows the mean to categorize and integrate the components of e-Health system into the global strategy of implementation in favor of medical personnel and patients as it is displayed below [13].

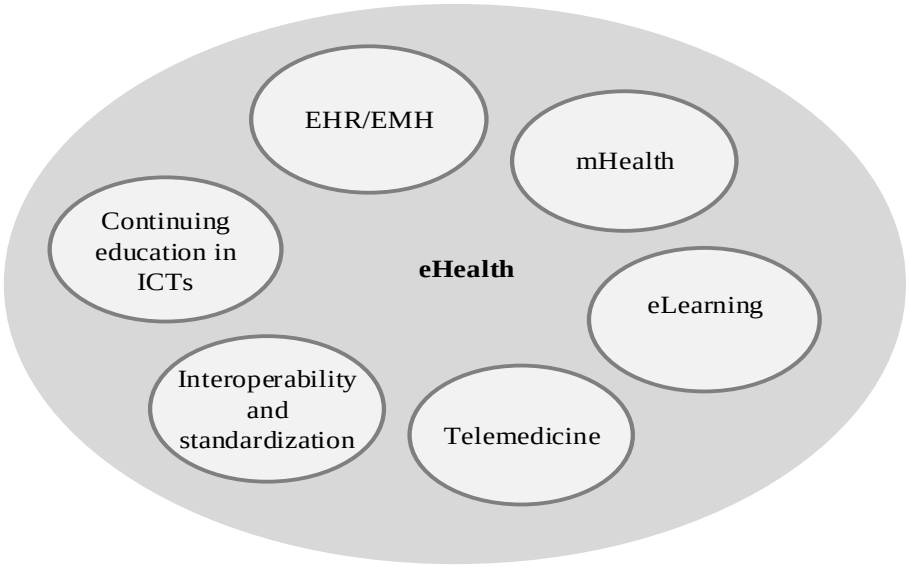


Figure 2.1. Components of e-health

*Electronic Health Records (EHR):* It is related to electronic documentation of current and historical health, laboratory results, medical reports and medical treatments concerned with the health of a person. This e-Health application is storing all specific medical data of any patient by reducing the gaps in decision making through a better access to patients' information.

*Telemedicine:* It is an e-Health system which has the capacity to bring healthcare services to patients in distant zones via an improved quality of health services by using accordingly and efficiently the health budget. It is also a technology that reduces travel time and stresses for the patients.

*mHealth:* This application is aiming at providing mobile access to EHR anytime and anywhere on any mobile devices like smartphones, tablets etc whose both patients and the medical staffs have an access. This helps medical staffs to use time more efficiently to achieve tasks like updating patient's medical data, keeping up with e-mail and prescribing medications at real time when it is needed and no matter the geographical zone.

*eLearning:* This mean is used due to the ICTs for learning in order to promote a sufficient number of qualified medical personnel. It helps improving the quality of education and increases access to it through innovative methods.

*Continuing education in ICTs:* The provision of courses or programs is delivered for health professionals including the medical staffs, who are not formally accredited just only to help them developing their skills in ICTs for application in health.

*Interoperability and standardization:* Interoperability is an e-Health tool dedicated to the communication between different technologies and software applications for the efficiency and accuracy of using and sharing of data. This relational system requires the use of standards that is necessary related to the rules, regulations, guidelines, or definitions with technical specification to achieve the integrated management and make health systems sustainable at all levels, by promoting the exchange and use of reliable data in an efficient and integrated method.

## 2.3. Functions and Outcomes of E-Health Services

The benefits of e-Health for Gabon can be presented as the means allowing to facilitate the treatment and sharing of information between medical staffs and patients via the use of e-Health technologies for an effective management of health system. The use of ICTs in healthcare system will significantly reduce errors, redundant examinations, unnecessary hospitalizations because data are in this case electronically stored by contrast to the former system based on paper which was causing errors while entering the patients' records. As matter of fact, they will enable better diagnosis and the reduction of health costs through a good decision-making policy.

Furthermore, such a system will reinforce the quickness and fluidity of healthcare provisions towards the patients with the quality and safety of the health information in order to ensure a more efficient management of healthcare system. The Figure 2.2. presents some functions and outcomes of e-Health Services.

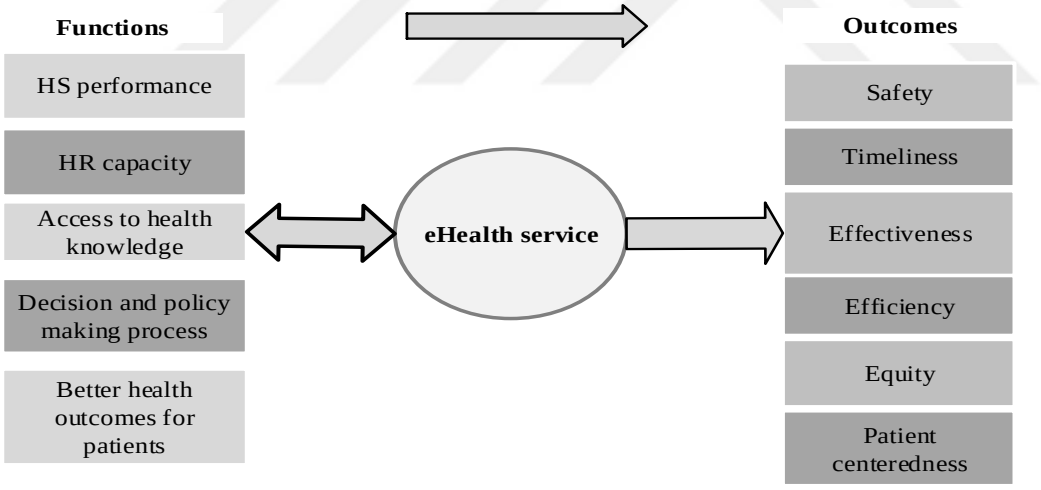


Figure 2.2. Functions and outcomes of e-health services

In addition, it is crucial to strengthen the medical staff's capacity to struggle against the lack of capacity by human resources through the tools like e-Learning or Continuing education in ICTs. Indeed, a proper training to e-Health technologies would allow care providers being able to face health challenges in rural areas and then to find efficient solutions to some illnesses and to the infant mortality issues in Gabon. Finally, a strong and operational leadership in the scope of decision and policy making process would enlighten global strategic and financial orientations to manage accordingly the health

system through some adequate monitoring and surveillance mechanisms of actions and decisions made by health system stakeholders.

### 2.4. E-Health National Strategies

In global framework, the different components of e-Health strategies (Figure 2.3. Components of an e-Health strategy) are established to maintain a formal institutional scope and guarantee the good operation of the overall infrastructures. In this view, it is relevant to state that each component is specific and then achieves a particular target. Among the main concepts of e-Health strategy, the "Coordination aspects" are the one that is related to the central organizational policy with the purpose to strategize the functioning rules and to forecast and execute the major investments into health system.

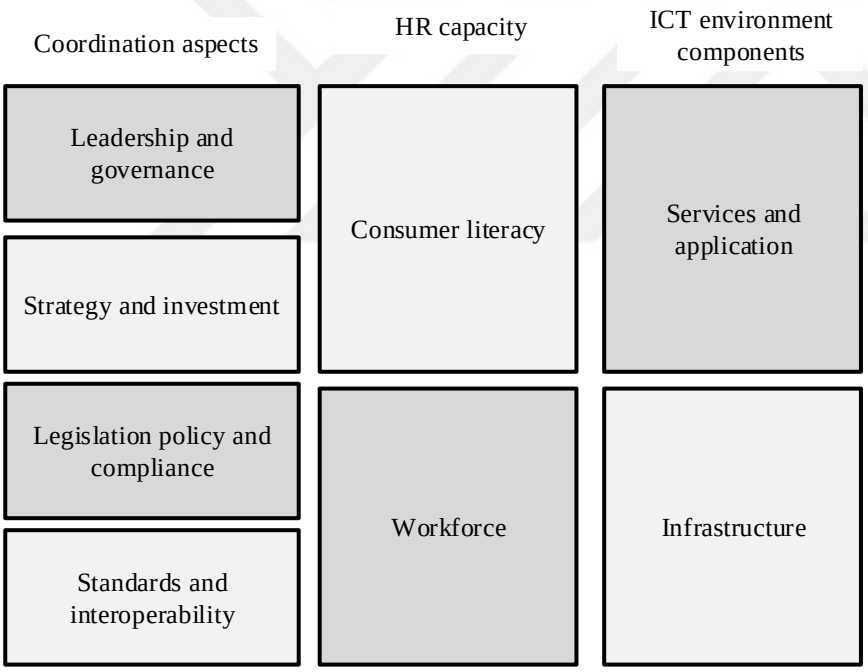


Figure 2.3. Components of an e-Health strategy. Adapted from [14]

As far as concern, the *"leadership and governance"*, refers to some tasks that involve with team members who make the major decisions in the goal to perform operations and assess the results of the projects. The *"strategy and investment"* tackles the creation of a strategic planning for seeking financing mechanisms in order to fulfill the national health engagement. Concerning the *"legislation, policy and compliance"*, it encompasses the

strategic environment for legislating and regulating the use of data in the purpose of e-Health development.

The fourth toolkit about the e-Health strategy is the *"standards and interoperability"* which essentially indicates the scope of standards that is necessary to achieve the operability by maintaining the exchange of information between the different systems available within e-Health system.

The second concept of e-Health strategy is essentially based on an adequate training of health professionals. Indeed, "Human resources capacity" is also required in terms of *"workforce"* that performs the basic knowledge and skills needed for the development of e-Health efficiency through the education and training mechanisms and also the technical cooperation with the private sector in order to perform an appropriate health workforce. The Human resources aspects are also characterized by the *"Consumer literacy"* which is normally not included among the components of e-Health strategy but represents a significant aspect including electronic literacy for the development of a system according to the WHO.

The other concept but not the least is focused on the "ICT environment components" such as technological services into health system. In fact, it emphasizes on the *"Infrastructure"* which has the goal to promote the exchange of information beyond the health system borders by collecting, organizing, saving and sharing data. The other component is related to the "services and applications" that is basically referred to the implementation of ICT tools for e-Health purpose and the software applications through they are applied.

### 2.5. Limitations to E-Health

The aspects below are considered as the major limits to e-Health.

#### 2.5.1. Legal limitations

Legal barriers refer to the legal concerns faced by healthcare organizations when adopting e-Health solutions. The main problem faced by healthcare organizations in regards to this barrier is enforcing privacy of data [15]. Even though, it exists several laws to struggle against fraud, abuse, mistrust, liability in order to minimize suspicion in the

implementation of IT in healthcare, the main challenge here is to be able to ensure that the law of privacy can be applied while health organizations are adopting e-Health solutions. Besides, there are no legal laws displaying the specific conditions that the medical personnel need to follow before having access to patient data by specifying who are the authorized medical staffs and how they can get access to these medical information.

### 2.5.2. Technical limitations

As the technology innovation is getting developed day by day, the misuse and cyber criminality increase as well. The implementation of e-Health in any health organization necessarily brings security implications and then represents a major threat within information security. Also, it is known that the e-Health architecture is only based on patients and their data but, it remains crucial to record anyone who get access to the patient data at real time by following the Confidentiality, Integrity and Availability (CIA)' s example model [16].

### 2.5.3. Operational limitations

The operational limitations refer to the interoperability of e-Health system which must provide an interface enabling to existing computer system to communicate with the new one brought by e-Health. In addition, it is mandatory to use a common standard electronic language between the healthcare organizations about medical data related to patients or hospital internal records on the basis on an agreement upon the best method of communication to use.

### 2.5.4. Cost/benefit barriers

This limitation is related to the cost supported by the stakeholders while implementing e-Health solutions. The required expenditures are made in appropriate way with the purpose to do benefits in agreement with the stakeholders. By knowing that, the implementation of e-Health solutions is profitable for healthcare organizations in comparison with former methods such as the paper-based record, the benefits of implementing e-Health remain satisfying and may not exceed the costs of implementation.

## 2.6. Gabon Health System

Gabon is a country of Central Africa, bordered to the South-East by the Republic of Congo, in the North-West by Equatorial Guinea and in the North by Cameroon (Figure 2.4. Gabon geographical map). A country with an area of 267 667 km2 whose the estimated population is 1 725 290 of inhabitants in 2015 with a density of 6.3 inhabitants/km2.


Figure 2.4. Gabon geographical map

Gabon is covered by 80% of the forest characterized by a very rich fauna and flora. Apart from its forest resources, Gabon is recognized as one of the most prosperous countries in Africa thanks to its mineral and petroleum resources. Indeed, it is the country with the highest Human Development Index (HDI) in sub-Saharan Africa, according to a report by the United Nations (UN) established in 2014, with the second per capita income behind the Equatorial Guinea and before Botswana [17].

### 2.6.1. Gaps in gabon health system

The Gabonese health system comprises four (4) sectors: public, para public, paramilitary and private whose the function is essentially based on the Direction Regional de la Santé (DRS) which manage hospitals, medical centers and human resources [18]. Indeed, in 2013 Gabon has approximately 32 health centers and 501 dispensaries, half of which are exclusively located in large urban areas such as Libreville and Port-Gentil [19]. In addition, according to a publication by WHO published in 2014, the density of physicians per 1000 people was estimated at 0.29 in 2004 meanwhile in 2009 it was 3 per 10000 inhabitants as the table shows below. As for the density of nurses and midwives, it was around 50 per

10000 inhabitants in 2009 (Table 2.2. Gabon health workforce). Despite, all the government's endeavors, the number of health providers is still low and poorly distributed over the country and consequently do not enable to efficiently face with the healthcare challenges in the remote zones and sometimes in more urbanized areas. Furthermore, the lack of qualified health workers and the inadequacy of training regarding the current health problems constitute also other meaningful issues that need practical solutions [2].

Table 2.2. Gabon health workforce. Adapted from [20]

| | |
|---|---|
| Density of physicians per 10000 inhabitants (2009) | 3 |
| Density of nurses and midwives per 10000 inhabitants (2009) | 50 |
| Density of Physicians per 1000 inhabitants (2004) | 0,29 |
| Density of nurses and midwives per 1000 inhabitants (2004) | 5,01 |
| Other health workers density per 10000 population (2004) | 0,146 |

Moreover, the overall healthcare structure in Gabon shows the poor distribution not only of the medical staff but also of the medical and hospital centers throughout the country. A situation that could be explained partly by the inefficient policy of government in the matter of spatial planning, which is reflected in the problems of medical desertification, judging by the significant number of general practitioners and specialist physicians working in large urban centers to the detriment of isolated areas which results in the absence or the scarcity of health care services in rural areas. In addition, it should be noted that the lack of access to health information, particularly due to the lack of an efficient and reliable digital database and the dysfunctions of the information system, contribute negatively to the improvement of the health of Gabonese populations.

Besides, there are still many deficiencies in Gabon's public health despite the authorities' efforts in promoting the prevention and sensitizing campaigns against some communicable diseases such as HIV, Hepatitis, Malaria, Meningitis, Tuberculosis, Measles etc and the non-communicable illnesses like Diabetes, Cancer, Stroke accident, Chronic diarrhea but also the infant and maternal mortality's issue whose the situation is needed to be viewed in deep. Indeed, all these diseases are negatively affecting the population health and the life expectancy to some extends (Table 2.3. Gabon health indicator). As example, the under-five years infant mortality rate is still high (56 % in 2013), in spite of the improvements by government with its willingness to strongly reduce the number of deaths of children [2].

Table 2.3. Gabon health indicator

| | |
|---|---|
| Population total (2015) | 1 725 290 |
| Infant mortality rate deaths per 1000 live birth (2013) | 39 |
| Under five mortality rate deaths per 1000 live birth (2013) | 56 |
| Stillborn rate per 1000 total births (2009) | 17 |
| Neonatal mortality rate deaths per 1000 live birth (2015) | 23,2 |
| Maternal mortality ratio per 100000 live births (2015) | 291 |
| Total health expenditure % Gross Domestic Product (GDP) (2014) | 3,4 |
| Communicable diseases rate% (2012) | 68 |
| Non communicable diseases rate % (2012) | 23 |
| Global population Life Expectancy at birth (Female and Male) (2014) | 63 |
| Prevalence of HIV among adults aged 15 to 49 (%) (2015) | 3,8 |
| Deaths due to HIV/AIDS per 100 000 population (2012) | 143 |
| Malaria number of reported confirmed case (2014) | 31 900 |
| Malaria number of reported deaths (2014) | 159 |

From this regards, it can be assumed that more there are children deaths (high rate of infant mortality), less there are people who will be educated or trained within the population because the life expectancy will get declined. As result, this could cause at long-term a reduction of the created resources meaning as the Gross Domestic Product (GDP) that could consequently raise some problems in process of development in Gabon.

Despite the fact that, it is free and easy to access to public health facilities notably through the social protection scheme of the Caisse Nationale d'Assurance de Maladie et de Garantie Sociale (CNAMGS), the supply of care is limited because of the various shortages which have been previously mentioned. In view of solving these problems, the establishment of several modern health structures throughout the country does not unfortunately respond entirely to the difficulties encountered by Gabonese populations who still rely heavily on traditional medicine in rural environment, which represents then an unsustainable and insufficient solution in terms of national health policies.

### 2.6.2. E-health solution to enhance Gabon health system

In order to make a sustainable and effective solution to this imbalance by strengthening the existing solutions, it seems essential to use the means of ICTs through e-Health. In other words, Gabon should settle down an e-Health system to optimize the provision of

healthcare including qualified health workers in order to better manage patients and qualitatively improve Gabon health system. Table 2.4. shows gaps, new proposals and expectations in Gabon's health system.

Table 2.4. Gaps, new proposals and expectations in Gabon's health system

| GAPS | PROPOSALS | EXPECTATIONS RESULTS |
|---|---|---|
| Dysfunction of health information system<br>Low quality of health care services | An adapted e-Health system so as patients or health provider can access directly at their home. | To enable a better follow-up system for the patients.<br>To reduce government public expenditures on health services. |
| Absence of reliable and efficient digital database for managing health information<br>Lack of accessing health information | The settlement of an effective database system.<br>The settlement of an EHR system | To ease access, treatment and sharing information between health professionals and patients. |
| Medical desertification (Few health providers in rural areas) | An adapted a Telemedicine system | to enable easier access of healthcare and provide better healthcare services |
| Lack of qualified health workers | An adapted training through an eLearning system.<br>Training of ICT to medical staff. | To improve the quality of service toward patients. To increase the number of health providers |

If only Gabon could have a telemedicine system that allows medical consultation and monitoring at distance, then an EHR system that gathers all the medical data of patients like laboratory analysis results, prescriptions, imaging, treatments etc by integrating a good quality of training within ICTs tools towards medical personnel, this will facilitate the treatment and sharing of information between health professionals and patients for the effective management of the latter. In addition, the adoption of such ICTs in healthcare system will lead, for example, to reduce redundant examinations, unnecessary hospitalizations, a better diagnosis and the optimization of health costs through good financial governance. Furthermore, the use of e-learning in Gabon's health system would necessarily improves the provided healthcare services and then increases the number of qualified health workers by enabling a better distribution of health providers all over the territory.

Considering the fact that, the lack of practical information towards population is generally one of the main causes of diseases prevailing in Gabon, it seems important to propose an educative digital platform with the goal to inform directly at anytime and anywhere the population about the illnesses that we can avoid, the first attitudes to adopt in case of

sickness, or the right medications to take etc. This will help patients and other users of that platform to get access to all necessary information about health issues in order to reduce certain diseases or some public health problems like the infant and maternal mortality.

### 2.6.3. Requirements for adopting e-health in Gabon

The implementation of the e-Health in Gabon is merely related to some prerequisites such as high-speed internet coverage throughout the entire territory and the health personnel training to ICTs in terms of quantity and quality that must adequately and efficiently respond to the health needs. From this regards, it has been observed that, the internet networks are still growing up with the involvement of telecommunications' companies and the State's endeavors in the matter of developing internet access.

Internet evolution status

In its 2014 ranking of the African countries most developed according to their index of ICTs, the International Telecommunication Union (ITU) considers that Gabon is the best in Central and Francophone Africa [21]. Thus, mobile telephone operators and the State of Gabon have made numerous investments for the development of this sector, which in the year 2014 had contributed of 5% to the country's GDP and generated a turnover of 293 billion CFA francs according to the Ministry of the Digital Economy and the Post. The ICT's sector employs directly or indirectly more than 12 000 people and the penetration rate of the mobile is 193%, so 2,947,681 subscribers that of the fixed is 1.22% and the penetration rate of the internet is estimated at 86% with a predominance of mobile Internet [22]. Unlike many sub-Saharan countries, Gabon introduced a few years ago the 3G technology and then recently the 4G one. The competition among the telecommunications' companies promotes an increase in operators' service proposals and a continuous improvement of these services. Today, the economy of services is therefore an important lever of the non-oil sector. It then accelerates the process of diversifying the economy by contributing to the emergence of small and medium-sized enterprises and some service structures more open to the world.

Table 2.5. Gabon internet annual growth rate. Adapted from [23]

| Years | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| Internet Penetration Rate | 17,78% | 33% | 41% | 76% | 67% | 72,56% |
| Subscribers | 282 776 | 497 371 | 742 538 | 1 150 814 | 1 009 719 | 1 101 231 |

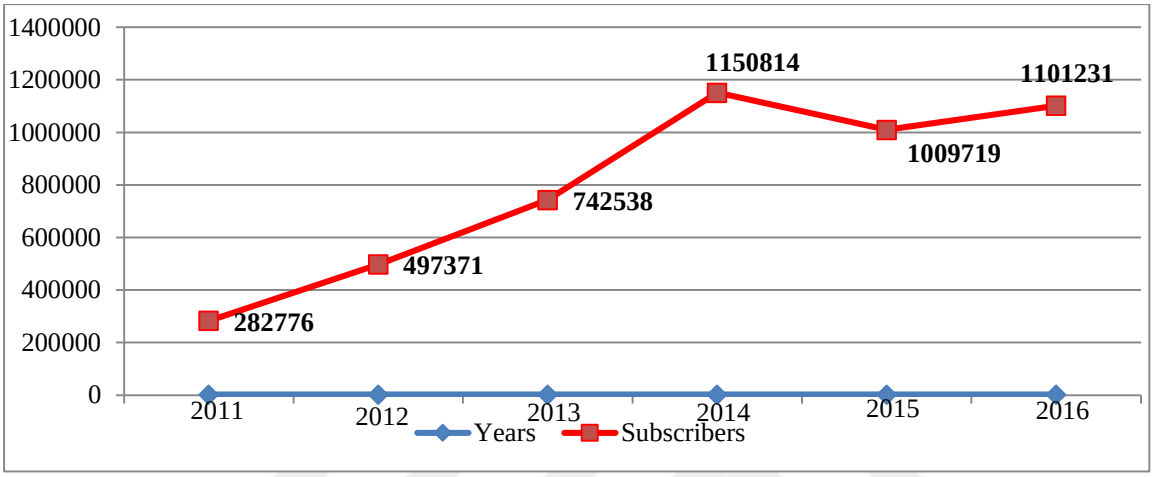


Figure 2.5. Annual evolution of internet penetration rate in Gabon. Adapted from [23]

Through the explanations mentioned above, it is obvious that Gabon shows enough potential allowing the implementation of e-Health technology. Knowing that one of the first prerequisites is the internet access over the country. In fact, from 2011 to 2016, it is clearly noticed that the penetration rate of internet is being relatively and positively stable (Table 2.5. Gabon internet annual growth and Figure 2.5. Gabon annual evolution of internet penetration rate adapted) on the basis of the population estimated at 1 517 685 inhabitants [23]. By considering the low level of population, it seems that Gabon is displaying good internet coverage in order to install e-Heath technology not only for the population well-being but also to reinforce technical health system installations.

Current government ICTs projects in Gabon

In the framework of Plan Strategique Gabon Emergent (PSGE), the Gabonese authorities have put in place several projects related to the development of the digital economy to meet the diversification needs of the national economy, including: the Africa project Coast to Europe (ACE), which aims to extend Gabon's Internet connection via an optical fiber submarine cable to boost Internet network capacity on the international scale. Similarly,

through the project Central Africa Backbone (CAB), which supposed to be intercommunity, the country which wants to obtain its autonomy in international telecommunications, will be able to use this infrastructure to connect to the sub-region within the framework of the fiber project Optical Central Africa Backbone (CAB4), funded by the World Bank for $ 58 million, whose execution level has already reached 82% [24]. It also seeks to increase the geographical coverage of high-bandwidth networks and reduce the cost of communication services on the territory of the Gabonese Republic (Table 2.6. Gabon Governmental Current Projects).

Table 2.6. Gabon governmental current projects

| PROBLEMS | GOVERNMENT CURRENT PROJECTS | EXPECTATIONS RESULTS |
|---|---|---|
| Weakness of Internet Network capacities | -Central Africa Backbone(CAB)<br><br>-Africa Cost to Europe(ACE) | Extension of the geographical high-speed network coverage.<br>Decline of communication services 'costs.<br>Improvement of the internet network capacities at international level to provide a better connection and security all over Central Africa Region. |
| Weakness of digital economy | Cyberty Project in Mandji Island | Development of digital ecosystem promoting innovations thanks to the creation of jobs through the breed of start-ups that produce apps and services related to health information.<br>Creation of a regional digital hub for eLearning, Telemedicine, eCommerce and eGovernment through the establishment of ICTs' companies like Google, Microsoft and Siemens.<br>Innovation of new methods of managing health needs. |
| Lack of efficiency health system | -eGabon | Improvement of the basic healthcare's management.<br>Efficiency of health system. |

These two major projects that are linked together will enable Gabon which is one of the only African countries to have 2 submarine entry points to be a hub of digital governance in the sub-region of Central Africa. They will provide greater security and connectivity for the entire sub-region. In this context, since 2011 Gabon is being sheltering the ACE fiber optic submarine cable landing station. At the end of the deployment of the national fiber optic network, the e-Government will become operational and make public services accessible directly on-line, knowing that administrations will be networked to improve the effectiveness of government actions. Gabonese people will be able then, to experience

technological innovations such as telemedicine, e-teaching, e-commerce, e-visa in support of national growth and this will enable to develop a national HIS plan in the framework of the e-Gabon concept.

Indeed, today it appears crucial to introduce the technologies of e-Health in Gabon’s health system because this will permit to ease more the treatment and to share efficiently health information, by improving the quality of services through and reducing the government public expenditures on health services.

# 3. TOOLS AND METHODOLOGY

The e-Health technology through the EHR is based on the electronic documentation of current and historical health, laboratory results, medical reports and medical treatments concerned with the health of a person. This e-Health application is collecting, storing, managing and ensures the transmission of the all specific medical data of any patient provided from different sources such as laboratory, radiology, pharmacy data and others by reducing the gaps in decision making through a better access to patients' information. However, as regards to the constant evolution of data created by the explosion of digital information such as text, videos, images belonging to various patients from different medical organization, it is crucial to use the Big Data tools in order to manage, analyze the gradual amounts of data comparing to the traditional techniques which can no longer afford the current volume of data [25].

## 3.1. Concept and Characteristics of Big Data

As Big Data refers to a large number of data collections, it is used to simplify the processing of data through tools and procedures enabling an organization such as a health system infrastructure to create, modify and manage huge data sets by providing storage facilities.

Big data technology is able to process quickly for proper interpretation via new technique and analysis tools with the goal to handle data while they are spreading every minute so that to facilitate the decision making and then provide support and optimize the processes. Besides, this technology is different from the traditional relational database management systems (RDBMSs) in the sense that it performs variety of diverse formats of data in several areas [26].

In addition, big data takes into account billions to trillions of records of any people and from various sources as sales, customer contact center, social media mobile information etc. It generally includes petabytes (1,024 terabytes) or exabytes (1,024 petabytes) as methods of processing and storage. Nowadays, these data represent a huge volume of information produced per second that can be used as structured or unstructured data [26].

The concept of Big Data can be characterized in 5V dimensions that put on stage its real goals and benefits.

- *Volume:* It refers to the amount of data produced per second. Hereby, considering the whole data sets generated by social media and other types of data, it is possible now to store these data with the help of distributed systems brought by this software.

- *Velocity:* It is related to the speed at which the data is created as well as the speed at which the data spreads. Here, Big Data performs a tool to analyze the data while it is being created without ever storing it into databases.

- *Variety:* It refers to the various kinds of data that can be used today as structured and unstructured data. Apart from analyzing, it also compares and proceeds with acknowledge and classifying of the different types of data.

- *Veracity:* It is dealing with the reliability and credibility of the data collection. It is hard to testify the accuracy and quality of these data knowing that the Big Data enables to collect every types of data in very huge amount.

- *Value:* It concerns every benefits related to the use of Big Data. It is not just enough to having access to Big Data, but it is more significant to turn it to value in order to acknowledge that value is the most important V of the Big Data.

### 3.2. Big Data Computing Processing and Storage Tools

By regarding the huge number of data to process with including their variety, Big Data is facing with several challenges relating to its quantity and complexity. The vast majority of data provided by big data is considered as unstructured. One of the challenges concerns with the way of the unstructured data can be transformed into structured data in order to understand and capture the most important data. The other challenge is how to store the volume and variety of these data. Below are the technologies and tools used to store, manage and analyze them [27].

Apache Hadoop

Hadoop is the most powerful and important platform of storing and analyzing Big Data. Its existence comes from the need of ability of companies like Google, Facebook and Yahoo that wanted to store and analyze huge amounts of data from the Internet to face with commercial challenges, knowing that other companies also had to develop their own platform.

Apache Hadoop is an open source framework for distributed storage and processing large scale of varying structured or unstructured data over eventually massively parallel cluster of servers and it written in java. Hadoop is composed of Hive, HBase, Pig, Zookeeper, and Kafka; meanwhile, the main components and most used are linked to Hadoop Distributed File System (HDFS) and MapReduce [28].

HDFS: It manages and dispatches the data across the different servers. It allows many different servers to be managed in parallel and does not need a data model to store and process data. It writes and reads files in blocks of 64 MB by default. It can store, access and manage all kind of data (e.g., XML document, Web logs etc) of any structure as long as the data can be set in a file and copied into HDFS, because it is not a Relational Data Base Management System (RDBMS) [29].

MapReduce: It takes amounts datasets, extracts and transforms useful data, spreads the data to the different servers where processing occurs, and gathers the results into a smaller, easier to analyze file. The Hadoop architecture runs MapReduce programs by using a programming or scripting language such as Java, Python, C, R, or Perl in parallel [26].

As MapReduce is a programming language specially designed to read, process and write very huge data collection, it is characterized by two functions Map () and Reduce ().

Map: It is the name of a high-level function that applies a given function to each of the elements within a list and sends back a list. It carries out a specific operation on each data element.

Reduce: It applies a given function to all elements within a list and sends back a single list. It gathers the elements according to a particular algorithm and provides the result and then,

it recovers the data conceived in the mapping step and analyzes it in order to withdraw the significant information [26].

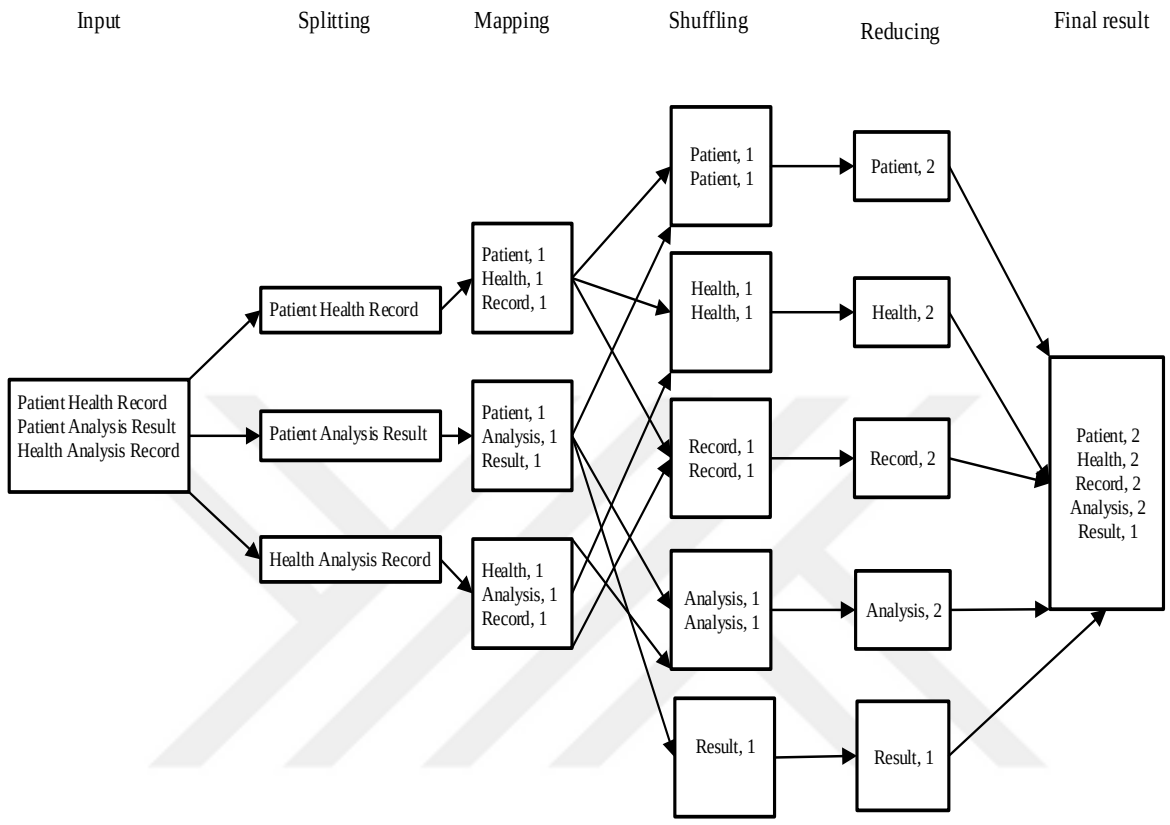


Figure 3.1. Hadoop MapReduce processing flow

The Figure 3.1. Shows how processing is done with Hadoop/MapReduce infrastructure. At the left, is a data file with records encompassing Patient, Health, Record, Analysis, and Result. The goal here is to count the number of times each word is involved. The first step is to split the records and dispatches them over the clusters of servers. The processing of these records are made by various map programs such as Java and R running on the servers. In this sample, the main objective is to gather data by a split on the basis of words. The MapReduce platform highlights the shuffle/sort outcomes for input to the reduce program which then provides an abstract of the number of times each word involves. Thus, the output can be input to database where it can be mixed with other data or directly accessed to them by various Business Intelligence (BI) tools such as Tableau and Micro Strategy in the purpose of analysis [30].

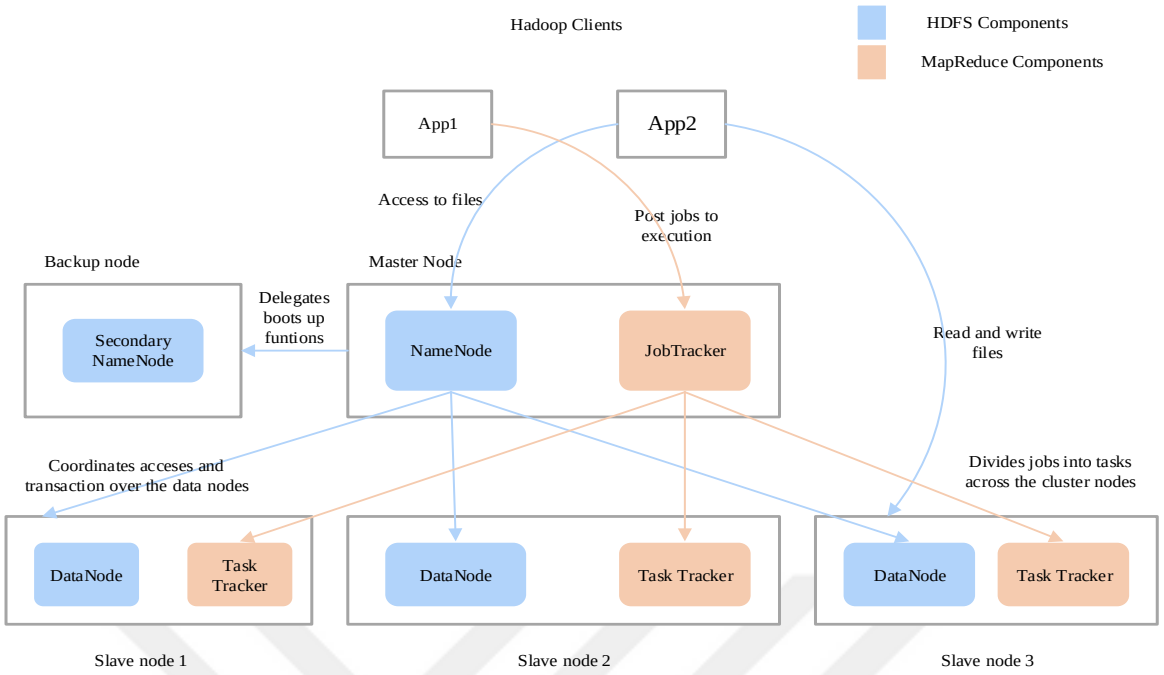


Figure 3.2. General Architecture of HDFS and MapReduce components. Adapted from [31]

The Figure 3.2. shows general architecture of HDFS and MapReduce component. An HDFS cluster firstly consists of NameNode that stores and manages file system metadata and DataNode that stores current data. In the purpose to write a HDFS file, the client sends a request to NameNode in which the client indicates its desire to write a block and then this NameNode gives him instructions about the DataNode to contact. The client sends the block to DataNode, then the DataNodes replicate the block between themselves and the cycle is repeated for the following block [31].

Dealing with reading a HDFS file, the client sends a request to NameNode of the cluster in which the client indicates its desire to read a file, then this NameNode gives instructions about the size in blocks of the file and for each block, a list of different DataNodes is provided. Then the client gets in touch with the concerned DataNodes in order to obtain the blocks that the client rebuilds under the form of the file. In case of error or inaccessibility about a block, the client contacts an alternative DataNode  of the list to obtain the block [31].

The operation of MapReduce takes into account 4 actors as following:

- Jobclient is the one that submits a task to the MapReduce.

- Jobtracker which is the software that coordinates the task submitted by the jobclient. It finds single on the cluster and receives the MapReduce tasks to execute, then organizes their execution on the cluster.
- TaskTracker carries out sub-tasks divided by the jobtracker. There are several TaskTrackers on the cluster and the latter executes MapReduce task by itself under the shape of punctual Map task and reduce the associated input data.
- Finally, the Distribute File System (DFS) consists in sharing tasks 'files between several tasktrackers.

In sum, in order to execute a MapReduce program it should :

- Write Input data on HDFS
- Submit the program to JobTracker of the cluster
- Recover Output data from HDFS

*Hadoop advantage and disadvantage*

Hadoop comprises many advantages and disadvantages such as showing in table 3.1. Hadoop advantage and disadvantage.

Table 3.1. Hadoop advantage and disadvantage

| Advantage | Disadvantage |
|---|---|
| • Fault Tolerant: Data is replicated on multiple nodes in order to prevent errors, unavailability or failure machine. For instance, if a node fails or is slow, another node takes over the processing of the data for the recovery.<br>• Cost effective: It uses cheaper low end cluster and not high end server for the commodity of machine and facilitates the transfer of computing code.<br>• Scalable: Hadoop manages huge volume of data, and it is able to expand storage node and disk.<br>• Portability: The platform is able to work with several heterogeneous hardwires and operating systems commodities. | • Hadoop is not suitable for real time data applications because MapReduce and HDFS use batch processing platform and this does not fit for the real time accesses.<br>• Hadoop is not suitable for small files as HDFS only considers high speed optimization.<br>• The Single Point Failure is also a disadvantage because HDFS as well as MapReduce do not afford with a single master causing then points of failure.<br>• Hadoop performs poor performance by showing low efficiency due to its inability to join efficiently multiple data sets.<br>• Hadoop does not handle repeated behavior that is common to any type of procedural programming paradigm. |

Apache Cloudera

This tool enables analysts to assess huge volume of data by using the features of SQL tools to achieve real time analytics through the help of a HBase or a HDFS platforms to store data with analytics. As major advantage, it is able to perform as flexible data model by holding structured as well as unstructured data. As disadvantage, it is not allowing to delete individual rows and does not support internal indexing for files [32].

Apache Hive

Hive is based on Apache Hadoop and it is data warehouse tool which has the faculty to perform huge volume of data stored in HDFS. It refers to the storage, analysis and queries of huge volume of data. The language of query is HiveQL and similar to SQL features. As advantage of Apache Hive it allows easier to produce data extract, transform and load operation. It separately reads and writes file formats. However, it does not suit for real-time queries and not able to make updates and to delete at row-level [33].

Apache Hbase

Hbase refers to a set of tables performing large volume of rows and columns and facilitates the same skills to HDFS of Hadoop as the Big Table. This tool helps scaling horizontally because it is based on a wide-column data stores. It is also characterized by a fault tolerance supporting and handling failures between the servers. It permits in real time the interaction with data by supplying bloom filters and blocks caches. In terms of disadvantages, Hbase performs single point failure because of the partition of rows into regions and each region is transformed into Region-server as a single point of failure. It is also operationally inflexible due to the existence of only one Master which reads and writes and this fact enables separation between different replicas in a cluster [32].

NoSQL Database

NoSQL refers to non-relational or Not only SQL database. It handles unstructured data while the traditional SQL deals with huge volume of structured data. NoSQL databases do not take into account specific features to store unstructured data. Hence each row can have

its own set of column values. NoSQL provides effective performance in storing huge amount of data.

They are four major types of NoSQL database [34] such as:

- Key-value store: This type of database enables to store all data as a pair of key and value. As example, Riak, Redis, DynamoDB, Azure Table Storage, BerkeleyDB etc. Figure 3.3. shows an example of key-value entry.

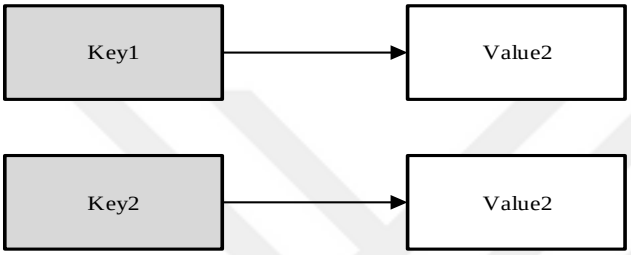


Figure 3.3. Example of key-value entry

- Column Store: It almost works like RDBMS because all data is stored under the form of rows and columns but the difference is the fact that the number of columns can change from a row to another. Cassandra, HBase can be quoted as examples. Figure 3.4. shows an example of column store.

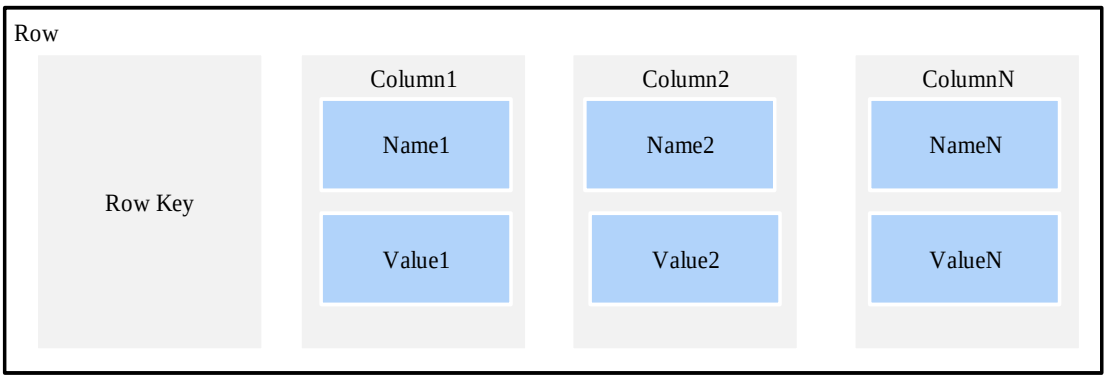


Figure 3.4. Example of column store

- Document Store: In this type of database, all data is stored in document form using different forms of standards like JSON or XML. The advantage of this kind of database is to be able to retrieve and manage structured oriented-information. MongoDB,

CouchDB, RavenDB are the most known as example. Figure 3.5. shows an example of document store.

```
{ “user” : {
    “id” : “…”,
    “name” : “…”,
    “contact” : [

                {phone: “...”,
                 email: “….”

                }

 ]

}
```

Figure 3.5. Example of document store

- Graph Databases and Triple Stores: Stores all data under the form of graph which are structured as nodes and relations. For example Neo4j, Infinite Graph, HyperGraphDB, Openlink Virtuoso. Figure 3.6. shows an example of Triple Store RDF dataset and its graph.

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
      xmlns:dc="http://purl.org/dc/elements/1.1/">
 <rdf:Description rdf:about="http://www.gazi.edu.tr/people/oulfath/">
  <dc:title>Oulfath OMANDA's Home Page</dc:title>
  <dc:creator>Oulfath OMANDA</dc:creator>
  <dc:publisher>Gazi University</dc:publisher>
  <dc:date>2017-08-23</dc:date>
 </rdf:Description>
</rdf:RDF>
```

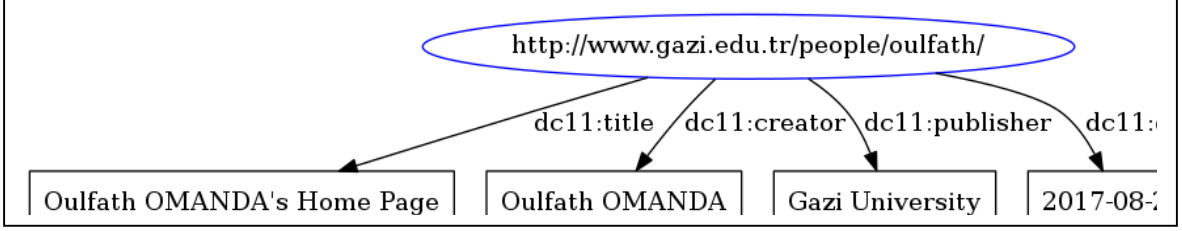


Figure 3.6. Example of triple store

In terms of comparison, Column Family databases are generally used when the amount of write operations extends over the reads and this happens while logging into the system. To contrary to the previous type of data, Graph databases are more suitable to work with connected data in the sense of analyzing social connections between individuals, road maps and transport systems. As for Key-value Store databases, it would be more profitable for managing stocks and products through data analysis in real time. This advantage is relating to the fact to have good retrieving speed that allows the retrieving of specific keys and values while the greatest volume of data can be mapped into memory. By contrast to the previously quoted databases, in the case of Gabon e-Health implementation, Document Store databases would be the more suitable type of database for working with large number of documents that can be stored into structured and unstructured files, such as text documents, emails or XML and CMS and CRM systems [34].

NoSQL advantage and disadvantage

Table 3.2. NoSQL advantage and disadvantage

| Advantages | Disadvantages |
|---|---|
| • Open source.<br>• Scalable: no need to extend server sizes.<br>• Multiple storage system: data can be stored as key value or document.<br>• Automatic repair: Systematic repair is performed for failed task data.<br>• Simple and easy layout: Simple and easy to create design layout. | • Setup issue: skill and system will be needed with specific configuration in order to install and setup.<br>• Maintenance: Being an open source it has so less possibility to afford assistance<br>• No backup: It is mainly for storage and less efficient for data backup |

## 3.3. Big Data Advantage and Limitation

Big Data comprises many advantages and disadvantages as showing in table 3.3. Big Data advantage and limitation.

Table 3.3. Big Data advantage and limitation

| Advantages | Limitations |
|---|---|
| • Large volumes of structure, semi structured and unstructured data<br>• Object-oriented programming that is easy tu use<br>• Flexible architecture<br>• Higher performance and availability<br>• Massive scalability<br>• Quick and cheaper to set up | • No declarative query language<br>• Weak guarantee<br>• Lack of privacy |

# 4. SYSTEM DESIGN AND IMPLEMENTATION

This section will basically deals with the design and implementation of an e-Health platform within the healthcare system. In the first hand, we will focus on the system design then the tools and models needed to be used for this purpose will be introduced. In the second hand, we will discuss about the system functions by displaying a partial implementation of the said system.

## 4.1. System Design

The main objective of implementing e-Health system in Gabon would be to provide an educative and informative platform to populations so that the users can be able to perform by themselves self-care management and health self-education. The platform should comprise certain functional features such as:

- Self-care education and communication platform: The platform must be a communication platform that should provide to users all kind of information relating to public health information in terms of prevention and care services of diseases such as non-communicating sicknesses and communicating sicknesses.
- Authorities assigning: The platform should distribute the roles to users in according to the corresponding authorities. The user can login in login page in order to get information relating to their health status, and to be able to record and display health data in the system so that the physician can have access to them. The physician must be allowed to get access to the user's health data for better healthcare services. The administrator must have the authority to check all the users and physicians information.
- Adaptability: The e-Health platform must be compatible not only with mobile devices but also with fixe devices such as tablets, smartphones and PC. It should also be visited at anytime and anywhere. The real-time interaction must represent a crucial feature in the platform.
- Security: The platform should display privacy for any user considering the fact every people wishes to keep protected his personal data. It must develop security measures in terms of access control and database selection and management.

- Reliability: The application should provide self-care service related to education for people and personal health data storage and checking by displaying reliable effectiveness.

### 4.1.1. Users requirement

Through this system the patients will be able to get access their own electronic records and capable to manage their self-care education. In addition, they can consult their medical records via their own account in every hospital sharing the same system by having the possibility to assign health authorities about the access and the management of their medical information's.

The hospital's administrator will be in charge of the system management and the connection between the hospitals. Here, the administrator must be able to manage the platform as modifying, adding or deleting hospitals or hospitals' details, and may agree or not the decision of physician to modify the patient's records.

### 4.1.2. Operational system

The platform displays some functions as shows below in which the different users can operate according to their own tasks. It presents the various functions of each user within the system.

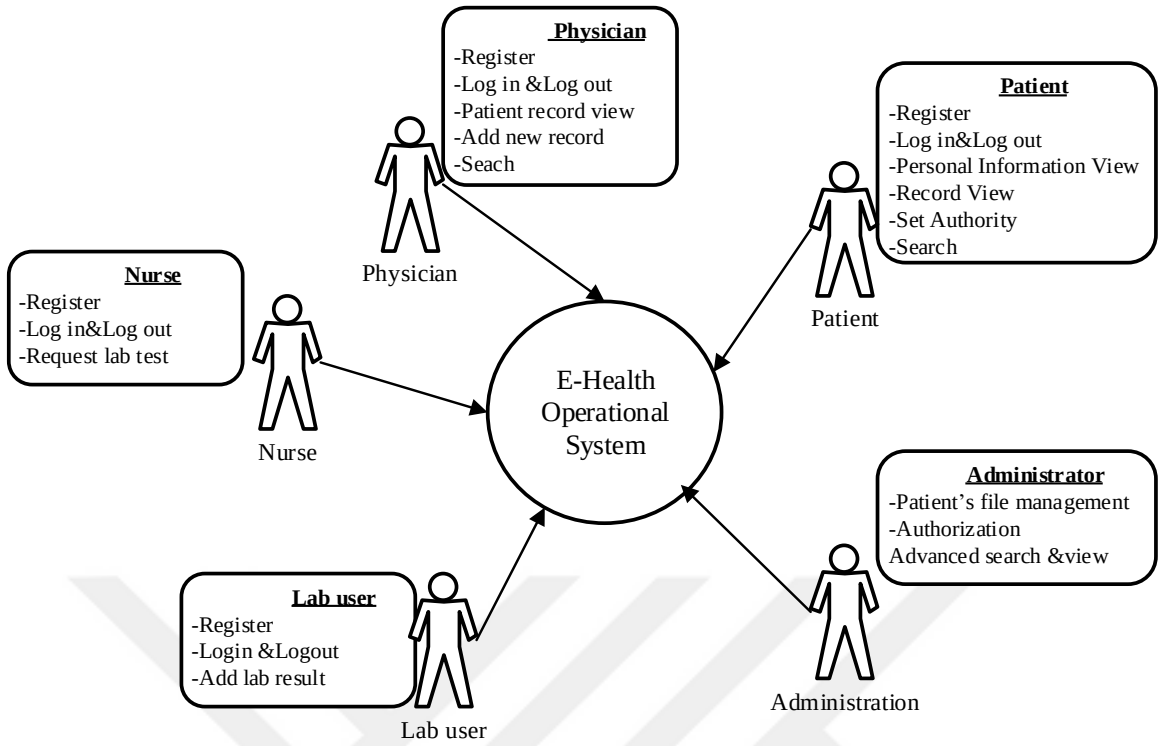


Figure 4.1. E-health operational system

As Figure 4.1. shows patient's functions, the patient can login his account through three entrances such as personal information, educational information and medical results. He is able to view, check and record his personal data into the system. The physician has the possibility to process with the patient health data when the authorization is granted. The laboratory can register and send analysis results into the e-Health system to the attention of the physician.

### 4.1.3. Access control

There are several access control models which meet the legal requirements such as: Role-Based Access Control (RBAC), Usage Control (UCON), Digital Right Management (DRM) and Mandatory Access Control (MAC).

RBAC: In This model the responsibility are assigned to users regarding suitable role for each of them**.** In fact, the users can bear the responsibility of that role once they become a member. The distributed role is corresponding to their authority and qualification. From this view, the patients and physicians can access their related interfaces by considering their role [35].

UCON: It is constituted by three features such as subject, object and right. And the, other three features are linked to authorization rule, conditions and obligations. The authority is related to the attribution of subject and object including authority requirement. UCON model comprises RBAC, MAC and DRM. UCON system is more complex but in comparison with the other access control models, it brings more potential model for future design [35].

DRM: It refers to a pair of keys composed of public key and private key, generated by the record creator. The digital authorization center distributes the key pair through a third part which is trusted by users. In this access control model, the public key is used to encrypt while the private key is employed to decrypt and this is the only one which can read the message. The particularity of this access control is to prevent from unauthorized copying or distribution of data through the encryption system [36].

MAC: In this model, the access control is handled by the administrators that design the fundamental policy, because they categorize the users (objects and subjects) into different security levels by determining if yes or not they can grant or deny access to users by considering their security level. But in this type of access control, it is possible to face with some difficulties in terms of the flexible roles' authority by holding a higher security level [37].

In comparison with all the access control models, UCON is an eventual model for design. A UCON based system is more complex than the others regarding the fact that it is more expensive, by spending more time to design and implement. By opposite, RBAC model is much easier to design than UCON model in the sense that it has high level security and flexibility. As for an E-Healthcare institution, RBAC security model is considered as suitable because permissions are assigned to roles. The users in the hospital can be simply classified into two roles: patients and doctors [35].

### 4.1.4. Interoperability

The main objective of the interoperability is to realize the information sharing between several health organizations in a safe way. Every user has his own authority and can access when it is needed. But the medical records can be accessed by a visitor only if he has been

authorized. There are two basic solutions of interoperability which are used today. The first is standard, and takes into account HL7 (Health Level Seven) and openEHR. Both of them have the purpose to create a worldwide standard to store and transform medical records. As for HL7, it is a very complex unit of standards involving policies and hard to use fully to implement an EHR system (e-Health system).The other standard related to openEHR, presents the same problem in the sense that so many policies are displayed and they make it so complex to realize e-Health system. The second solution of interoperability is the semantic tools that are based on the Semantic Web. They constitute a very suitable method of the information sharing between heterogeneous systems providing the possibility for the health organizations, to develop their own e-Health system, without sharing information between them. However, the accuracy of the semantic tools depends on the number of heterogeneous systems. Whether the number is low, the semantic mapping is easy to implement. But to the contrary, if the number is large, the semantic mapping will be made complex and its accuracy will be reduced. The semantic tools must be used at a high level of accuracy to avoid negative consequences by using the semantic mapping in a health care organization [38].

For example, if different hospitals have their own database, a patient after having a surgery in hospital A can make stored his medical records in A hospital's database. Then when he goes to hospital B, the doctor from hospital B will need to check his medical records created in hospital A. The doctor can ask the patient to change the access authority and with the agreement of the patient who can login in B hospital, the doctor from B hospital will access to records from hospital A [38].

### 4.1.5. Security requirements

The security of information access becomes a priority to avoid some unexpected behaviors like information stoles or the misuses. In the goal to prevent from abusive registration, every user in the system should register only one account for each people. Moreover, it is necessary to set a security system that will permit to all the users to change their password or to modify their password when they forget it. Also, the user will be required to answer some security questions and given his email so that he will be able to select the right questions and the right answers when they want to change their old password. Because, in case he forgets his password an official email will be sent to his mailbox to change or

modify his password safely if he is registered into the system. It is known that only the person who knows the password can access to the account because the password is always encrypted as well as personal information during the medical information transmission [38].

### 4.2. System Architecture

The system architecture is generic disciple with the goal to handle existing or to be created object which are characterized by the composition of hardware and software system used to deliver a solution to the final consumer of the service.

#### 4.2.1. Software architecture

The software architecture of a program or computing system is the structure or structures of the system, which comprise software components, the externally visible properties of those components, and the relationships among them. This general organization highlights several factors such as Business strategy, human dynamics, quality attributes, design, and IT environment [45]. The Figure 4.2. below shows the follow up system of an software architecture.

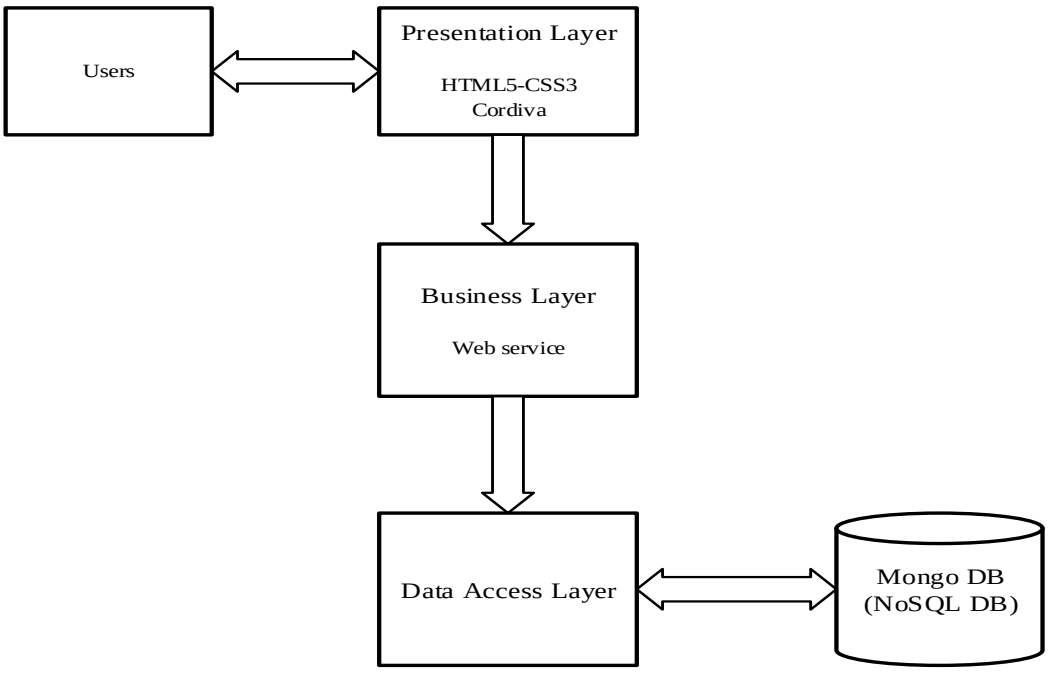


Figure 4.2. Software architecture

The general software architecture includes 3 layers such as Presentation Layer, Business Layer and Data Access Layer.

Presentation Layer: refers to interfaces that users can have access and interact with. It does not put on stage any transactions and only communicates with the business layer where the web services are available.

Business Layer: Makes sure that every link between data layer and presentation layer occurs according to security measures.

Data Access Layer: Contains components that manage the insertion, selection, modification and deletion of data. It comprises the MongoDB database.

### 4.2.2. Hardware architecture

The e-Health platform uses the browser/server (B/S) architecture which is the mainstream web application model. In this architecture, the client can access to browser through different types of devices like PC, tablets or smartphones etc.

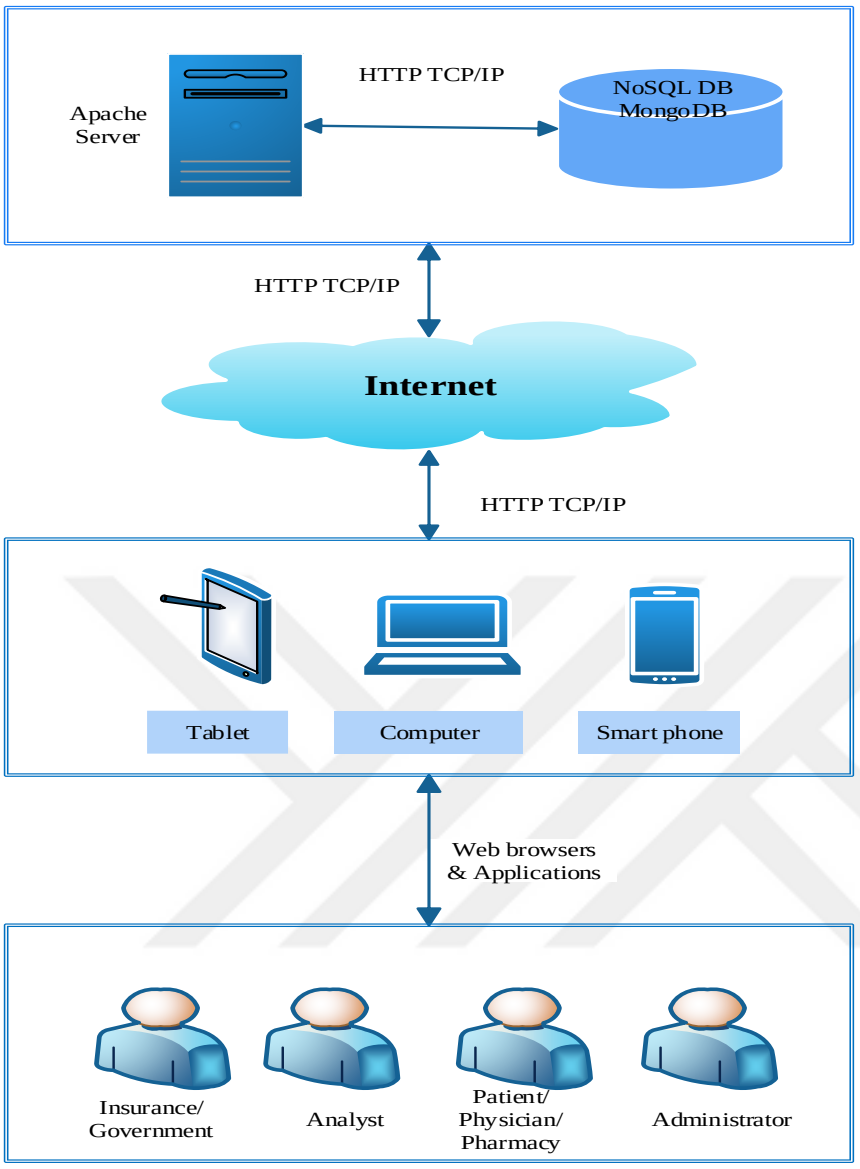


Figure 4.3. Hardware architecture

As showing in Figure 4.3. the client is represented by the browser which sends requests to the server on the behalf of the client. Apache and NoSQLDB servers are installed on the server side of the platform. PHP requests from the client are interpreted in Apache Server and converted into HTML5 and CSS3 languages which are the browsers' understanding technologies.

### 4.2.3. Tools and models used in the system

In this part several tools and models used to implement the e-Health platform will be introduced.

MongoDB

It is a flexible NoSQL document database wich is different from traditional database and does not store data in row and column. MongoDB stores the document data in binary form of JSON document and use for availability, performance and scalability. It helps for handling unstructured , semi-structured data or data which change frequently [39].

PHP

PHP is a Hypertext Preprocessor which is defined as a free and powerful tool for making dynamic and interactive web pages by scripting language and interpreting. This language is mostly used on Linux web servers and can be easily integrated to HTML.

HTML5

It is the standard markup language for creating web pages defined as Hyper Text Markup Language version 5. It performs the page structure of web pages by using markup. HTML 5 is more accessible on mobile phone applications in the sense that it is not needed to write applications for a specific smart phone but for commonly used applications for all phones. In addition, it displays flexibility by creating website and it shows facilities to introduce video, audio and images modules and do not need any other software [40].

CSS3

Short for Cascading Style Sheets version 3, it is aiming at to describe and format content by applying style of an HTML document. It performs more flexibility and accuracy when defining the appearance of text and formats than standard HTML [40].

Bootstrap (CSS Framework)

It is the most commonly used HTML, CSS, JavaScript framework for developing responsive web sites. Focused on all types of devices and applications, it enables front-end framework faster and easier for web development processes [40].

Javascript

It is a dynamic and interpreted programming language of HTML use in the field of web development with the purpose to manage functionality on the web page. This form of language is commonly implemented to allow client side script to interact with the user and make dynamic pages. This can also enable many framework and plugin to grow the functionality and options that HTML and CSS cannot perform [40].

JQuery (Javascript framework)

JQuery is a fast and small feature relating to JavaScript library. Its role is to make easier the use of JavaScript on website for instance by manipulating HTML document traversal, handling event, animation and Ajax in simpler way. It can also provide a single line of code from the multitude of lines of JavaScript code in order to achieve them into methods in terms of versatility and extensibility [41].

Node.js

This open source framework is a Javascript runtime based on Chrome's V8 Javascript engine holding the advantage of scalability, modularity and asynchronous architecture. It employs a non-blocking I / O pattern related to a chronological order, knowing that its efficiency and lightness can be performed through the compatibility with MongoDB on which JavaScript is based [42].

Android

Android is an open source software application created for a very large scale of mobile devices. It holds advanced device patterns with various forms of features and having the capacity to create an open software platform for innovative projects towards the Android’s developers, and promote successful products by performing mobile experience which is highly useful and educative for users. Here, the main goal is to allow every user for developing a common product that they can customize and adapt following the need. The other important advantage, is relating to the cost because the preference for Android operating system is also due to the affordability of price apart from its adaptability regarding its ability to run on many different devices [43].

Cordova

It is an Android application library that uses web technologies such as HTML5, CSS and Java Script to conceive Native Mobile Applications on Cordova-based projects. Since web applications cannot use the native device functionality like Camera, GPS, Accelerometer, Contacts etc. Cordova Android can easily accomplish this task by packaging the web application into the devices installer format [44].

### 4.3. A Sample Implementation

In this section some of the e-Health web page will be displayed in terms of screenshots.

The Figure 4.4. displays the main headlines of an e-Health website which guide the users to get their own section.


Figure 4.4. E-Health website home page

The Figure 4.5. presents the register page on which the users can register by providing personal information in order to get a username and a password to enable them to access the platform when they login. In this step an email address will be asked in case of loss or modification of password.

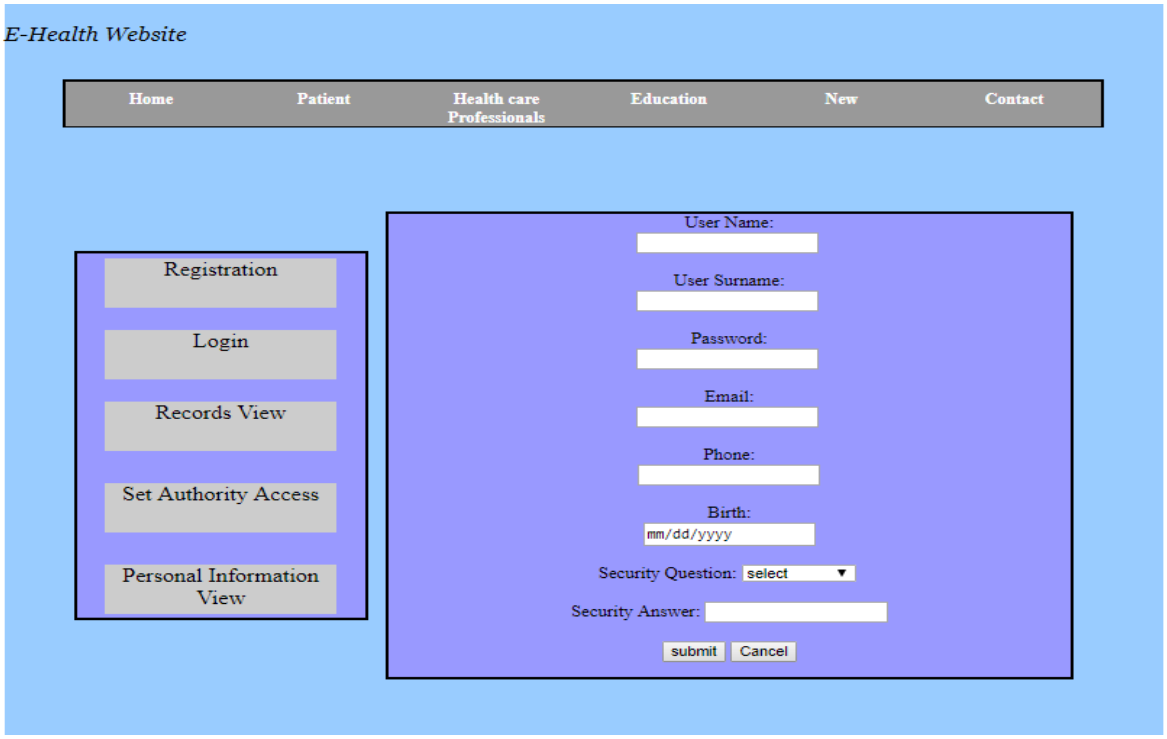


Figure 4.5. The register page for users

Firstly, the users should login before using the system by typing their username and password as showing in Figure 4.5. After that, the user (patient) can consult his medical results or doctor's report, then send his medical results to the physician if needed and also get educational information about prevention and care.

The doctor after logging in the system, he can click on his own tab to see the list of his patients and their medical records with their authorization. Once the doctor is authorized by the patient, he can view the required medical analysis, and publish his report by providing the necessary advices and medications.

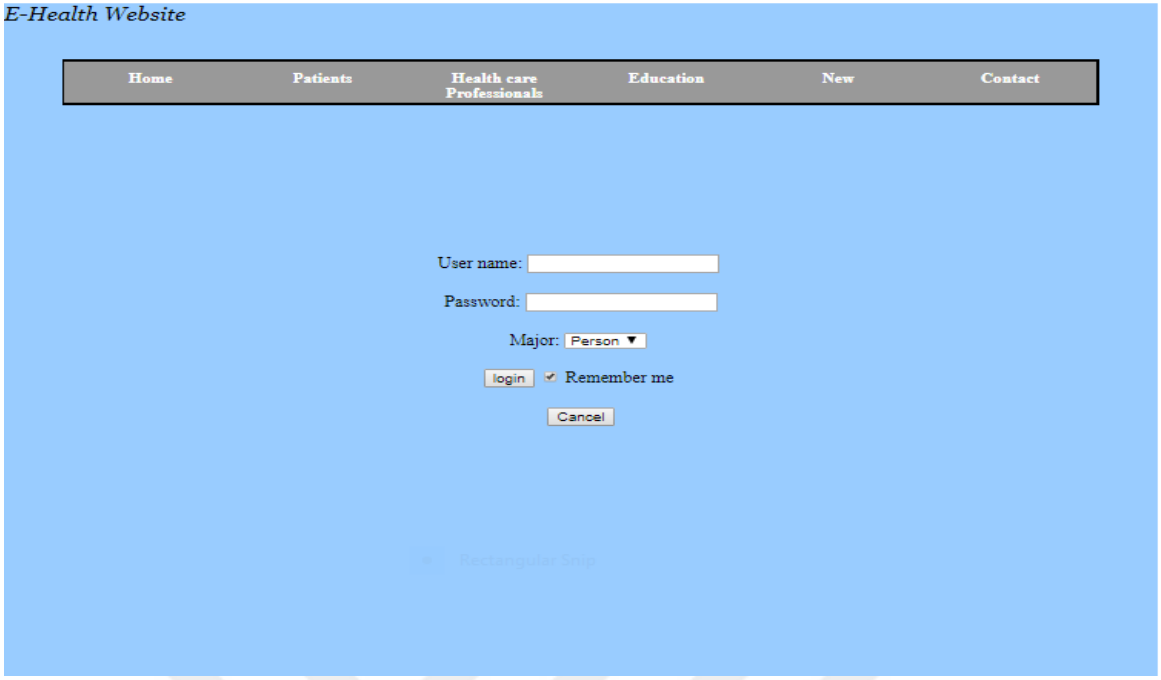


Figure 4.6. The login page for users


Figure 4.7. The educational page for users

The Figure 4.7. show an educational page where each user can get information about any kind of disease as they want.

### 4.4. System Integration

It is highly relevant to assert that, the integration of e-Health system in Gabon should be implemented in respect with some major challenges in order to meet effective benefits to all users including for the whole country. Indeed, how to manage and store huge volume of data held by such kind of platform knowing their complexity and diversity is one of the main purposes. It also needs to take into account the affordability of the system in terms of costs with the guarantee of its effectiveness. Moreover, the interoperability of systems is also crucial for assuring an efficient and safe communication between the various healthcare organizations. Every user must have his own authority and can access the system when it is needed. However, the medical records can be accessed by a user only if he has been authorized. In other words, it needs to be interoperable so that it can be able to store and communicate information from different and geographically distributed databases. Besides, implementing e-Health system means that healthcare providers have an obligation of confidentiality and privacy towards patients and must ask for their consent before sharing their data. Indeed, the performing of security into the system aims at allowing patient to keep private their data in order to monitor any kind of misuses or abuses as regards to the deterrent role that it can play. The security parameters are actually taking into account the patient control holding the possibility to restrict who may view their information. The other challenge is related to users' training which has the purpose to improve knowledge about who can access and use patient records and in what circumstances. For the case of Gabon, the installation of the system must include the staffs training by enabling software to be tested, and clinicians and the other healthcare providers to adapt gradually. Meanwhile, the present work highlights the basic proposals and the advantages of such system in Gabon as cost effective and affordable healthcare solution.

# 5. CONCLUSION

Through our investigation on Gabon health condition, this thesis has showed the main challenges and the opportunities in the purpose of e-Health implementation. Indeed, this has highlighted storing and processing tools such as NoSQL database which enabled to manage Big Data generated by the use of e-health technology in order to efficiently improve Gabon health system. Thus, a prototype of e-Health website was implemented to show how this can be profitable for both private sector and government by establishing functional strategies and legal framework for a more reliable and effective healthcare system in Gabon.

The e-Health tools while they are accordingly used could provide at all levels efficient healthcare services at low cost by considering the remote areas. As for developing countries like Gabon which are facing to many health issues in terms of illnesses and all kind of dysfunctions in management scope, the e-Health strategy could be the way to reduce the gaps and the absence of performance in health system. Considering the growing up of internet coverage in all over Gabon, the Telemedicine and the EHR for instance as tools of e-Health could be implemented in Gabon by using low cost software in order to improve the consultation and the medical monitoring at distance by including the processing and sharing of medical information between medical staffs and patients. Moreover, the use of e-Health must be standardized through a law framework that will allow offering better services in huge volume based on better quality. The role of national governments is crucial because they should be engaged in the adoption of laws facilitating the real use of this modern technology that can be strongly profitable for states in terms of health industry and in economic field as a pillar of economic development by optimizing the public health expenditures. The effectiveness of health system enables the well-being of people to produce wealth in the country. In the case of Gabon, structural reforms in health systems and the promotion of technology transfer are needed in order to settle e-Health down in the country.

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*GAZİ GELECEKTİR...*