

# E-Health Information System: Ensuring a High Level of Availability by Implementing Replication, Backup & Restoration Procedures

Abdelghani El malhi<sup>1</sup>, Mohamed Ahd<sup>1</sup>, Abdelrhani Mokhtari<sup>2</sup>, Abdelmajid Soulaymani<sup>2</sup>, Adil Echchelh<sup>1</sup> and Rachida Soulaymani Bencheik<sup>3,4</sup>

1. Laboratory of Electrical Engineering and Energetic Systems Ibn Tofail University, Faculty of Sciences, Kenitra, Morocco

2. Laboratory of Genetics and Biometry, Faculty of Sciences Ibn Tofail University, Faculty of Sciences, Kenitra, Morocco

3. Moroccan Poison Control and Pharmacovigilance Center, Rabat, Morocco

4. Faculty of Medicine and Pharmacy, University Mohammed V, Rabat, Morocco

**Abstract:** In a previous study, we suggested an information system to store, manage and treat millions of gathered patient's information. The application is able to fulfill the most important criterions, mainly measurement, monitoring, guidance, Data management and their analysis. The developed e-Health system can be accessed via the Internet. Availability, confidentiality and security issues arise that have to be considered carefully. The highest level of availability of these services is required. The main objective of this paper is to improve and enhance the both aspects of an information system: availability and reliability. The information system should be reachable constantly to satisfy the professional requirements. Today, the new technologies could help to resolve some infrastructure and connection problems. Connected machines are increasingly being introduced into safety-critical health care systems. Concretely in this study, we introduced replication, backup and restoration procedures to obtain a safe and continuous data management system in order to guarantee a highly reliable concept. By integrating the new technologies, we profited from the innovative connection utility—Internet of things -, which offers several possibilities to ensure the continued and desirable service. By implementing a distributed information system, we were able to increase the percentage of uptime to 99.8% (down time less than 20 mins/week). The vulnerability and the penetration tests were also successful and demonstrate the efficiency of the implemented redundancy, replication and restoration procedures.

**Key words:** E-Health, replication, system vulnerability, backup and restoration, availability.

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## 1. Introduction

Several studies have shown clearly that the scorpion envenomation remains a public health problem with a considerable frequency and lethality. It occupies the first position among all causes of poisoning in Morocco (an incidence of 71 per 100, 000 population). In 2013, 27.9%, of victims are children under 15 years. The sex ratio (M/F) was 0.99 and bites without envenomation (class I) represent 91.06% of cases. The death has affected 65 people [1]. Taking a quick and

adequate decision is decisive in terms of rescue. Over 20 years, the Moroccan center for anti-poison and Pharmacovigilance has been acted actively in order to improve the situation. The objective of this work is to design, model and develop an efficient and secured IS (information system) to treat vitals sings by the victims of SS (scorpion stings). The application provides a practical environment to navigate and to explore the patient's data. It will help the health professionals and authorities by the decision-making. The tool offers essentially five basic features: the measurement, the monitoring, the orientation, the data

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**Corresponding author:** Abdelghani EL MALHI, Dr. Ingenieur, research field: bio-informatic.

handling and their analysis. The deployment of information technology in the health sector has been increased exponentially in recent years. This paper sheds some light on this unsolved problem that affects many people. It aims to enable clinicians to monitor various vital signs and possibly to select the best hospitalization (type of medicine, resuscitation, treatment...). The main objective is to improve the effectiveness of the medical interventions.

A major issue is the reliability, since virtually all the operations depend on the services provided by the information system. Though a high availability of these services is required, standard technology may not offer a compatible reliability level. When this happens, improvement solutions such as the redundancy of data servers and communication systems or the installation of diagnosis aid tools have to be implemented [2].

The above figure (Fig. 1) illustrates a prototype of a distributed information system.

The design approach is seen as a prototype that can be deployed or simulated with other clinicians or health professionals. It is adaptable and extensible to cover other types of topologies.

An e-Health system may include wireless communication technologies, for local (Wi-Fi,

Bluetooth, etc.) and/or remote connectivity (cellular, satellite, etc.). An important problem is to ensure smooth coexistence of all these concurrent radio technologies, avoiding any form of interference in uncontrolled, heterogeneous operating environments [3].

The application availability is calculated based on the percentage of time the software is accessible and available for use.

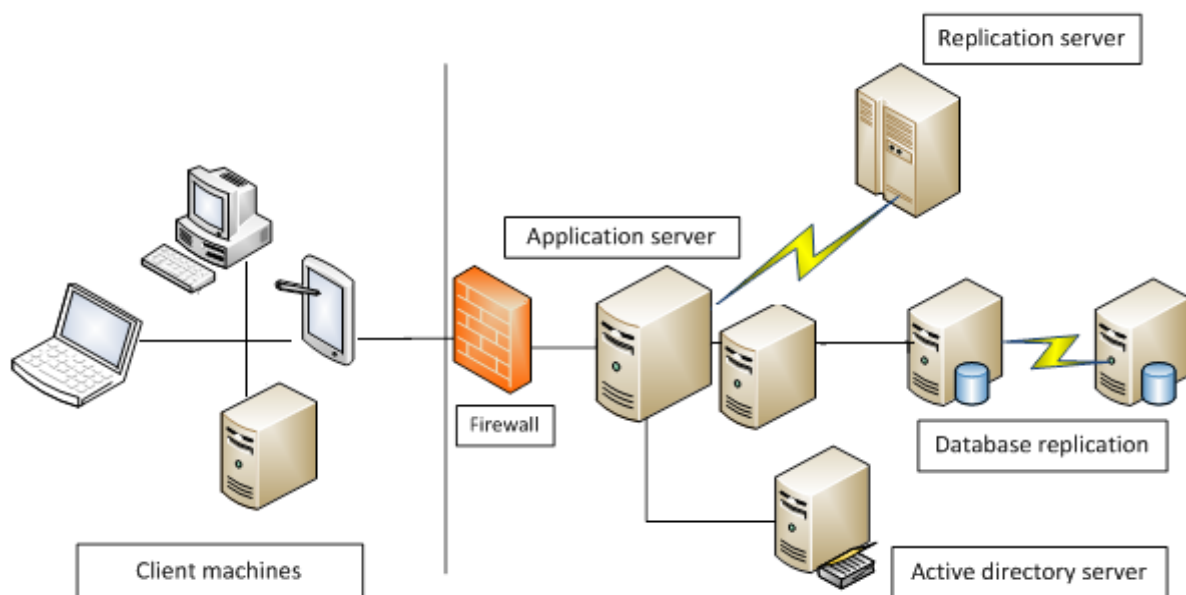
Availability % =

$(\text{Uptime} \div (\text{Uptime} + \text{Downtime})) \times 100$ .

## 2. Materials and Methods

An IS consists of all the components that work together to process data and produce information. Almost all business information systems consist of many subsystems with sub-goals, all contributing to the organization's main goal [4]. The e-Health care system contains data with sensitive character, so it is crucial that these records are accessible only for eligible people. Consequently, one has to consider an efficient system with a high availability.

Daniel Slamanig proposed to use pseudonymization, identity management, obfuscation and anonymous authentication in order to prevent the attacks and to ensure a high availability as far as possible [5]. Madjid



**Fig. 1 Distributed information system.**

Tavana developed a risk analysis model for assessing cyber-attacks on the availability and integrity of information system. He measured the availability and the integrity and used an interactive model to plot the fuzzy availability and fuzzy integrity measures [6]. Daniel Edwin Burman proposed the building of a data distribution system and method that replicates data efficiently and allows data to be accessed during network impairments with minimal disruption to users. It is further desirable that the system be simple to configure and manage [7]. Another detection approach to improving system availability is discussed by Qadeer Ahmed, early fault discovery and its management are vital elements to ensure overall system availability. He describes a decision tree-based computational intelligence model to suggest the appropriate action to avoid unscheduled failures [8]. Jose Faria combined the reliability model with the cost one to identify the performance indices and eventual economic damages [1]. Celentano presented a concept by focusing on the peculiarities of pervasive Internet of things e-Health services [3].

Protect sensitive data and their transmission in the health sector are big challenges. The storage and the processing of millions of patients information in a conventional manner are expensive in terms of money and time. Approaches that have been used since a long time are not sufficiently productive to build Dashboards and consequently to define a lasting national strategy. The selecting of a suitable prototype for designing the platform is crucial. We followed the model of “Spiral” which presents an enormous adaptability that can accommodate major changes during all the realization phases. It contains four phases: Analysis of objectives, assessing the needs and issues, development and testing and the planning of subsequent iterations.

Human, organization and technology are the essential components of Information Systems. These three evaluation factors can be evaluated throughout the whole system development life cycle namely

planning, analysis, design, implementation, operation and maintenance [9].

This leads us to propose a holistic e-Health system, which combines hardware and architecture improvements with additional security measurements.

Having a strategy in place to test the application, their features and eventual weaknesses during the development means that the security aspect is being built into the code and the architecture rather than retroactively achieved through post changes. The design and modeling of the used bioinformatics methods are based on using the latest web standards. We used essentially the freeware technologies (open source) to profit from their flexibility, quality and safety.

### **3. The Following Frameworks Are Deployed**

PHP: is part of Easyphp packet and stands for Hypertext Preprocessor, It is a server-side scripting language designed essentially for web development. PHP is a widely used open source general-purpose and can be embedded into HTML.

Apache: Developed and maintained by Apache Software Foundation. It is a freely available Web server that is distributed also under the “open source” license, which runs on most operating systems. Apache supports a variety of features; some of them are implemented and integrated as compiled modules, which extend the core functionality. These can range from server-side programming language to authentication schemes and connection’s adapters.

MySQL: is one of the popular Open Source SQL database management system, which is needed to add, access, and process the data stored in a computer database. The SQL part of “MySQL” stands for “Structured Query Language”.

FPDF: The best things in using PHP are that it is extremely simple, but able to offer many advanced features for a professionals. FPDF is a PHP class, which allows generating PDF files with pure PHP [10]. It has several advantages and features (choice of

measure unit, page format and margins, Automatic page break, Image support (JPEG, PNG and GIF), Colors, Page compression...)

JpGraph: The JpGraph library is a 2D graph plotting library for PHP5 ( $\geq 5.1$ ) and PHP7.0. It is meant to significantly simplify the creation of dynamic graphs using PHP scripting. The library can be used on its own or as an embedded part of a large WEB development undertaking. In addition, the library allows images to be created using the command line version of PHP [11]. It supports advanced Gantt-charts, multiple Y-axes and several plot types like spider-plots, pie-charts (both 2d and 3d), line-plots, filled line-plots, accumulated line-plots, bar plots.

Cobian Backup: is a scheduler for security copies. It is a multi-threaded program that can be used to schedule and backup files and directories from their original location to other directories/drives in the same computer or other computer in the network. FTP backup is also supported in both directions (download and upload) [12].

The proposed application provides an easy-to-navigate environment for data exploration and decision-making. It provides the following capabilities [13]:

- Data extraction and analysis
- Reporting and distribution
- Decision helper
- Accessibility and robust

The privacy and security issues become a significant concern. They need to be guaranteed during a transmission between patients and clinical centers through the insecure internet, a secure authentication schema is thus essential to safeguard data integrity, confidentiality, and availability for the telecare medicine system [14].

We deployed the following essential guidelines to achieve an IS with a high level of security:

(1) The establishment of a relational database to store, to retrieve and to process the collected data.

This will be used in the construction of dashboards and helps by making the decisions.

(2) The implementation of the adequate logical and physical security layers: 3/4-tier architecture, hardware redundancy, access determination, continuous correction of defects and bugs, setting up specific communication protocols (HTTPS-SSL/TLS).

(3) The replication of files, folders and database records: the objective is to allow multiple accesses to the data. This favors the continuity of the service and guarantees the maximum availability.

(4) Determination of a backup politic and a system restoration strategy. This is very important by any eventual attack or unexpected disaster.

It is equally important to mention that the deployment of such tools is time-saving and will allow the health professionals to benefit from various advantages like: live monitoring, accessibility, security, ability to share information, data and images transportation and organizational efficiency [15]. The e-Health technology is often confronted by some adoption problems. The health professionals should see the benefit of such systems in order to gain their active participation. The final product should answer the need of all stakeholders.

Technically, to keep the developed IS alive, it is mandatory to have the following three services constantly up and running:

(1) Active directory service: the service is necessary to authenticate the users, to manage the accounts, the passwords and the policy rules.

(2) Database service: serves to store, retrieve and manipulate the data. MySQL provides a scalable and flexible platform that is oriented toward self-service and easy management. The tool provides enough monitoring capabilities to track the status of the service.

(3) Webserver service: First of all TCP/IP networking must be installed and working. A web server is software that listens for requests and returns data. If it is down, no data exchange is possible over

the network.

To measure the availability we track the downtime for each service once it happened from the corresponding log. In a weekly basis, the system administrator performs a complete analysis. The clocks on all nodes must be synchronized in order to get accurate readings and statistics.

From the logging files, the following information is traced:

- A service starts, stops, or fails, suspended or resumed.
- A resource/network is taken offline or moved.
- Users login and logout

The below statistics are tracked:

- Percentage of uptime/downtime
- Amount of uptime/downtime
- Longest period of uptime/downtime

The committed time of availability (C): This is usually measured in terms of number of hours/minutes per week, or any other suitable period.

Outage hours (O): This is the number of hours/minutes of outage during the committed hours of availability

We calculate the achieved availability as follows:

$$\text{Achieved availability} = ((C-O)/C) * 100 \text{ percent}$$

A group of engineers (programmer and tester) was asked to verify the code vulnerability and to perform the Penetration assessment. They try to find flaws that could endanger the applications. They simulate the actions of an outside attacker that aims to breach the system security.

## 4. Results & Discussion

Availability means that service or data would always be available when it is needed. The availability of e-Health systems is also of great importance because denial of medical service may jeopardize a patient's personal life [14]. The developed application contains certainly confidential and sensible data; the general concept should be designed so that it is safe and secure. Additionally, it is web oriented to

facilitate the communications and the exchanges between the different health facilities. The introduction of internet and communication technologies offers countless opportunities to build a reliable and accessible system.

The client machines are connected to the server from a 3-tier architecture. This is a logical model, which contains a stack of three software levels: the presentation layer, data processing, and then the records storage in a warehouse. This architecture has many advantages in terms of security and maintenance. The three layers are physically distinct and can be retained separately. The IS-safety is enhanced by the introduction of the SSL certificates and the HTTPS protocols. Backup scenarios and replication procedures are the main millstones when a recovery is needed.

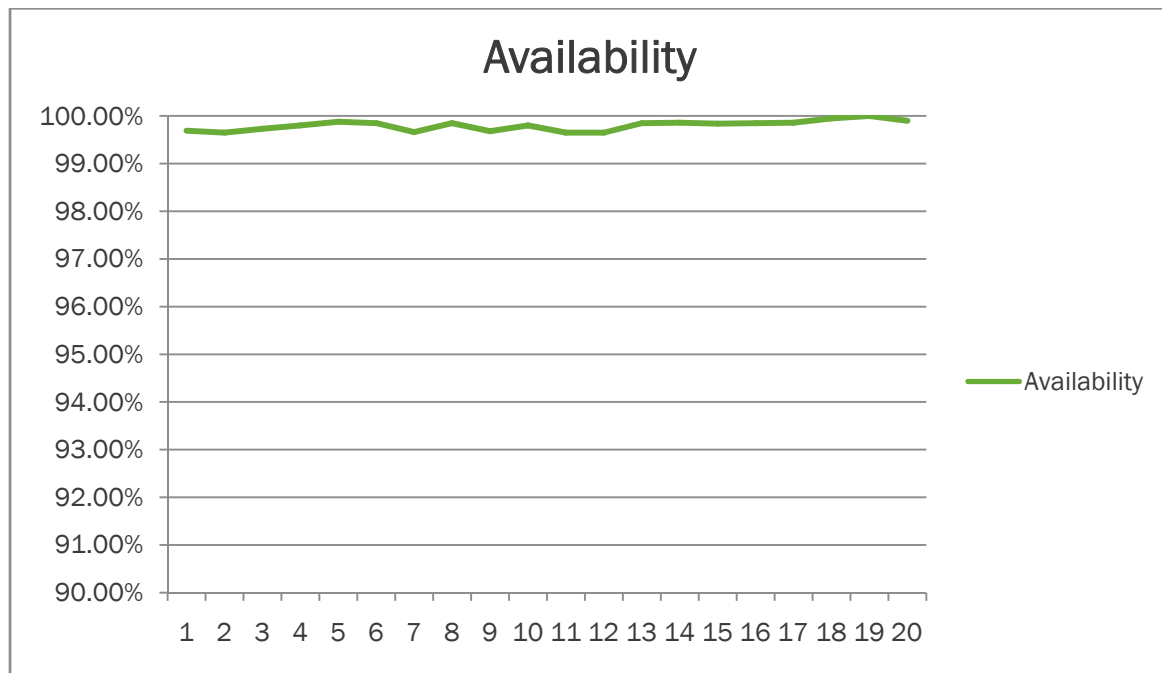
The availability of tools and system performance measurement are challenging especially for the IT infrastructures. Two additional actions are critical to improve the IS accessibility:

- (1) The establishment of a specialized hardware infrastructure;
- (2) The creation of appropriate processes to reduce errors and accelerate recovery in case of failure (backup and replication).

Authentication mechanism can ensure that illegal users do not obtain the system's resources fraudulently. Password-based user authentication scheme is one of the simplest and the most convenient authentication mechanisms in targeting insecure networks. The current Internet environment is vulnerable to various attacks such as replay attacks, on-line and off-line password guessing attacks, modification attacks, and stolen-verifier attacks. Hence,

**Table 1 Availability parameters.**

Percentage of uptime/20 weeks	99.8%
Amount of uptime/20 weeks	3,353.28 h
Longest period of uptime/20 weeks	238 h
Percentage of downtime/20 weeks	0.2%
Amount of downtime/20 weeks	6.72 h
Longest period of downtime/20 weeks	0.75 h



**Fig. 2** IS availability during 20 consecutive weeks.

a strong authentication scheme is needed between users and server [16].

The availability average is at 99.8 %.

After investigating and analyzing the generated logs from the three services, we obtained the following weekly-achieved availability (Fig. 2).

Using available tools and techniques, the testers attempted to exploit critical systems to gain access to the network or the database itself.

Mainly the following tests are performed successfully:

- (1) Security degree of the passwords;
- (2) Verify the access controls (Application/Operating systems);
- (3) Evaluates the efficiency of the communication protocols;
- (4) Check Session Management;
- (5) Verify the system/services/network configuration;
- (6) HTML/SQL/LDAP injection;
- (7) Check for Error Codes/Stack Traces;
- (8) Verify the possibility to execute malicious script.

If a security hole is found because of vulnerability checks, a correction procedure will be started immediately in order to protect internal systems, sensitive data from threats and attackers.

The obtained results are promising. It approves the efficacy and the efficiency of the proactive approach we applied by:

- Applying an adequate 3-tier architecture;
- Redundancy in the hardware and network topology;
- Preventing the system from external attacks (Authentication's algorithm, HTTPS;
- Automatic restart of the services after any eventual failures;
- Adapted backup and recovery scenarios;
- Adjusted replication procedures (database, files and folders);

Being able to send and receive data securely over a network is of growing importance. To that end, many web applications force users to use SSL certificates to encrypt traffic between the client browser and the server (application server). SSL is a secure method to encrypt data from your computer and send to the

server, keep information private and safe [17].

The vulnerability assessment methodology has the mission to understand the system design and architecture in order to determine the failure modes and identify consequences of the down time. The assessments may identify options for reducing the number of security holes, improvement of equipment, firewalls, hardware.

Actually, the attendees' different users by providing a computer system are not always the same. The interface is designed to respond to more functional and ergonomic criteria. It must meet the medical professionals who seek a concise and timely information. The basic use of a relational database allows us to avoid the appearance of duplicates (absolute or relative) in the tables, which ensures the consistency and integrity of records.

The SI must support careers and guide them to the correct diagnosis by presenting useful information and relevant suggestions. Clinical decisions are taken a careful manner.

The development and implementation of effective surveillance systems produce reliable and comparable indicators, enabling health professionals and policy makers to trace differences, to study trends and make better decision on planning and evaluating preventive programs health care delivery resource allocation and research [18].

To minimize the effort of medical professionals most processes are automated: instantaneous monitoring of the evolution of vital signs, alert generation, calculates Glasgow score, creating references sheet, finalization of dashboards, the backup and replication operations...etc.

## **5. Conclusion**

E-Health technologies often face adoption challenges in a context of excessive transformations of the life styles, an efficient health treatment is required to include the concept of IT resource management, data archives and rescue. In this paper, we exposed

first some findings from similar works in the literature, then we proposed some guidelines to achieve an IS with a high level of security and availability. We shared the results of an executed vulnerability and penetration tests.

Since e-Health Application can be accessed via the Internet, confidentiality and security issues arise that have to be taken in account. The electronic care system we developed for envenomation stings contains data with sensitive character, so it is crucial that these records are constantly accessible, but only for eligible people. Consequently, one has to consider an efficient system with a high availability. Numerous measures took place and demonstrated an improvement in the Serviceability and Usability. The storage and the processing of millions of patients information in a classical manner are expensive in terms of costs and time. We deployed the N-tier architecture, which allowed us to treat the physical and logical layer separately. Replication, backup and restoration procedures are defined and considered. Dashboards can supervise the system data in a real time manner.

Formally the developed dashboards are a kind of culmination of a functional SI, which is able to aggregate, analyze, monitor, exchange, share and synthesize data (patient records, monitoring of vital signs, diagnostics, treatments, drugs...). The responsible authorities must take the opportunity to define and develop strategies of struggle and audience.

We introduced an adaptable proactive approach by preventing IS damages or failures to happen. We focus on continually improving the provided service and therefore increasing the productivity and efficiency. The generated warnings and errors are intelligently captured and handled in a runtime mode. It is expected from an administrator or even more from the system itself to take the adequate action timely.

In conclusion, this work presents a concept of a web application architecture for modeling, processing

and dynamically manage the information related to envenomed people, especially the monitoring of their vital signs. The SI is able to safeguard the set of electronic services, essentially the measurement, monitoring, orientation, data management and analysis.

At some point, we should rely on the IT to ensure the proper functioning of the business and technical features. As the services are curtailed, it is mandatory to establish the right level of redundancy.

It is crucial to recognize that it can be a challenging task to reduce the down time of a system. The technicity and clear procedures are needed to get the system back online. The length of recovery time correlates closely with several factors (complexity, software issue, hardware problem, network concern...etc.).

To guarantee a continuous service, some operating systems and virtual machines possess a key feature. They can restart the application if it dies unexpectedly.

The more complicated and diversified the system, the longer it takes to repair it. It depends to the topology and redundancies, to the system architecture and if the shutdown is really needed to perform the changes.

Finally, the SI architecture should:

- Develop a strategy to deal with the serious potential problems he may face.
- Define and implement ways and procedures to minimize the negatives consequences if an attack or a failure occurs.

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