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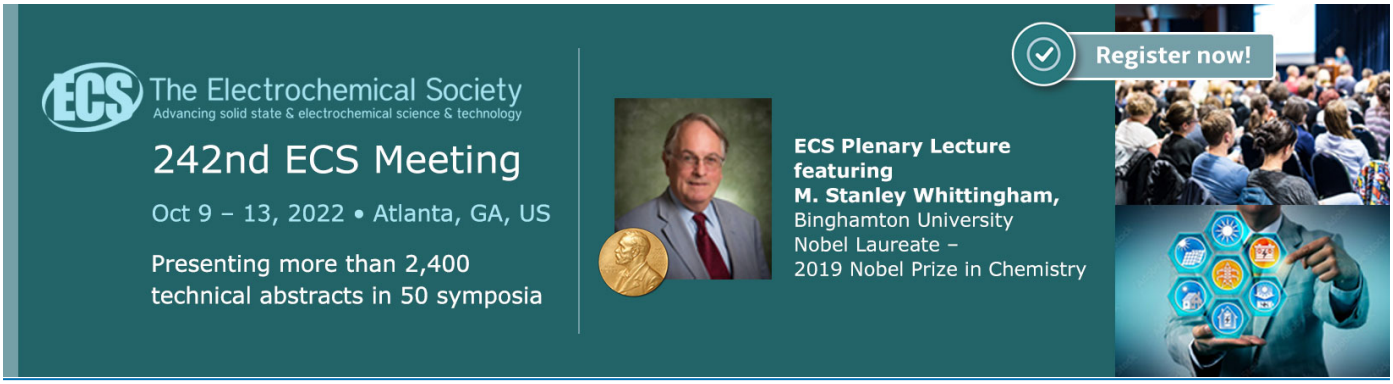

Design of a telemedicine system for the provision of primary health care (PHC) services

D. Jaramillo[1], M. Mondragon[1], A. Morales[1], S. Sanchez[1] and H. Romero[1],

[1]Antonio José de Sucre University Corporation (Colombia).

alex_morales@corposucre.edu.co

Abstract. Currently, technological progress has allowed health-related issues to be worked on collaboratively, expanding their learning, managing to provide health services in remote places, guaranteeing one of the fundamental rights of every human being, among these technological advances are Telemedicine stands out, which has been playing a leading role especially in these times of pandemic. For this reason, the objective of this research is to design an information system that integrates multiple technologies to support the provision of primary health care services. The research is descriptive and technological development in scope. As a final result, block diagrams and flow diagrams were obtained to represent the set of technologies to be used and the information data flow of the proposed system. It is concluded that the proposed system would facilitate the provision of health services in areas with or without internet connectivity, as well as support decision-making by executives of health organizations, in addition, telemedicine is a new technological trend for what projects like this allow Colombia to be at the forefront in health and technology issues.

1. Introduction

The interaction of technological advances, government regulation and market dynamics in the telecommunications industry has been a booming topic in the context of research [1]. In the last decades the generations of telecommunications called 1G, 2G, 3G, 4G and now 5G have experienced extremely rapid growth and promising deployment of use in all sectors that benefit from telecommunication [2]. Among these sectors is the health sector, which must ensure the provision of high-quality services to its users, because health is a fundamental right of every human being, and thanks to the increase in the use of mobile phones and access to high-speed mobile networks, an expansion has been created in the offer of activities that link to health. Among these activities we can highlight telemedicine, which is the focus of this document.[3]. Telemedicine allows the health ecosystem to be able to visualize, communicate and transfer patient data through a communication network, contributing to collaborative learning in the health area and to the timely treatment of patients who are located in neighboring areas or who, for Disability reasons make it difficult for them to travel to health centers.

Nowadays in different countries they make use of this new technological trend through simplex or duplex communication, the first is characterized by the fact that there is a single transmitter and receiver in the communication scheme, allowing data and information to be transmitted in a single direction, while the second consists of a two-way communication scheme during telemedicine sessions, in which tele-consultation, tele-monitoring, live surgical skills training, tele-mentoring, among other techniques that require two-way interactive sessions can be applied. [4].

Colombia presents a challenge in matters of health service coverage, due to the fact that a large percentage of Colombians live in areas near the urban area, which often do not have a complete road infrastructure, making it difficult for these populations to move to the benefits they provide. They are located within the urban area, it should also be noted that in Colombia few rural areas have health centers, so that the urban area becomes the epicenter of the provision of health services.

For this reason, the research proposes the design of an information system that allows telemedicine to be carried out in rural areas of Colombia, taking into account the little technological infrastructure and internet coverage in these places. The document is divided into the following parts, initially the theoretical framework of telemedicine is proposed, then the methodology of the study is exposed and finally the results and conclusions are described by the researchers.

2. Theoretical framework

2.1 Telemedicine

According to Daniela Chueke [5], Wilson Giovanni, Jhoanna Jiménez and Sareth Acuña [6], affirm that telemedicine is the exchange of medical information between two sites through information and communication technologies, wired and wireless, such as video conferences, smartphones, emails, among others, to your Once the use of these devices improves the clinical health of a patient, providing education and care.

Likewise, Reyna M. Durón, Néstor Salavarría, Heike Hesse, Andrea Summer, Kenton Holden [7] Imayasil Castellón Rodríguez [8], Olga Stolik Lipszyc, Claudia Jáuregui Izquierdo, Laura Galeano Zaldivar [9], establish that telemedicine is the provision of remote media services, through electronic telecommunications means, which includes the diagnosis, treatment, education and medical research of patients, guaranteeing the quality of health services provided in any geographic environment that requires medical attention for its inhabitants.

For her part, Jenny Paola Buitrago Aguilar [10], defines telemedicine as the use of information and communication technologies to bring health services to sectors that are far from the urban case, generating the optimization of the provision of these services.

Unquestionably, telemedicine is distance medicine that relies on the constant evolution of information and communication technologies to provide optimal health services in hard-to-reach areas, guaranteeing the well-being of patients and the quality care provided to these through the valid exchange of information on diagnosis, treatment and prevention of diseases, given through doctor-patient interaction, through the use of technological tools such as: the internet, videoconferences, smart phones, portable ultrasounds, videophones , radio, among others.

2.2 Telemedicine services and classification

Today, telemedicine offers tele-consultation, tele-monitoring, tele-diagnosis, tele-assistance, teleradiology, health emergencies, tele-surgeries, among others, which are carried out through various classifications of the telemedicine.

For Wilson Giovanni, Johanna Jiménez, Sareth Acuña Gómez[6] and Jenny Paola Buitrago Aguilar [10], telemedicine is classified into three groups:

- *Storage and shipping*, are the processes that are carried out through an asynchronous communication route, for example, email, by which exam documentation or other documentation can be sent, to be studied by medical personnel, to later send the respective results to the birthplace.
- *Remote monitoring*, allows health service providers to monitor patients in settings outside health centers, that is, it is done at home.
- *Interactive telepresence*, this type of telemedicine consists of the provision of health services in real time, where the doctor-patient interacts synchronously, either by videoconferencing

or another ICT tool, which allows simultaneous communication between the patient and the health professional.

2.3 Conditions and elements for the implementation of telemedicine

Every technological advance at the time of being implemented or executed requires conditions and elements for its proper functioning and evolution, for telemedicine is no exception, in the case of conditions Reyna M. Durón, Néstor Salavarría, Heike Hesse, Andrea Summer, Kenton Holden [7], establish that for the implementation of telemedicine it is necessary to ensure that:

- *Network security,* establish passwords and protection software that ensure tampering with the network.
- *The privacy and confidentiality of patient information*, You must work and store patient information in a prudent manner, without compromising their integrity.
- *Informed consent* It is important to use this instrument and have the monitoring of the ethics committees of the participating institutions.
- *The benefits to the patient*, the patient will always benefit from the case discussions. However, the legal responsibility for second opinions should be noted.
- *Ethical training of suppliers*, all participants in the tele-consultations must be trained on the privacy and confidentiality of the service.

For their part, Olga Stolik Lipszyc, Claudia Jáuregui Izquierdo, Laura Galeano Zaldivar [9], determine that the conditions to keep in mind for the management of telemedicine are:

- *ICT infrastructures*, to have multimedia network services for healthcare.
- *E-Health infrastructures*, the general aspects of ICT necessary for the development of the telemedicine service must be determined and ensured.
- *Support from research and education networks*, this aspect refers to the link with specialized providers of high-speed internet services, dedicated to supporting the exchange of data.
- *Ensuring the usability and technological scalability of the service*, it is necessary to ensure the usability and technological scalability to guarantee the correct implementation and development of the telemedicine service.

From another perspective, Jenny Paola Buitrago Aguilar[10], recommends that for the implementation of Telemedicine it is necessary to take into account elements such as: the determination of the demographic and epidemiological factors of morbidity and mortality, the economic capacity of the region and the resources available for the implementation, visit and prepare a detailed questionnaire of all the hospitals object of the implementation as infrastructure and to establish the services that are provided in the institution.

2.4 Advantages and Disadvantages of Telemedicine

The implementation of telemedicine brings with it advantages and disadvantages that are reflected at the time of its execution, starting from the perspective of different authors. In figure 1, several conceptions expressed about the advantages of the implementation of telemedicine are reflected. Similarly, in Figure 2, the disadvantages of this new health technology are analyzed.

Figure 1. Advantages of Telemedicine. (Source: Own) referenced information[5], [6], [7], [8], [9], [10], [11]

Figure 2. Disadvantages of Telemedicine. (Source: Own) referenced information from[10]

3. Methodology

The research is initially descriptive according to Hernández Sampieri, this type of research seeks to specify the properties, characteristics and profiles of people, groups, communities or any other phenomenon that is subject to analysis. [12]. Within the research process, an analysis of the state of the art was carried out to know the latest telemedicine findings and determine the minimum technical requirements and technologies that the system to be designed must have.

The final phase of the research is of a technological development type, according to MinCiencias this type of study occurs in the application of the research results, or of any other type of scientific knowledge, for the design or development of new processes, systems or provision of services, as well as the substantial technological improvement of pre-existing materials, products, processes or systems. This activity will include the materialization of the research results in a plan, scheme or design, as well as the creation of non-marketable prototypes[13]. The final purpose of the research is to generate the design of a computer system that implements telemedicine activities using technologies to meet the minimum needs for rural populations in Colombia.

The research is embodied in two phases, taking into account the software development methodology called Cascade.

In the requirements phase, the documentary analysis of the information organized with the bibliographic matrix and analyzed with the content analytical matrix was carried out, in addition to the application of semi-structured interviews with health personnel, in order to identify the functional requirements and non-functional of the system proposed in the present investigation.

For the design phase, block diagrams and flow diagrams were used to outline the architecture of the system and illustrate the communication between the different technologies that make up the system.

4. Results

Initially, a survey of requirements was made (see table 1) through documentary analysis, using the bibliographic matrix and content analytical matrix instruments, in addition, semi-structured interviews were implemented with health personnel from the Cruz Rojas Sucre Section in Sincelejo. Based on these requirements, the proposal of the system architecture is made, through block diagrams and flow diagrams.

Table 1. Requirements.

Functional	Not functional
Registration, consultation, elimination and updating of data related to patients, doctors, auxiliaries and administrators of the System.	Intuitive interface
First level data record in patient health or physical examination.	Terms and conditions for the treatment of information
Data storage on the web server (online) or locally on the device (offline)	Security in the transmission of data over the network.
Allow synchronization of device data with web server data (online)	Use of technologies such as HTML, PHP, Ajax, SQL, Chart.js library and SSL certificate
Elaboration of graphs of circular, bar and linear type using information stored in the database	MVC architectural design
Registration, consultation, elimination and updating of diseases and causes	Use of data entry techniques.

By drawing up the block diagram (see figure 3), the behavior of the functional requirements of the telemedicine prototype is illustrated, where the systems based on both the cloud and the local are shown in each block, the scheme of which presents the following technologies, a) structure of the view or interface (HTML), b) PHP, c) Database (SQL), d) chart.js library, e) Ajax and f) 4G technology, Communication protocols and protocols are also displayed in each layer. security, such as: a) HTTPS protocol, b) IP protocol, c) TCP protocol and b) SSL protocol.

Subsequently, the general operation of the telemedicine prototype is defined, and the activities carried out by each of the technologies mentioned above.

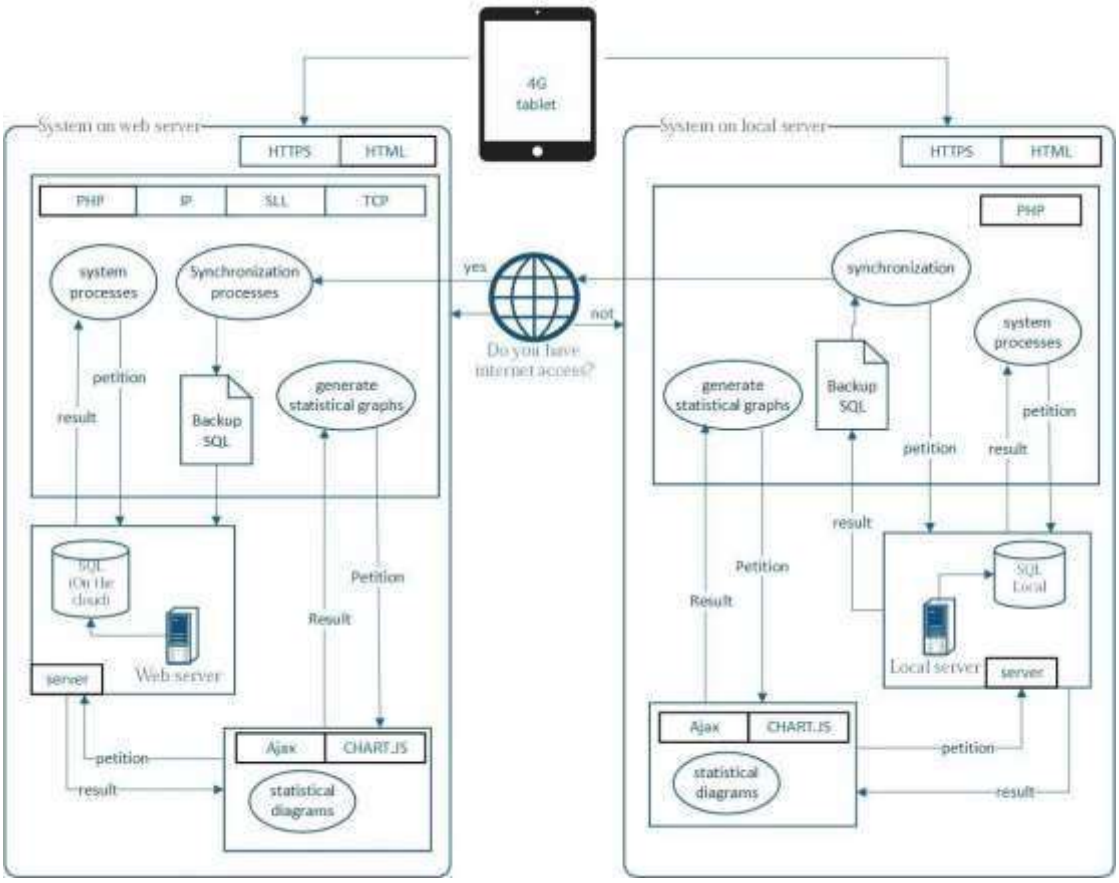

Figure 3- Block diagram - telemedicine prototype. (Own source).

When starting the telemedicine system 4G technology is used, the system verifies if there is internet coverage in the area, since there is no internet, the system will proceed to work offline, recording the data registered in the local database.

Once the data records are finished and the internet has access, the synchronization process is carried out, which makes a request to the database (local SQL), which allows the download of the SQL backup to carry out the upload and update in the database (SQL) that is in the cloud.

After performing the synchronization (whether or not the web server database (Cloud SQL) is updated) the system will have the ability to make Ajax request to the database (Cloud SQL or Local SQL), where it generates a query, later returns a response that is processed with the chart.js library, generating statistical graphics, which benefits when making decisions. The technologies that make up the system are:

- *HTML*: It is the hypertext markup language, which is responsible for the interface or visual for the client side, this is used for the creation of web pages.
- *PHP*: This is an open source programming language, based for web development, which processes on the server side, performs all kinds of processing such as the connection with the database, and performance of internal system processes, this on the other hand it can be embedded with HTML.
- *SQL*: This is the structured query language, where it facilitates the manipulation and integrity of the information established in the database stores.
- *Chart.js*: It is a library based on JavaScript to make graphics of all kinds, where it represents data based on a given information, either through a file, data structures such as lists, stack and array or

in the form of a query to the stores of database, displaying the data graphically (data bar, pie and donut pie charts, line charts, radar chart, among others).

- *Ajax (Asynchronous JavaScript and XML):* It is a technique that combines several programming languages, it consists of requesting data from the server, it returns the data, while the page has a response time, to obtain the results on the client side.
- *4G technology***:** It is the fourth generation of mobile technologies (wireless modems, Smartphone, among other mobile devices), in data transmission, it is based on the IP protocol, for processing access to the network, it also has a capacity of 100Mbit / s in motion and 1Git / s idle with respect to internet access speed.

The flowcharts, each of the following components, system data log, physical exam log, system stat graphs, and timing are described in detail below.

4.1 Data logging component in the system.

Next, the data recording process in the telemedicine prototype is defined, using a flow diagram (see figure 4).

Initially the system has a login to allow user access, for this it makes a verification of the database, depending on whether it has internet access or not, then it returns a result of existence, if the result is no, it returns to login with a login error message, if the result is yes, it is entered into the telemedicine system.

Once the entry has been validated, internally the system must validate the access level of the user, whether he is an administrator, doctor or assistant.

If you give him administrator user permission, he has the functions of a) access to the registry of information about patients, doctors, assistants and system administrators and b) access to the registry of diseases and their causes.

If you give permission from a doctor or assistant, you are allowed to a) register patients and b) medical records of patients.

The administrator records the information of the patient, doctor, assistant or system administrator, if the system is connected to the internet the data is stored in the database that is in the cloud, if not, the data is stored in the local database. It also records diseases, for them a search query is made in the database, if the disease does not exist, it proceeds to register it, if the disease exists, the user can give the causes of the diseases, at the final if the system has internet access the data is stored in the cloud database, if not, it is stored in the local database.

The doctor and assistant, verify the patient's stock in the system, if the patient does not exist, it is added to the system, if the patient exists, make a new patient consultation.

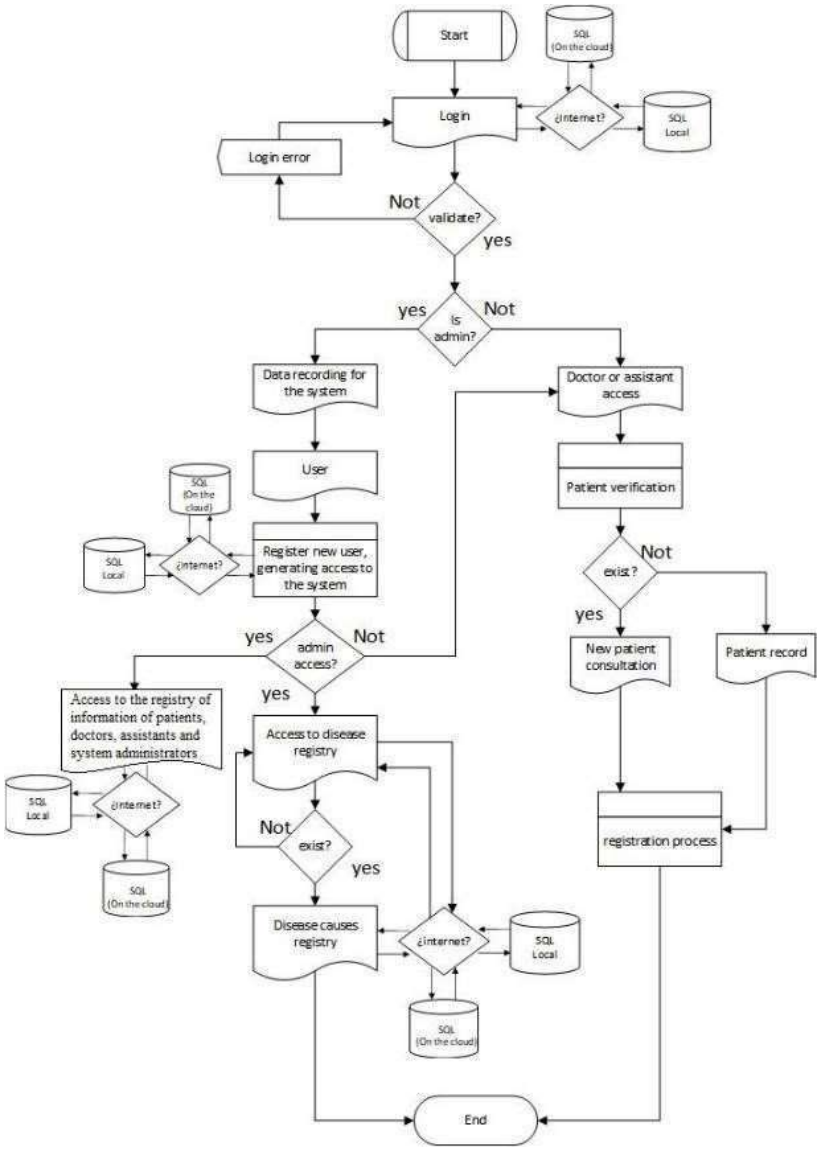

Figure 4 Flow chart, data recording in the system. (Own source)

4.2 Physical examination record component.

In this section, the existing and non-existent patient physical examination record diagram is defined in the telemedicine system (see figure 5).

Initially, the patient process performs an existence search, for them, if it has internet access, it will search the cloud database, if it does not search the local database.

If the patient does not exist, a patient not found message will be displayed, and it will be redirected to enter data for the new patient, this will ask for the personal data of the new patient, data from the physical examination, doctor or assistant in charge, current location of the consultation, if the patient has any disease or not, and reason for the consultation.

If the patient exists, a new consultation is added, where you must enter the following information, data from the physical examination, doctor or assistant in charge, current location of the consultation, if the patient has any disease or not, and reason for the consultation.

Once all this data has been collected, depending on the internet access, if you have the data it is stored in the cloud database, if it is not stored in the local database.

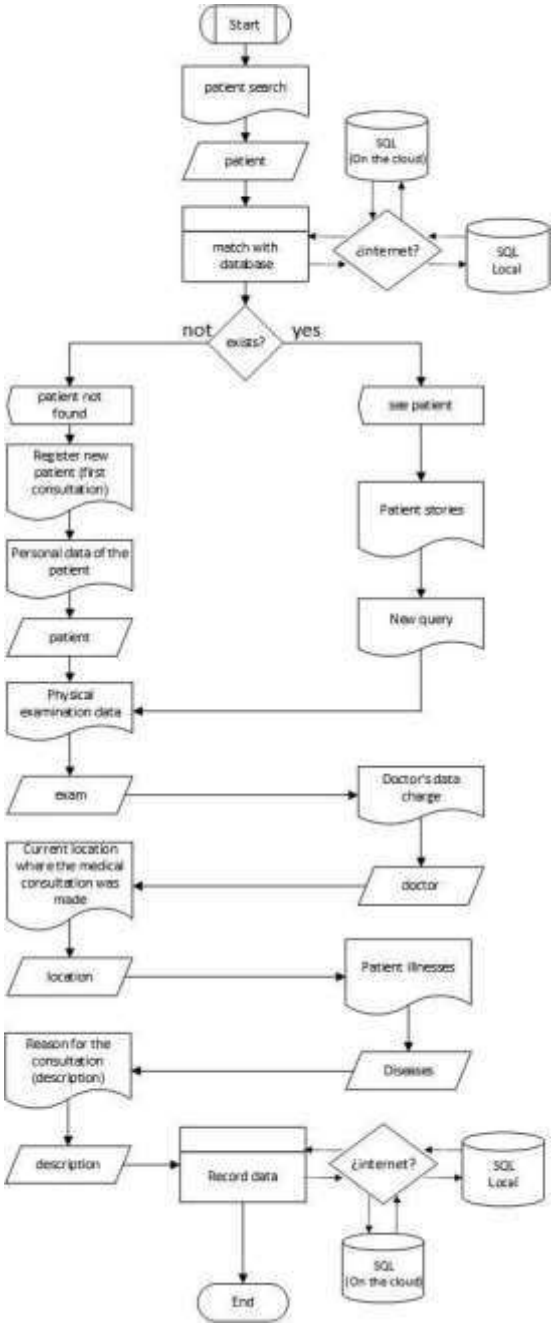

Figure 5 Flow chart, physical examination record. (Own source)

4.3 Statistical graphic components of the system

Subsequently, the flow diagram was elaborated (see figure 6), where the statistical generator process of the telemedicine system was determined.

It starts with a simple question, what statistical graph do you want to generate? Gradually, you enter the query to be generated.

Then an internal process is carried out which makes a request through Ajax, if the system has internet then the query is made to the cloud database, if it is not, the query is made to the local database.

Once a result of the request has been obtained, it generates a statistical graph with the query generated previously.

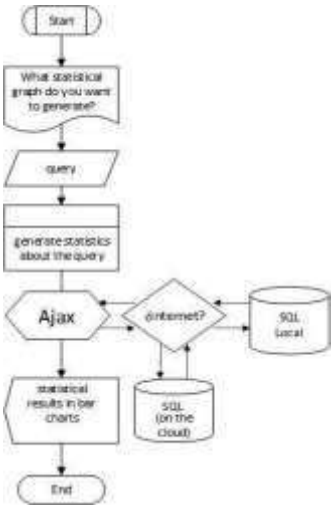

Figure 6 Flow chart of the statistical graphics component. (Own source)

4.4 Synchronization components.

Finally, the synchronization flow diagram of the local database with that of the cloud is described (see figure 7).

When starting the synchronization process, it must be ensured that the mobile device has internet access.

If you do not have access to the internet, it can carry out the registration processes on the local system, in the certain processes they are saved in the local database.

To achieve synchronization, this download a backup of the local database, once this action is performed, it is asked again if it has access to the internet, if so, it proceeds to the cloud system, where the process of upload the backup to the cloud database.

If it has always been on the Internet, what it does is save all the records and processes carried out in the cloud database.

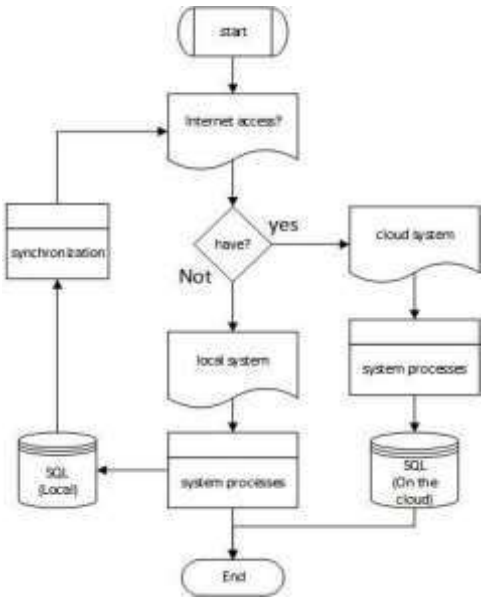

Figure 7 flow diagram of synchronization of the local system with the cloud system. (Own source)

4.5 Discussion

Telemedicine is one of the technological trends in the field of health that has been studied by different researchers in the area of health and engineering in the last two decades, expanding its role in the provision of health services; which leads to continue developing research and innovations in this field of technology and engineering. Reviewing what is involved in this research, it is detailed that there are two types of telemedicine according to the authors consulted that stand out for the provision of health services in places of difficult access, among them there is remote monitoring or home consultations through technologies and Interactive telepresence or consultations through videoconferences or other technological tools that allow synchronous communication between patient and doctor.

On the other hand, the proposed system seeks to offer representations of important data for health organizations, such as the most frequent diseases, characterization of rural populations in terms of health, segmentation between genders and their health states, segmentation between age and their health states. health, among other possible categories in order to be able to make more accurate decisions when planning future health brigades in these communities.

This system seeks to support the provision of first-level health services in places far from the urban area or areas of difficult access, mitigating the different disadvantages raised by the authors consulted, among these advantages is the low interaction between patient and doctor, difficulty in the development of health protocols, confidentiality of patient information, quality of the information provided by the patient in the consultation and interruptions due to technical difficulties, which are solved with the home consultants, where the health personnel guarantee compliance with all these tasks; If it focuses on the last disadvantage, interruptions due to technical difficulties, this is where the synchronization system can support the lack of technological infrastructure in the place of residence of these communities.

5. Conclusions

At present, telemedicine has become a strategy to break down barriers to physical access to health services, supporting its development in new information and communication technologies, which allow tele-consultation to tele-surgery. In the same way, telemedicine has allowed asynchronous and synchronous communication between the health professional and the patient.

In the same vein, it can be concluded that the implementation of telemedicine brings benefits to society and mainly to the field of health, such as the reduction of cost and time to patients, improves the quality of services health, greater opportunity to access the right to health, among others.

On the other hand, it is concluded that the integration of statistical graphics in the proposed telemedicine system provides organization of the data, through these various variables can be compared, yielding various results, which facilitate and favor decision-making for positions administrative, to establish strategies to improve the provision of health services.

It should also be noted in conclusion that the operation of synchronization brings as an advantage access to the telemedicine system, without the need for an internet connection, that is, it favors health brigades that are carried out in areas without internet coverage, ensuring the provision of the health service and the registration of data that will later be updated with the web server through synchronization.

To conclude, it should be noted that telemedicine is a new technological trend that is being implemented in different countries of the world, and projects like these allow Colombia to be at the forefront in health and technology issues.

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