The design and implementation of an IoT-based health monitoring system in Burkina Faso

Manegaouinde Roland TOUGMA[1], Désiré GUEL[2], Justin P. KOURAOGO[3], Yann SANOU[4], Boureima ZERBO [5]
{ manegarodrol@gmail.com[1], guel.desire@gmail.com[2], kouraogo@gmail.com[3], yann.sanou@bf-yeltech.net[4], bzerbo@gmail.com[5] }

Département Informatique, Université Joseph KI-ZERBO (U-JKZ), Ouagadougou, Burkina Faso [(1,2,3)],
Yeltech Technologies, Ouagadougou Burkina Faso [4]
Université Thomas Sankara, Ouagadougou, Burkina Faso [5],

Abstract.

We present a health monitoring system for patients in Burkina Faso with the objective of preventing the spread of disease and obtaining a good diagnosis even at remote. An IoT application has been realized in three phases by: designing a web application; designing a digital records tracking system; and field testing. In order to locate the level of integration of the IoMT-based system in our health centers, a field survey was conducted. The system is based on a Raspberry Pi that has been deployed as a WiFi AP (Access Point). An ESP32 is associated with a MAX30100 sensor to create a saturometer with local resources. It has been developed in Python and implements websockets for real-time connection to allow automatic feedback of data from the oximeter to the application.

Keywords: Internet of Medical Things (IoMT), ESP32, MAX30100, Raspberry PI, Websockets

1 Introduction

Internet of Things (IoT) have spurred a great advance in the fields of domestics, smart homes, healthcare systems, goods monitoring and logistics. IoMT-based health systems solutions allow multiple vital signs to be self-monitored via connected medical sensors, including weight, pulse, temperature, blood glucose, blood oxygen, and electrocardiogram (ECG) or respiratory conditions. They can be connected to medical devices or medical applications sharing self-measured health data with designated people (doctors or families), accessible in a controlled manner by the patient. While chronic diseases are responsible for 63% of deaths worldwide according to the World Health Organization (WHO); Burkina Faso is no exception. In orderto find an effective response to the management/monitor of these diseases, we propose to design an IoMT platform for health centers

JRI 2021, November 11-13, Bobo-Dioulasso, Burkina Faso

DOI 10.4108/eai.11-11-2021.2317992

in Burkina Faso. The main goal is to provide a standard tool that could be used in any medical center, accessible and very inexpensive that are able to capture important constants well reflecting the patient's condition. Therefore, we have been interested to oximetry sensors that could address the following problems:

- Knowledge of a patient's state of distress whatever his condition
- The patient's cardiovascular state: cardiac arrhythmia, poor oxygenation by irrigation, pulse too weak
- Ensure the proper functioning of the lungs: poor oxygenation by pneumopathies, asthma, Covid19
- Check the physical condition of people in reception, emergency and trauma services: injured by accidents, domestic injuries, burns, etc.
- To be able to check the physical state of a person having undergone a psychological shock and unable to express himself: cardiac arrhythmia, anxiety attacks

This article is organized in four main points After the introduction we present similar work. Then we detail the methods and materials used in this project. And at the end the conclusion and the perspectives.

2 Similar works

2.1 Similar works

The set of the different works related to this project, we consider two (02) groups for the analysis.

The first group of works addresses the developing tools problem to measure the patient constants with certain precision which have not been designed or implemented within the monitoring platform [1] [2] [3]. The system presented in [1] allows the monitoring of constants such as heart rate, oxygen saturation ratio, body temperature and eye movements, in the IoMT network. The developed system has been implemented but no specific performance measures are described for any patient.

Article in [2] introduces a IoMT based Healthcare Monitoring Kit developed to monitor some basic human health parameters such as heart rate, electrocardiography (ECG), body temperature and respiration. The major drawback of the system is that no data visualization interface is developed. The main hardware components used here are pulse, temperature, BP, ECG sensors and Raspberry Pi. The data are collected from the sensors and sent to the Raspberry Pi microcontroller- based system for processing and sent back again to the IoMT sensors network.

The toolkit Spartan3 is used for parallel data processing in FPGA based architecture [3]. The results of the MCU (Microcontroller Unit) are displayed by an LCD screen, and all the sensors are connected to this unit. All the elements of the architecture are not integrated in one unit.

The second group regroups the works in which are implemented some global platforms and tools to measure patients' constants. However, the hardware used doesn't meet our goals to ensure real-time processing in the context of autonomous healthcare center [4] [5] [7] [8] [9].

Disai et al [4] have addressed the issues of IoMT data processing using fog computing services. Their work has reduced latency by transmitting signals to remote servers, which can improve medical services delays in different areas. Latency reduction is one of the necessary features of computing platforms that can enable successful healthcare operations. Specially this concerns large-scale medical projects implemented to achieve critical and intensive services. One of the main issues to address in Fog Computing system is the lack of security. Failures in the security services of data can affect the safety of patients and their records, so users may not trust the hospital center.

Gregoski et al [5] developed an intelligent healthcare monitoring system using a sensor system and an ESP32 microcontroller device which ensures real-time data transfer to a platform. With the system developed, patient status is transmitted via a portal to medical staff, who process and analyze the camera to track finger blood flow and calculate cardiac output based on blood flow. This is an excellent design but is not feasible when continuous cardiac monitoring is required.

In Oresko et al [7] a fully functional platform for smartphones is presented. It allows real-time coronary rhythm monitoring, did not track heart rate over time and could not detect any cardiovascular disease.

Trivedi et al [8] propose an Android-based device for monitoring health parameters. The analog data collected by the sensors and sent to the Arduino Uno board. The major drawback is that Arduino uno is not suitable for monitoring data from multiple patients. Also, the integrated Bluetooth does not cover a large area. With the integrated analog-to-digital converter, the recorded analog values are converted into digital data. The Bluetooth transmits the device developed resources consumption level to an application.

The authors of [9] have designed a system organized into 3 separated layers such as control, device and transport layers. A DS18B20 sensor was used for body temperature measurement in the control segment and a pulse sensor is used for measurement. The data have been uploaded from Arduino to a cloud platform using a Wi-Fi module and the Ethernet shield in the transport layer. The framework layer finally collected the details from the server. However, Arduino Uno is not suitable for monitoring data from multiple patients, and therefore, many sensors cannot be processed properly.

Our project proposes a monitoring platform, with more powerful, sensitive and accessible tool. It takes into account the energy consumption issues by proposing an energy-saving system, which power supply is not directly connected to the electric power sector.

2.2 Systems-based IoMT in Burkina Faso:

The health sector in Burkina Faso has been in change by the information and communication technologies. Projects aimed at improving health conditions are emerging. They remain unrecognized for most Burkina Faso people due to lack of communication. We have listed a few projects that have been carried out even if the proposed applications are not directly involved in patient monitoring.

HealthStatus:[11] HealthStatus is a Health technology whose ambition is to optimize the care time in the emergency services. HealthStatus' solution embeds the minimum data in an electronic health card. These data are read by the reception service and then allow the medical profession to promptly start the patient care. The main goal is to make emergency services more efficient by speeding up response time. HealthStatus is incubated in the Digital Incubator of Joseph Ki-Zerbo University, INCUB@UO in the IT department.

MobiSan: MobiSan is a project that has developed in Fada N'Gourma and Diabo municipalities thanks to Gret association with Djantoli's partnership and APAC and ABF Fandima associations. The project offers the following services: regular home health monitoring for children under 5 by health workers or Djantoli service. The follow-up of children suffering from acute malnutrition and the AlloLaafia service which consists in sensitization on the nutrition and childcare's health, the follow-up of pregnancy and family planning.

2.2.1 Synthesis

The low level of equipments in Burkina Faso hospitals means that the approaches proposed by similar works present inadequacies either in energy autonomy, or in the methods of efficient measurement of constants.

3 Methods and Materials

we have now a better understanding of the different approaches proposed based on the existing IoMT systems studies; we have also been inspired by certain works, tutorials, and small open source projects to implement our solution. The advantage of this method is to get started and quickly create added value to our platform. This part describes the selected methods as well as the IoT equipment that will achieve the set objective.

3.1 Methods

3.1.1 Data collect

The first step in our approach was to determine:

- The usage of IoT in Burkina Faso health centers and hospitals

- The benefits of the project for caregivers
- The caregivers permeability an IoT solution to facilitate patient care and monitoring.

All these questions led us to carry out a preliminary survey of public and private urban and peri-urban health centers in Burkina Faso.

Health centers - Burkina Faso health administration is divided into several categories according to their capacity for admission in terms of number of beds, equipment and resources : University Hospital Centers (CHU), Regional Hospital Centers (CHR), Medical Centers with Surgical Antenna (CMA), Medical Centers (CM), Health and Social Promotion Centers (CSPS), establishments private hospital care and private hospital care facilities.

According to the Ministry of Health[14] (2018 report), Burkina Faso counts 06 CHU, 08 CHR, 45 CMA, 1896 CSPS, 131 Dispensaries isolated, 09 isolated maternity hospitals, 135 Private Hospital Care Centers, 409 Private Non-Hospital Care Providing a total of 2,639 health centers in all categories. With a probability sample on which we applied the stratified sampling technique, we retained a population of 100 (rounded to 106) individual centers out of a total of centers (2639) distributed.

Table 1: The categories of health centers in Burkina Faso

	CHU	CHR	CMA	Isolated Centers	CSPS
Public	06	08	45	544	1896
Private	-	-	135	-	409

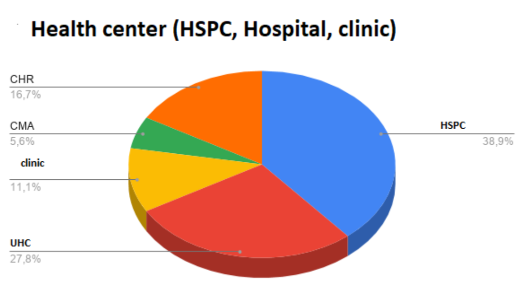

Fig. 1. Study sample Distribution of health centers

After determining the sample, we refine the survey in order to determine the common diseases in Burkina Faso, the new pathologies encountered, and the heart problems encountered. The main objective being to have a global view of the diseases that the Burkina Faso population face and to propose an adequate solution. The results from the survey are illustrated in figure 1.

Common diseases in Burkina Faso - In order to be in tune with the medical world, we inquired about the state of common diseases in Burkina Faso.. This question is more related to the experience and the department in which the respondent works. It allows you to have a general view. Indeed several diseases stand out. But malaria 16.7%, respiratory diseases 16.7%, accidents and trauma 11.1%, heart disease 9.7%, diarrhea 6.9%, are more common in Burkina Faso.

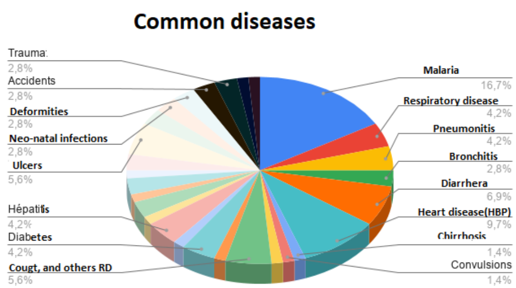

Fig. 2. Common diseases in Burkina Faso

New pathologies The objective of this question is to draw up a list of the diseases that are most prevalent by the number of deaths caused per year. As showed in figure 3, our study reveals of severe cases of heart disease 34.1 % followed by cancer 15.9 % and diabetes 15.9 % then come asthma 9.1 %, STI (Sexually transmitted infection) 6, 8% renal failure 4.5% but also other diseases greater than 5%.

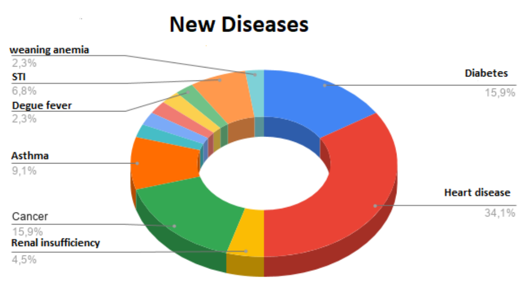

Fig. 3. New pathologies

Cardiac problem We remind that our objective is to propose a solution to the greatest evil in Burkina Faso people. The previous graph shows a strong trend in heart disease with a rate of 34.1%.

This is how we ask the question whether the nursing staff has ever encountered a patient suffering from a heart problem during their service. As showed in figure 4, the major part (94%) of the staff (old or new) confirm this evil.

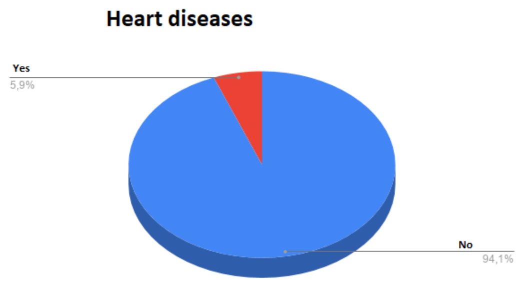

Fig. 4. Cardiac problem

The urgency After having obtained the information on the trends of diseases in our health centers, we were interested in the care aid systems. The objective of this part is to know if a patient arrives in a critical state (vital prognosis clear), do our centers have the means to detect this? How are patients sorted at reception and do they offer sorting methods? If so, using what technology?

Patient triage method To find out if a patient's life-threatening prognosis is involved, the centers have visualization test tools beyond even professional experience. It is therefore in our interest to find out whether the centers concerned have sophisticated sorting tools. According to the center and its technological equipment, 63.6 % have rapid diagnostic tools and 36.4 % do not.

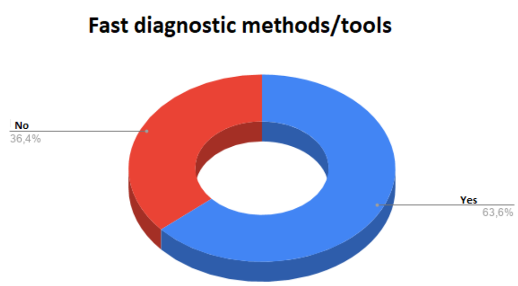

Fig. 5. Sorting methods

Need for a sorting tool In view of the insufficiency of sorting methods and the ineffectiveness of certain methods vis-à-vis the number of patients from the evolution of technology, this section has for aim to know the favorable centers for the establishment of a sorting system for the most frequent diseases mentioned above. On this point all the centers are ready to apply a new sorting method based on new technologies even if all the centers are not ready to immediately integrate these new applications (more than 60% will be ready at the latest in two years) .

Fig. 6. Needs to setup a welcome protocol

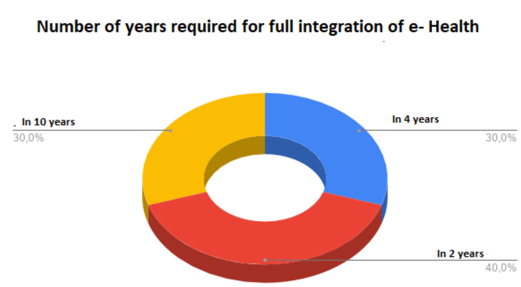

Fig. 7. The times that it'll be take for eHealth full integration

Requirement expressed For patients management (reception, sorting, etc.), most of the health actors wish to use a tablet for the management of medical data.

After analysis, we have an idea of the diseases that affect the people in Burkina Faso in general. We also have new pathologies that are developing and that heart disease is the most severe in terms of number of victims. Caregivers lacking assistance or sorting tools have clearly expressed the need for an innovative tool that will allow them to sort patients according to the emergency. Now that we have an idea of the challenges and needs of health centers, we present to you in the following section

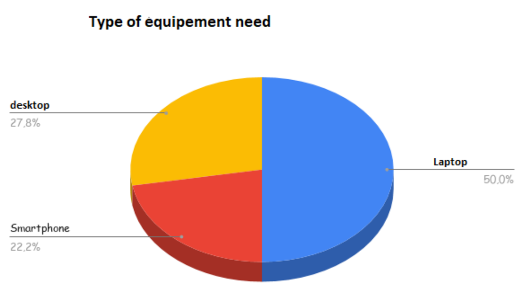

Fig. 8. Device requirement

the modules chosen to effectively meet these needs.

3.2 Prototype's choice and Development Toolkit

Global system Figure 3.2 below illustrates the overall monitoring system. The captures are used to collect data in a hospital setting. The sensors are all connected to a processing unit called ESP32. Once these sensors (oxygen, heart rate) are connected, the ESP32 functions as the heart of the system. The ESP32 collects the data from the sensors and then transfers it wirelessly to the servers which is the Raspberry pi. The board uses its own WiFi and processing unit, which is an Xtensa dual-core 32- bit LX6 microprocessor. Using wifi as connectivity, the physiological data is sent to the server in hexadecimal. This data in hexadecimal is then converted to comprenhensible data by an algorithm on the server.

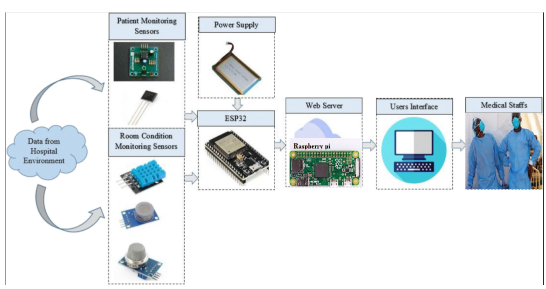

Fig. 9. Global System

Paspberry PI :

Raspberry PI is a nano-computer, developed by the foundation of the same name. It comes in the form of a motherboard with various components on it and a series of ports (Ethernet, USB, CD card). By installing the Linux operating system, we can plug it into a monitor and keyboard to make it a regular computer, but that's really not the point. The main advantage of this nano-computer in this project is that it allows us to deploy our application server and the database.

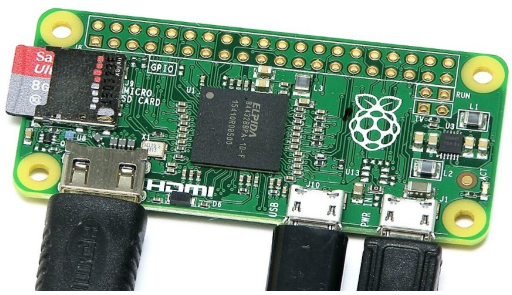

Fig. 10. Raspberry PI

ESP32 microcontroler

In addition to its built-in wireless communication functions and signal converters, the ESP32 has 15 pins with a capacitive sensor (touch sensor) and a thermometer. So we can easily make our connected projects even more interactive, the ESP32 is equipped with a dual processor. This allows for smoother and faster operation. One of the processors manages the communication (WiFi or Bluetooth), and the second processor takes care of the control of the inputs and outputs. This makes the micro-controller more efficient [12].

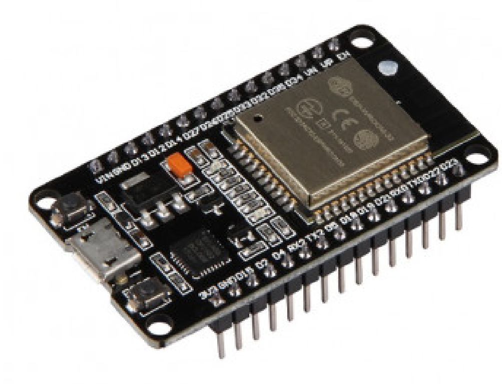

Fig. 11. Esp32

Pulse and oximeter sensors

The pulse oxymeter allows continuous measurement of the amount of saturated oxygen of saturated oxygen circulating in the arteries. The term arterial hemoglobin saturation is used when hemoglobin is carrying oxygen, it is said to be ”saturated”.

Fig. 12. Oxymeter

4 Results,Test and validation

4.0.1 Test and validation with certified equipment

To test the mobile app that has been developed, we used the jumper oxymeter to capture vital data. But before starting we make sure of the efficiency of the equipment used. This is how we carried out a comparative study on Monday September 14, 2020 at Bogodogo Hospital at the pediatric level. The results are shown in the table 2.

Table 2: Comparison of percentages.

	Masimo SET		JUMPER Oxymeter		
Age	SpO2	Pulse	SpO2	Pulse	Pi
29 years	98	102	99	103	1.2
2 years	99	102	99	102	5.7
4 years	96	119	99	120	8.1
4 years	94	107	94	106	0.3
3 months	99	120	0	0	0
2 months	100	175	0	0	0

4.1 Keneya App

Keneya app is the monitoring platform that we have developed. The prototype of the saturometer is based on this application developed and will monitor vital constants. It converts the data collected in hexadecimal, integer, percentage (%) or graphical format depending on the information we want to read. Keneya app is an intuitive, ergonomic and easy to use application. The following screenshots show the main interface of the application.

Constants in numeric: This data can also be displayed in numeric for easier reading as showed in figure fig13 which shows the value of constants for a patient. We can easily read at this moment that the patient's pulse is 78 bpm and he has an oxygen level of 98%.

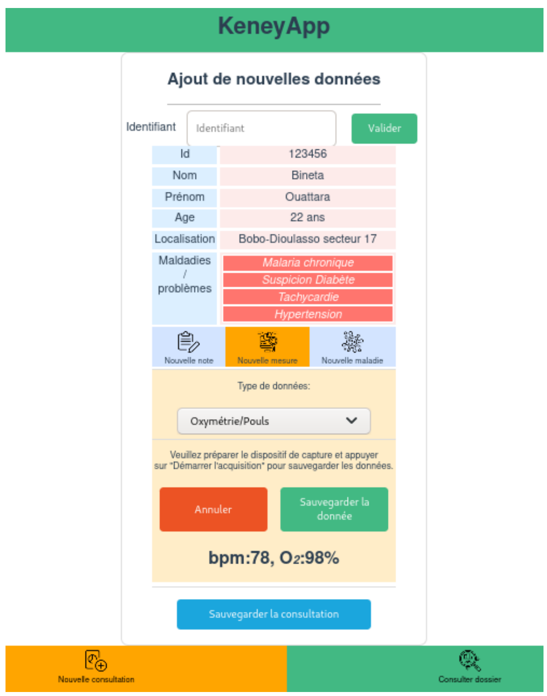

Fig. 13. Constants

Search for a patient The following is the result of a patient search. It is easy to identify the person's identity and physiological data (pulse, diseases, patient's condition, etc)

Add a patient And this time, the image shows a window for adding a patient. To do this, you need an id (valid document number), the relative information and of course the disease from which

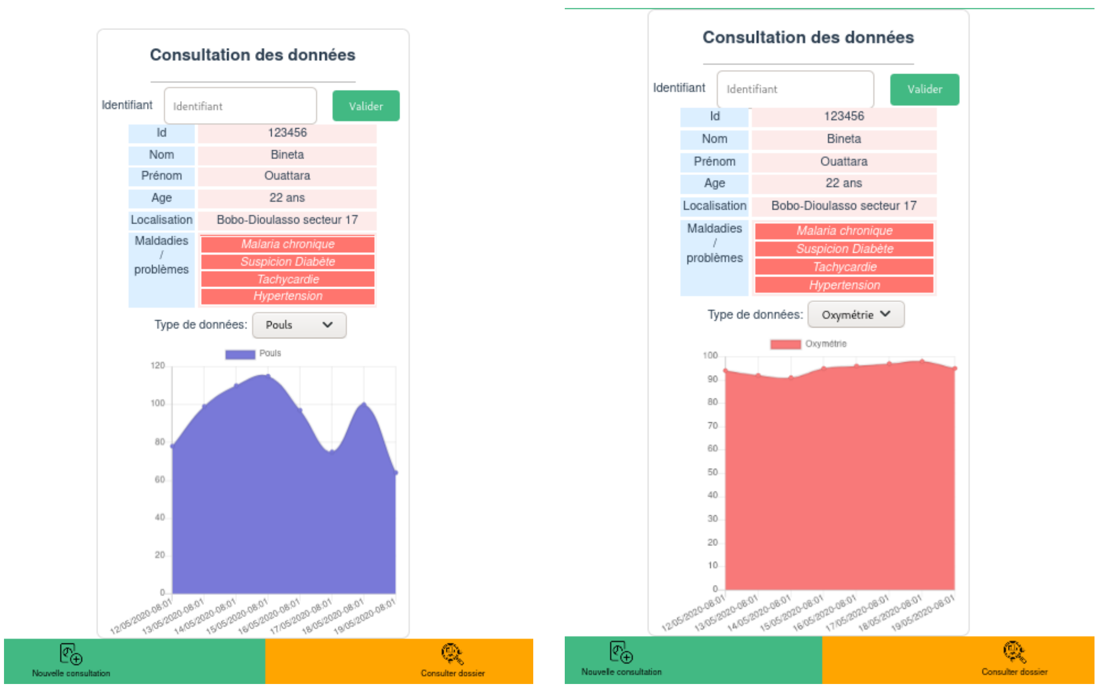

Fig. 14. Pulse and Oximetry

he suffers.

Websockets

Real-time connection is a necessity because we are processing emergency medical data. To implement the real-time connection, we use Websockets technology. The reason for using of WebSockets is to provide a mechanism for web applications that need two-way communication with servers that does not require opening multiple HTTP connections and thus avoid the overhead inherent in the HTTP protocol.

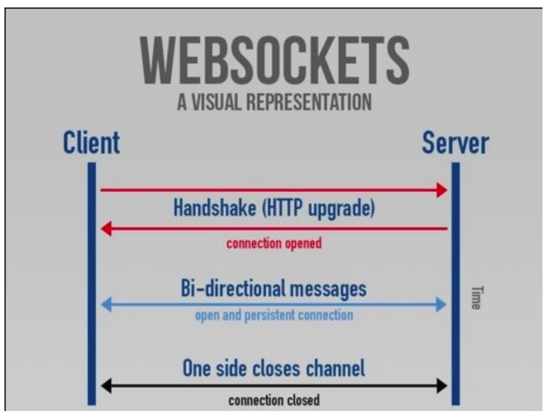

Fig. 15. Websockets

5 Analysis

The validation of our literature consists of a comparative study of similar platforms to highlight the strengths and weaknesses of our platform. The main outcome of this study is summarized in the table below. After analysis, we find that our application has a guaranteed smooth response (15 microseconds) in its local environment. This local environment constitutes a pillar of security and a platform of first choice (according to the survey carried out) because it is not exposed to the Internet. In addition to its reliability, its web application allows visualization of vital constants for nursing staff. This solves a time or the concern of the flexibility of the saturometer.

Table 4: Comparative analysis

	IoT based health monitoring system	IoT-guided healthcare monitoring system to manage real-time notifications by fog IT departments	Internet of medical objects: Design of a medical device for patient monitoring in Burkina Faso
Communication Type	GSM	GSM	Wi-Fi/Bluetooth
Application web	-	-	Yes
Graphical interface of the oxymeter pulse	More flexible	More flexible	Less flexible
Server	remote	remote	local

Fig. 16. Analysis

6 Conclusion and Perspective

Conclusion

Our project was carried out as part of the search for a suitable and economical solution to meet certain needs of Burkina Faso medical centers based on connected object technology. The proposed IoMT-based health system tries to offer the most efficient health service in Burkina Faso and nursing staff additional comfort that helps its daily decision-making in a context of lack of resources (human and material). In this paper, we proposed methods and tools to create a patient monitoring platform in Burkina Faso. We started by conducting a survey within health facilities to assess the level of integration of IoT in health services. Then we broke the project into several sections including a section devoted to developing the mobile application named "Keneya app" and the other section to the designs and development of the pulse oxymeter. The results of this development are presented in the last section with the creation of graphical interfaces as well as the processing of the data collected into information usable by the nursing staff.

Perspective

As we can see, our project for the future aims for an autonomous system accessible to all, whose patient monitoring will be done completely through our platform. Despite the accomplishments we have been successful in achieving, we believe that there is still a long way to go to develop a better performance pulse oxymeter to improve sensor sensitivity (especially in children). Which leads us to explore new avenues of work: First, integrate the "Keneya app" and the automatic reading of vital constants. Then, implement the saturometer in miniature, starting from our electronic diagram. Finally, integrate the different parts of the project, move on to full-scale tests with more patients and health centers.

Acknowledgements

Acknowledgments. Many Thanks to Yeltech (a company based in Burkina Faso headquartered in Ouagadougou. Evolving in the field of connected technologies) for having proposed the subject and for having contributed to the design and implementation of the IoT-based health monitoring system in Burkina Faso.

References

[1] V. Tamilselvi, S. Sribalaji, P. Vigneshwaran, P. Vinu and J. GeethaRamani, "IoT Based Health Monitoring System," 2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS), 2020, pp. 386-389, doi: 10.1109/ICACCS48705.2020.9074192.

[2] A. Acharya and S. Patil, "IoT based Health Care Monitoring Kit," mar. 2020, p. 363-368. doi : 10.1109/ICCMC48092.2020.ICCMC-00068.

[3] M. Gregoski, M. Mueller, A. Vertegel, A. Shaporev, B. Jackson, R. Frenzel, S. Sprehn et F. Treiber, "Development and Validation of a Smartphone Heart Rate Acquisition Application for Health Promotion and Wellness Telehealth Applications," International journal of telemedicine and applications, t. 2012, p. 696 324, jan. 2012. doi : 10.1155/2012/696324.

[4] J. Oresko, Z. Jin, J. Cheng, S. Huang, Y. Sun, H. Duschl et A. Cheng, "A Wearable Smartphone-Based Platform for Real-Time Cardiovascular Disease Detection Via Electrocardiogram Processing," Information Technology in Biomedicine, IEEE Transactions on, t. 14, p. 734-740, juin 2010. doi : 10.1109/TITB.2010.2047865.

[5] S. Trivedi and A. N. Cheeran, "Android based health parameter monitoring," 2017 International Conference on Intelligent Computing and Control Systems (ICICCS), 2017, pp. 1145-1149, doi: 10.1109/ICCONS.2017.8250646.

[6] S. Kumar, V. Samson, U. Sai, P. Rao et K. Eswar, "Smart health monitoring system of patient through IoT," feb. 2017, p. 551-556. doi : 10.1109/I-SMAC.2017.8058240.

[7] M. R. Desai and S. Toravi, "A Smart Sensor Interface for Smart Homes and Heart Beat Monitoring using WSN in IoT Environment," 2017 International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC), 2017, pp. 74-77, doi: 10.1109/CTCEEC.2017.8455124..

[8] S, Cheeran AN, "Android based health parameter monitoring," 2017 International conference on intelligent computing and control systems (ICICCS). IEEE, p. 1145–9, 2017.

[9] SP, Samson VRR, Sai UB, Rao PLSDM, Eswar KK. , "Smart health monitoring system of patient through IoT," International conference on I-SMAC (IoT in social, mobile, analytics and cloud) (I-SMAC). IEEE, p. 551–6, 2017.

[10] https://web.facebook.com/HealthStatus.bf/

[11] https://www.sante.gov.bf/accueil