INTERNET OF THINGS FOR SMART HEALTHCARE: A REVIEW ON A POTENTIAL IOT BASED SYSTEM AND TECHNOLOGIES TO CONTROL COVID-19 PANDEMIC

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ABSTRACT:

Healthcare is an important part of life. Sadly, the spread of Covid-19 has strained the majority of health systems and the demand for resources from hospital kits to doctors and nurses have become extremely high. However, the significant advancement in the computing sector have led to the emergence of Internet of Things (IoT) which has now become one of the most powerful information and communication technologies due to its capability to connects object such as medical kits, monitoring cameras, home appliances and so on… Capitalizing on the efficiency of data retrieval from smart objects in the health sector, it is clear that a solution is necessary and required to improve the health sector in the era of Covid-19 pandemic while continuing to provide a high-quality care to patients. In this paper, a real-time covid-19 monitoring system is introduced in a form of an IoT based bracelet that measures body temperature and blood oxygen level, which are essential factors for determining the patient's condition and whether he needs a quick intervention to enter ICU room. The bracelet also has a GPS tracker to determine the patient's commitment to quarantine and social distancing. Based on the study conducted with more than 50 medical stuff, the IoT based bracelet was identified as a promising tool that can help control the spread of the covid-19 virus, by providing a modern access to medical healthcare services anywhere and anytime which is useful for the patient and hospital management stuff.

1. INTRODUCTION

The Internet of Things (IoT) has been globally known as one of the most potential solutions to enhance and boost healthcare systems to a new level. It can be defined as a huge network, in which physical objects/devices are interconnected and can be controlled or monitored remotely. These objects are connected to the Internet and can interact with each other without human intervention. Therefore, they are considered intelligent objects.

There are different types of IoT devices (portable devices, smart thermostats, IP cameras, robots, health monitoring devices …), and the majority of them have sensors which can automatically detect event and transmit these data to servers. A large amount of this data is collected from different devices, then transmitted using network protocols to servers (cloud) for analysis purposes, and finally the results are shared with other devices in order to improve the user experience.

Several studies have shown novel designs for smart healthcare solutions using IoT based systems. An in-depth study is presented in (Islam, Kwak, Kabir, Hossain, and Kwak, 2015), focusing on some of the available solutions, well known applications and remaining problems. Each subject is considered separately, rather than as a part of an overall system. In (Dimitrov, 2016), the exploration, storage and analysis of data are considered, with little mention of their integration into a system. The types of sensors are compared in (Poon, Lo, Yuce, Alomainy, and Hao, 2015), with a certain emphasis on communications. Finally, in (YIN, Zeng, Chen, and Fan, 2016), the detection and management of big data is considered, with little consideration for the network which will take charge of the communications.
This article therefore provides a survey of IoT based systems in the health sector and showcase one of the most relevant solutions to the pandemic we're currently facing (COVID-19) that can help the overcrowded hospital to reduce the strain on resources while controlling the spread of this virus.

This paper is structured as follow: At first, we present in section 2 the general three-layer architecture of IoT. Then in section 3, we highlight the important role of smart healthcare based IoT systems focusing on some of the IoT devices that are used in the healthcare field. Afterwards, we present in section 4 an overview of the new global virus (Covid-19). Finally, we project a digital solution in a shape of a bracelet that helps authorities prevent further spread of COVID-19, while also tracking those that are unfortunately infected

2. THE THREE-LAYER ARCHITECTURE OF IOT

If Internet is connecting the people, the Internet of Things (IoT) is connecting all the objects. These interconnected objects (controlled by the people) have data regularly collected, analysed and used to initiate action, providing a wealth of intelligence for planning, management and decision making.
The Internet of Things (IoT) also called the Internet of Everything or the Industrial Internet is a new concept in the technology and communication world which provides the capability of transferring data for anything (human, animal, or

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object) via a network connection. In another way, we can define it into three categories as below: Internet of things is an internet of four things: (1)- People to people, (2)- Machine or Things to people, (3)-People to machine or things, (4) Things or machine to things or machine Interacting through internet.

The main goal of IoT is to enable things to be connected anytime, anyplace, with anything and anyone ideally using a mixture of different hardware & software t that are used to transfer; store and process data and communications technology. There isn't a standard architecture for Internet of Things yet, but many researchers commonly present this architecture as three basic layers: Perception/Physical layer, Network layer and Application layer as shown in Figure 1.

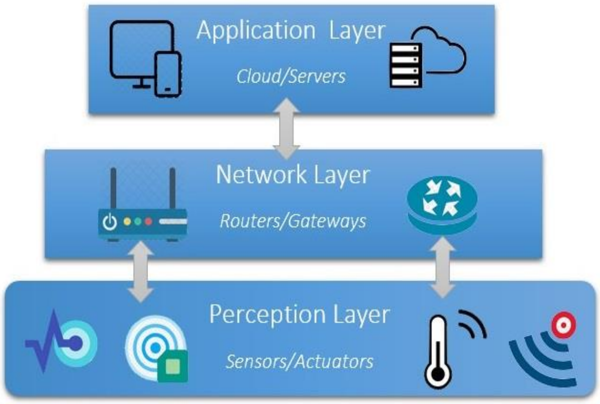

Figure 1 : IoT three-layer architecture

Perception layer: It includes the hardware used in the IoT ecosystem (sensors and actuators). In this layer we can find several technologies such as Wireless sensor network (WSN), Radio-frequency identification (RFID) and Near-field communication (NFC). The major requirements for this layer are the support of the heterogeneity of IoT devices and the energy efficiency, thus sensors should be operational for gathering and transmitting data in real-time (Li, Da, Zhao, 2018).

Network layer: The second layer is responsible to ensure the communication of IoT devices with each other, in the case of Wireless sensor networks (WSNs) for example, or in some other cases, the communication directly with the cloud via a gateway. Data are collected by the perception layer and transmitted for analysis and decision-making purpose by several communication protocols, such as Bluetooth Low Energy (BLE), IEEE 802.15.4 standard and ZigBee in the case of low-power and low-bandwidth needs, also WIFI, 4G and 5G are used in this layer.

Application layer: the third layer is the software part of the IoT architecture. It is responsible of presenting data after being collected and analyzed for a specific IoT application domain (e.g., healthcare, transportation, smart grid etc.). It is considered as the front end of the IoT architecture (Natarajan, Prasath, and Kokila, 2016). Several protocols are deployed in this layer, such as Constrained application protocol (CoAP), Message Queuing Telemetry Transport (MQTT), Hypertext Transfer Protocol (HTTP) etc (Romdhani I, 2011).

3. INTERNET OF THINGS FOR DIGITAL HEALTHCARE

Healthcare plays an important role in our societies, it makes a huge contribution to the economic progress. While the ultimate goal of many countries is to improve the health and well-being of people, there are different disciplines and solutions that contribute to it.
Healthcare systems are primarily focused on treating patient's conditions after a confirmed diagnosis and with the increase of storage capacity, advanced algorithms, smart objects and willingness to integrate IoT based solutions in healthcare, the effect of these solutions on the health system has increased considerably.
In a global context, Internet of Things allows seamless interactions and communications among different types of objects such as monitoring devices, medical sensor, home appliances... and because of that IoT has become more productive in 3 several areas that can be classified into 3 categories of IoT scenarios: Hospitals: IoT medical systems implemented into the medical structure (Distefano, Bruneo, Longo, Merlino, and Puliafito, 2017) (Dhariwal and Mehta, 2017) (Natarajan, Prasath, and Kokila, 2016), Home healthcare: IoT medical systems realized for home health monitoring(Avila, Sanmartin, Jabba, and Jimeno, 2017) (Pang, Zheng, Tian, Kao-Walter, Dubrova, and Chen, 2015) and finally doctor's Offices: smart system that support doctors in their activities (Oliveira, J. C. Sá, C. C. Sá, Monteiro, and Pereira, 2017).

A lot of studies have shown that remote healthcare using IoT based systems is important because of the benefits it could provide in different contexts. For Example, remote health monitoring can keep non-critical patients under systematic review by observing and checking their health at home rather than the hospital, which could help the overcrowded hospital to reduce the strain on resources like beds and medical kits. It could also be used to provide a better access to healthcare for those living in rural areas, or to enable elderly people to enjoy modern medical healthcare services anywhere, any time.

Many IoT healthcare systems have been developed using different technologies like radio frequency identification (RFID), wireless sensor network (WSN), smart mobile technologies and wearable devices.

RFID (Radio Frequency Identification): it's the heart of IoT connected systems. These microchips replace the printed labels allowing precise location of the objects. The association of the cloud and connected objects has made these identification labels one of the most used technologies to develop IoT health care based systems (Nanni et al, 2011).

WSNs (Wireless Sensor Networks) consist of spatially distributed autonomous devices to cooperatively monitor real-world physical or environmental conditions, such as sound, pressure, vibration, motion, temperature and location. The major components of a normal WSN sensor node are a transceiver, microcontroller, memory, power source and one or more sensors to detect the physical phenomena. The structure of the sensor node is generally divided into four major parts: sensing unit, processing unit, communication unit and power unit (Gope and Hwang, 2016).

Mobile health (m-health) consist of using mobile devices in collecting health data in real-time from patients, storing it to network servers connected to Internet. The m-health data help doctors to diagnosed, monitor, treat patients and predict health anomalies using wearable medical devices and body sensor (M.-Z Poh and Y. C. Poh, 2017).

Wearable devices are mostly known for healthcare observation and tracking. These wearable devices use one of the most essential elements in data collection which are the sensor. During recent years with the improvement of semiconductor technology, sensors have made investigation of a full range of parameters closer to reality (Germanese, Magrini, Righi, and Acunto, 2017) (Gottesman et al, 2013).

Each of these technologies is able to collect data about patients, doctors, nurses …, These devices can also send alarms in case of an emergency, tutoring patients during therapy, and managing information about medical services but the question is how can IoT help us get through the unprecedented measures that have been put in place in response to the global COVID-19 pandemic.

4. COVID-19 PANDEMIC

The novel coronavirus (COVID-19) was first emerged in China's Hubei in December 2019, since then the virus has spread rapidly around the world, affecting more than 183 countries, infecting over a million and killing more than 80,000 people. In March 2020, the World Health Organization (WHO) declared the outbreak of the coronavirus a pandemic as "global spread of a new disease" which was the first step towards a global health emergency (https://covid19.who.int).

This is not the first time an international health crisis occurred due to the spread of a novel coronavirus or other zoonotic (animal-originated) viruses, such as influenza that created the swine, bird and seasonal flu epidemics in recent history. Seasonal flu alone is estimated to result in three to five million cases of severe illness, and 290,000 to 650,000 respiratory deaths annually. Figure 2 represent different information and data collected on 3 known species of human coronaviruses.

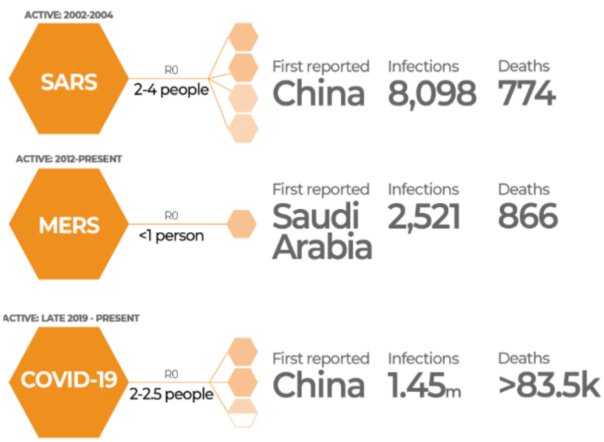

Figure 2 : Coronavirus outbreak

SARS (Severe acute respiratory syndrome) was first reported in November 2002 in the Guangdong province of southern China. The viral respiratory illness spread to 29 countries across multiple continents before it was contained in July the following year. Between its emergence and May 2014, when the last case was reported, 8,098 people were infected and 774 of them died. Various studies and the WHO suggest that the coronavirus that caused SARS originated from bats, and it was transmitted to humans through an intermediate animal - civet cats. The R0 (pronounced R-naught), is a mathematical term to measure how contagious and reproductive an infectious disease is as it displays the average number of people that will be infected from a contagious person. The R0 of SARS is estimated to range between 2 and 4, averaging at 3, meaning it is highly contagious.

MERS (Middle East Respiratory Syndrome) is a still active viral respiratory disease first identified in Saudi Arabia in 2012. Approximately 80 percent of human cases were reported by the kingdom, but it has been reported in 27 countries. However, human cases of MERS infections have been predominantly caused by human-to-human transmissions. MERS might show no symptoms, mild respiratory symptoms or severe acute respiratory disease and death. Fever, shortness of breath and cough are common symptoms. If it gets severe, it might cause respiratory failure that requires. R0 of MERS is lower than one, identifying it as it is a mildly contagious disease.

COVID-19: On 31 December 2019, a pneumonia outbreak was reported in Wuhan China, the outbreak was traced to a novel strain of coronavirus. As of April 7, 2020, the number of global COVID-19 cases was more than 1,290,000 with over 76,000 deaths. According to the WHO, approximately one out of every six infected people becomes seriously ill and develops difficulty in breathing. The WHO puts the R0 of COVID-19 at 2 to 2.5 (https://www.aljazeera.com).

In Morocco, The Ministry of Health has confirmed the spread of Covid-19 on 2nd March 2020 (Figure 3), when they detected the first case from an Italian who arrived to Morocco on February 27th. Since then The number of confirmed cases has gradually increased which made the country to implement social distancing measures and closure of land, air and sea borders. As of 26 May 2020, there have been 7577 confirmed cases, of which 4881 have recovered and 202 have died (http://www.covidmaroc.ma).

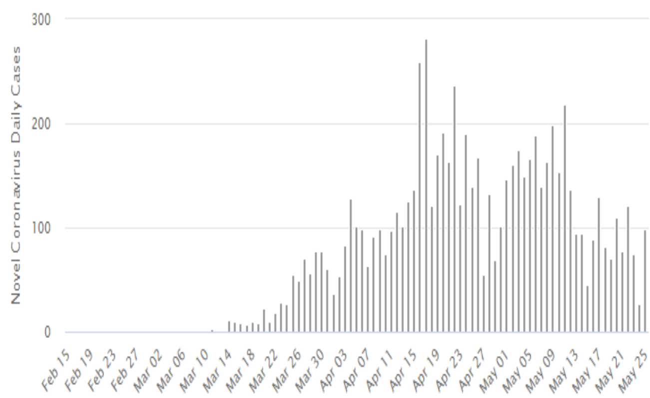

Figure 3 : Morocco daily new cases (From Feb 15 to May 25 – 2020)

The majority of people who are infected by coronavirus show common symptoms like fever, dry cough and tiredness. Others also have runny nose, sore throat, nasal congestion, or diarrhea (Figure 4). However, high body temperature and dry cough are the very common symptoms (http://www.covidmaroc.ma).

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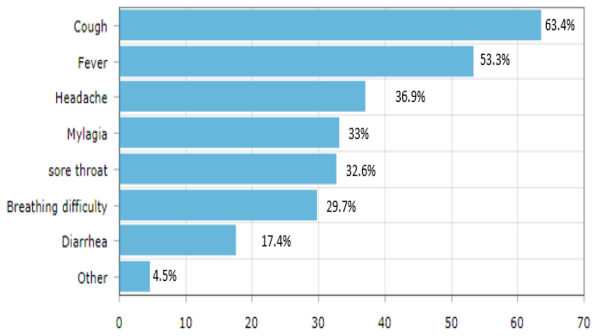

Figure 4 : Covid-19 symptoms

As the number of infected people keeps increasing and since there is no specific treatment for the virus till now, the only suitable way to prevent the spreading is the early detection of the symptoms, which can be extremely hard for the countries who don't have enough medical resources to perform thousands of diagnostic test per day to minimize the spread impact.

Numerus researches have shown that covid-19 can go through 3 levels of risks (Figure 5):

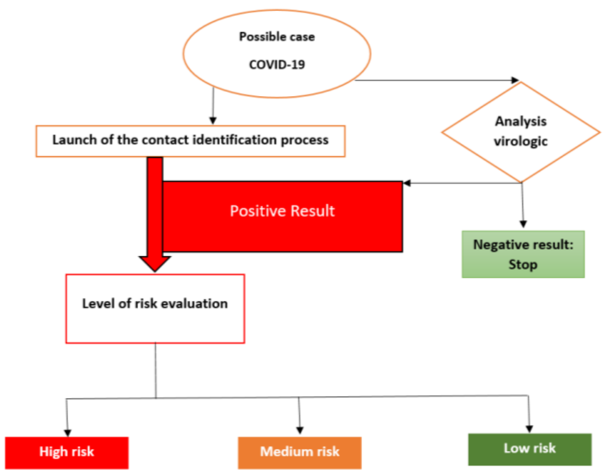

Figure 5 : Covid-19 three levels of risk

A **high level** of risk where the patient should stay under medical observation in the hospital.

A **medium level** of risk where the patients are responsible for protecting themselves at home by social distancing from others, they are required to sign an auto certification stating that they wouldn't visit public places unless for medical purposes.

A **low level** of risk which concerns the people who are of no danger to others, they can move freely yet they have to respect the basic precautions, unless they start showing the symptoms of infection.

The world is now struggling to control the spread of the virus which includes a record number of morbidities and mortalities that's why there is an urgent need for digital monitoring solution to prevent citizens from infection and to save those who are already infected.

For this reason, a group of countries worked to develop mobile applications that work to limit the spread of the virus. In the following table you will find applications for some Arab countries:

Country	Application	Technologies used	Usage
Tunisia	E7mi	Bluetooth & GPS	Voluntary
Qatar	EHTERAZ	Bluetooth & GPS	Mandatory
Bahrain	BeAware	Bluetooth & GPS	Mandatory for people in quarantine and foreigners
Saudi Arabia	Tatamman	Bluetooth & GPS	Mandatory for people in quarantine and foreigners
Morocco	Wiqaytna	Bluetooth & GPS	Voluntary

Table 1 : Covid-19 Tracking applications

These applications have been subjected to fierce criticism by researchers in terms of protecting personal information, and they emphasized that countries exploit this circumstance in order to collect information from users, while the responsible authorities defended it and emphasized its safety.

5. DISCUSSION

Morocco is one of the developing countries in the health sector, mentioning the fact that one bed is provided for approximately 1000 citizens in addition to a doctor for every 2000 citizens, what brings us to think about some more practical solutions to reduce the pressure on hospitals, especially in the current situation of this global pandemic of Corona virus.

In the previous section, we have provided a global research on the covid-19 virus and the types of infected patients. In this section, we will focus on patients with medium and low level of risk (asymptomatic patients) whose situation has improved, but they require periodic monitoring once every four hours for fear of the onset of symptoms requiring artificial respiration and intensive care unit.

For this, we will propose a bracelet that include a body temperature sensor, pulse oximetry sensor for continuous recording of the patient's condition and a GPS for tracking of the infected patient location. The collected data will be sent via a wireless connection to the patient smartphone and the server system. A software application will be developed using decision support technologies that predicts the emergence of disorders, which could help reduce the stress on doctor, reduce the number of patients kept inside hospitals and the strain on resources like beds and medical kits.

5.1 System Design:

The System architecture shown in Figure 6 describes the conceptual model that defines the general structure, behaviour and components that will work together to implement the overall system.

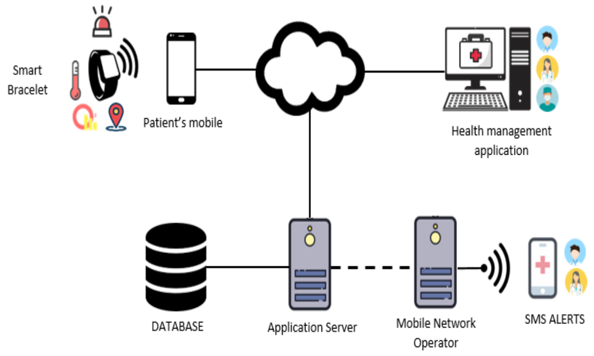

Figure 6 : System architecture

The main device of the system is the smart bracelet which contains a temperature body sensor that reads body temperature, an oximetry sensor for measuring blood oxygen level and finally a GPS to locate the patient and to inform whether he is committed to quarantine in the same authorized place. After consulting with doctors, it is not necessary to measure the blood oxygen level permanently, but the patient can be alerted by placing the pulse oximetry sensor on his fingernail every 6 hours for more accurate information, that's why the bracelet will contain an alarm that can only be stopped by receiving the necessary information from the sensor.

This electronic unit will be placed on the patient's wrist and will send signal and data wirelessly to the server through his mobile phone.
Furthermore, the server will store data on the database and visualize patients' status in real time through the doctor's platform. In case of low oxygen level in the blood or high temperature, an alert will be sent to the medical staff for quick intervention.

5.2 Recommended Component for Implementation

The essential element of our system is the smart bracelet which can be developed using these components:

Pulse Oximetry Sensor: it's a small, clip-like sensor that measure and monitor Blood oxygen level using small beams of light that pass through the blood. This sensor serves as an indicator of respiratory malfunction and can help in Covid-19 diagnostics and monitoring (Ženko, Kos and Kramberger, 2016).

Body Temperature Sensor: body temperature sensor is a useful diagnostics tool that can detect if the patient's situation is abnormal. Many IoT applications use thermistor-type sensors for the measurement of body temperature. In (Aqueveque, Gutiérrez, Rodríguez, Pino, Morales and Wiechmann, 2017) and (Narczyk, Siwiec and Pleskacz, 2016), the common negative-temperature-coefficient (NTC) type temperature sensors were used, NTC thermistors are a common type of temperature sensor to measure surface temperature. The sensor consists of a two wire connection which uses ceramic/metal composites properties resistance to measure temperature. Common uses for this type of sensor include skin probes, adult rectal and paediatric rectal.

Arduino UNO: Arduino is an open-source electronics platform which enable the creation of interactive objects. Arduino boards are able to read inputs from different sensors and redirect the output to the mentioned output pins. In the smart bracelet, Arduino UNO reads data from body temperature and pulse Oximetry sensors and transmit the output data wirelessly to the server. If the temperature read from the sensor by Arduino is greater than 37°C and blood oxygen level is lower than 94%, then Arduino forwards an alert to the server.

LEDS: Two LEDS red and green are used to indicate normal and abnormal situation. When the medical situation is normal then the green LED is blinking and when the situation is abnormal red LED is blinking. In our solution we can attached the LEDs to the bracelet to help inform the patient if situation goes abnormal.

Wires: Wires play an important role as connectors, they are used to connect all the above components together. In health monitoring system, wireless network is used to forward measurement through a gateway towards cloud (Navya, Murthy, 2013).

GPS Tracking Sensor: A GPS tracking sensor is a unit that receives information from GPS satellites and obtains the geographical position, latitude and longitude coordinate of the bracelet in a NMEA format using Arduino.

5.3 Methodology

In order to give more importance to the research, we have simulated a smart bracelet that monitor medium and low risked covid-19 patients and follow their health status using IoT technologies. Since the percentage of active cases of the virus in Morocco in this category exceeds 90%, the Covid-19 bracelet will be an effective mean of helping medical staff to manage and control the spread of the virus.

For this simulation, we have connected a body temperature sensor and an oximetry sensor with NodeMcu (a development board and an open source firmware based on the Wi-Fi module ESP8266 -12E). then we used Arduino IDE for development and real time data analysis.

For the simulation we have followed the following process:
Real time data storage: The real time data will be recorded and stored in the ThingSpeak cloud (an IoT analysis platform service which allows aggregation, visualization and analysis of live data streams in the cloud).

Data visualization (by doctors) using a web platform: For this part, the medical staff will be able to monitor the status of patients at the ThingSpeak platform, which allows the different data collected to be viewed in the form of figures or graphs.
Patients Geolocation: the GPS tracking sensor will receive information from GPS satellites and obtains the geographical position, latitude and longitude coordinate of the bracelet. The objective of this is to locate the patients and to allow other applications to interact with our database and obtain the position of covid-19 patients which will help to detect if there is an increase in cases in an area, inform them to wear their masks and to adopt preventive gestures.

Monitoring the patient's condition on a smartphone: At the smartphone level, the user will get access to all the data such as body temperature, oxygen saturation and the geolocation of the patient.

Alerts: If the patient's situation has worsened, the medical staff will receive a notification on a smartphone alerting them to transfer the patient to the resuscitation cell, for this situation we have defined two conditions either the temperature is above 37 degrees Celsius or the oxygen saturation is lower than 95%.

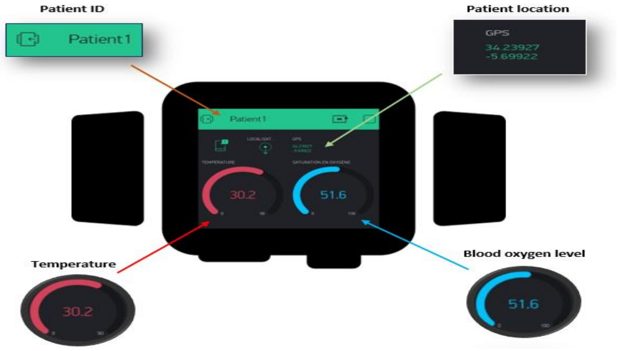

Figure 7 : Covid-19 smart bracelet

The Covid-19 smart bracelet (Figure 7) can detect body temperature, measure oxygen blood level and track the patient's location using some modern IoT technologies, then send the collected data to be viewed on other health management applications.

5.4 Discussion and Results

After introducing the solution to some of the medical staff (46 specialist doctors, 1 general practitioner and 8 nurses), we carried out a questionnaire that contains 13 different questions in order to evaluate the solution and obtain suggestions for improvement. Most of the participants work in different Moroccan hospital in different cities like Tangier, Rabat, Errachidia, Chefchaouen, Marrakech ... while the others work in UK and France.

The majority of participants recognized the interest of such a solution and its advantages that will help improve the healthcare sector by providing a modern access to medical healthcare services anywhere and anytime. The bracelet can monitor non-critical patients under systematic review by observing and checking their health at home rather than the hospital, which could help the overcrowded hospital to reduce the strain on resources like beds and medical kits, also reduce the over workload for nursing staff.

They also congratulated the choice of the target population which is the medium & low risk level patients considering that the percentage of active cases of the virus in Morocco in this category is the highest (by the Moroccan Ministry of Health). 51% of the participants said that the symptoms observed are sufficient to determine the patient's condition, while the rest asked to add other elements to analyse such as heart and respiratory rate commissures in order to better identify the seriousness of the patient's condition.

On the other hand, some participants pointed out a negative aspect of this system, which restricts the personal lives of patients by using GPS to track their movements, which is better than confining them to places required by the state. They also called on the reliability and availability of the system to eliminate the risk of not receiving updated data in the event of a technical problem.

Towards the end, 91% of the participants confirmed their desire to use the smart bracelet which they thought it was an innovative solution that can help them save time and improve the quality of care for the non-covid19 patients.

6. CONCLUSION AND PRESPECTIVES

In this paper, we have presented a project proposal in forms of an innovative real-time monitoring system using smart bracelet for Covid-19 patients whose condition has improved to the fact that they need periodic monitoring by doctors while adhering to quarantine procedures until full recovery.

The smart bracelet can detect high body's temperature, measure blood oxygen level and track the patient location using some of the best known IoT technologies, then send the collected data to be displayed on health management applications.

The proposed system is simple, energy efficient and easy to understand. It works as a link between the infected patient and the doctor to preserve the integrity of the medical procedures while providing the medical resources and kits to those who are in critical condition.

As the latest big issue nowadays is happening across the world, the presented architecture is a very promising solutions to help control the spread of the virus which motivated us as student-researchers and future computer scientists to develop more smart solutions in order to serve the medical field and to help preserve the human life.

REFERENCES

C. C. Y. Poon, B. P. L. Lo, M. R. Yuce, A. Alomainy, and Y. Hao, "*Body Sensor Networks: In the Era of Big Data and Beyond*," IEEE Reviews in Biomedical Engineering, vol. 8, pp. 4–16, 2015.

D. V. Dimitrov, "*Medical Internet of Things and Big Data in Healthcare*," Healthcare Informatics Research, vol. 22, no. 3, pp. 156–163, 7 2016.

D. Germanese, M. Magrini, M. Righi, and M. D. Acunto, "*Selfmonitoring the Breath for the Prevention of Cardio-metabolic Risk*,"no. c, pp. 96–101, 2017.

J. Oliveira e Sá, J. C. Sá, C. C. Sá, M. Monteiro, and J. L. Pereira, "*Baby steps in E-health: Internet of things in a doctor's office*," in Advances in Intelligent Systems and Computing, 2017, vol. 569, pp.909–916.

J. Ženko, M. Kos and I. Kramberger, "*Pulse rate variability and blood oxidation content identification using miniature wearable wrist device*", Proc. Int. Conf. Syst. Signals Image Process. (IWSSIP), pp. 1-4, May 2016.

https://covid19.who.int/. Accessed 26 May 2020.

http://www.covidmaroc.ma/.Accessed 26 May 2020.

https://www.aljazeera.com/news. Accessed 26 May 2020.

K. Avila, P. Sanmartin, D. Jabba, and M. Jimeno, "*Applications Based on Service-Oriented Architecture (SOA) in the Field of Home Healthcare*," Sensors, vol. 17, no. 8, p. 1703, 2017.

K. Dhariwal and A. Mehta, "*Architecture and Plan of Smart hospital based on Internet of Things (IOT),*" Int. Res. J. Eng. Technol., pp.1976–1980, 2017.

K. Natarajan, B. Prasath, and P. Kokila, "*Smart Health Care System Using Internet of Things*," J. Netw. Commun. Emerg. Technol., vol. 6, no. 3, pp. 37–42, 2016.

K. Navya, Dr. M. B. R. Murthy, "*A Zigbee Based Patient Health Monitoring System*", Int. Journal of Engineering Research and Applications Vol. 3, Issue 5, Sep -Oct 2013, pp.483-48.

Li S, Xu L Da, Zhao S (2018) 5G Internet of Things: A survey. J Ind Inf Integr 10:1–9 . doi: 10.1016/j.jii.2018.01.005

M.-Z. Poh and Y. C. Poh, "*Validation of a Standalone Smartphone Application for Measuring Heart Rate Using Imaging Photoplethysmography*," Telemed. e-Health, p. tmj.2016.0230, 2017.

O. Gottesman et al., "*The Electronic Medical Records and Genomics (eMERGE) Network: past, present, and future*," Genet. Med., vol. 15, no. 10, 2013.

P. Aqueveque, C. Gutiérrez, F. S. Rodríguez, E. J. Pino, A. Morales and E. P. Wiechmann, "*Monitoring physiological variables of mining workers at high altitude*", IEEE Trans. Ind. Appl., vol. 53, no. 3, pp. 2628-2634, May/Jun. 2017.

P. Gope and T. Hwang, "*BSN-Care: A Secure IoT-Based Modern Healthcare System Using Body Sensor Network*," IEEE Sens. J., vol. 16, no. 5, pp. 1368–1376, Mar. 2016.

P. Narczyk, K. Siwiec and W. A. Pleskacz, "*Precision human body temperature measurement based on thermistor sensor*", Proc. IEEE 19th Int. Symp. Design Diagnostics Electron. Circuits Syst. (DDECS), pp. 1-5, Apr. 2016.

Romdhani I (2011) Architecting the Internet of Things. Archit Internet Things. doi: 10.1007/978-3-642-19157-2.

S. Distefano, D. Bruneo, F. Longo, G. Merlino, and A. Puliafito,"*Hospitalized Patient Monitoring and Early Treatment Using IoT andCloud,*" Bionanoscience, vol. 7, no. 2, pp. 382–385, Jun. 2017.

S. M. R. Islam, D. Kwak, H. Kabir, M. Hossain, and K.-S. Kwak, "*The Internet of Things for Health Care : A Comprehensive Survey*," IEEE Access, vol. 3, pp. 678 – 708, 2015.

U. Nanni et al., "*RFID as a new ICT tool to monitor specimen life cycle and quality control in a biobank*," Int. J. Biol. Markers, vol. 26, no. 2, pp. 129–135, 2011.

Y. YIN, Y. Zeng, X. Chen, and Y. Fan, "*The internet of things in healthcare: An overview*," Journal of Industrial Information Integration, vol. 1, pp. 3–13, 3 2016.

Z. Pang, L. Zheng, J. Tian, S. Kao-Walter, E. Dubrova, and Q. Chen, "*Design of a terminal solution for integration of in-home health care devices and services towards the Internet-of-Things*," Enterp. Inf. Syst., vol. 9, no. 1, pp. 86–116, Jan. 2015.