International Journal of Electrical and Computer Engineering (IJECE)
Vol. 16, No. 3, June 2026, pp. 1261~1271
ISSN: 2088-8708, DOI: 10.11591/ijece.v16i3.pp1261-1271

An internet of things-telemedicine platform empowered by 5G mobile networks for Tunisian Rural places

Ibrahim Monia, Dadi Mohamed Bechir, Rhaimi Belgacem Chibani
Laboratory Modeling, Analysis and Control of Systems (LR-MACS), National Engineering School of Gabes (ENIG), Gabes, Tunisia

Article Info

Article history:

Received Aug 25, 2025
Revised Mar 30, 2026
Accepted Apr 26, 2026

Keywords:

5G
Internet of Things
Platform
Rural areas
Services
Telemedicine

ABSTRACT

With the advent of Internet of Things (IoT) technologies, offering new possibilities for remote healthcare delivery, the medicine sector has undergone significant advancements in recent years. New tools are used, and diagnostics have become more accurate. We suggest creating a platform that can be extended for several applications. This platform has been realized to attest and demonstrate how IoT technology offers devices that could be integrated to provide novel services like remote consultations. Our proposed platform contains novel functionalities such as real-time video calls, instantaneous messaging, live notifications, vital signs monitoring, and electronic health record access. This is accomplished with enhanced qualities of remote healthcare services. Added to this, healthcare access equity will be guaranteed. The paper emphasizes the potential of Laravel 11 as a framework offering powerful features for creating modern and high-performance applications. We have integrated Laravel Reverb, a powerful real-time communication package, to provide seamless real-time communication with users. With our application, notifications and interactions are dynamically created. This allows instant updates to delivery and engages the user experience. The database was designed based on the latest version of MySQL 8, coupled with the advanced capabilities of PHP 8.2. This combination provides unparalleled performance, scalability and reliability. Added to that, IoT's technology usage helps to improve healthcare access and delivery, especially in underserved areas. Human and machine cooperation is a main factor of the 5th industry level. This is widely respected by our platform. This offers great help, especially for those isolated and underserved areas, as we hope.

Corresponding Author:

Ibrahim Monia
Laboratory Modeling, Analysis and Control of Systems, National Engineering School of Gabes (ENIG)
ENIG 6029 Gabes, Tunisia
Email: monia-ibrahim@hotmail.com

1. INTRODUCTION

Digital transformation in the healthcare sector involves the integration of digital technologies into healthcare to deliver and support services. The integration of these technologies can significantly improve the quality of care and patient experience, enhance operational efficiency, and better meet the needs of a constantly growing population. In this regard, robotics, artificial intelligence (AI), the Internet of Things (IoT), and big data will be taken to the next level under 5G, which will foster the digital transformation of healthcare, hence the term e-health.

Telemedicine is modern technology; it uses telecommunication to assist a doctor in visiting their patients virtually. It is a means to share resources immediately with any doctor in the world. There are different types of telemedicine software, depending on the application. They can be classed into two categories: synchronous telemedicine software and asynchronous telemedicine software. Synchronous telemedicine software enables real-time services with live interaction between patients and healthcare providers via audio and video. Real-time telehealth services help maintain the patient-provider relationship, enabling providers to interact face-to-face with patients to assess, diagnose, and treat health problems [1]. Asynchronous telemedicine software does not require live interaction between patients and healthcare providers but enables services such as data storage and transfer [1]. Telemedicine can become more efficient by overcoming the critical factors/problems, which are: time and distance.

Cloud computing and IoT technologies are transformative tools that can encourage patient engagement with telemedicine [2]. Cloud computing provides an infrastructure for securely storing and sharing patient data in real time. IoT devices facilitate monitoring and collecting patient data, which improves the effectiveness and quality of medical therapies [3]. Together, these technologies create a robust framework that enables healthcare providers to deliver personalized care and ensure effective communication [2].

In this paper, we will show how this advancement has been really reached in the medical sector and services as a new Tunisian's medical sector trend. In fact, service is not adequately nor continuously offered and guaranteed in rural zones. Potential benefits of digitalization could help to offer and diversify such necessitated and vital services. As a plan of our paper, section 2 presents pregnant women's health status in Tunisia. Overview of the IoT, section 3 will talk about methods: System's architecture, components and the technology background of the implementation, section 4 will be concerned by results and discussion. Our paper will be termed by a conclusion and a references list.

2. BACKGROUND AND RELATED WORK

2.1. Pregnant women's health status in Tunisia

The analysis and diagnosis of the situation of maternal and neonatal mortality in Tunisia show that the reduction remains below the Millennium Development Goal of an annual decline of 4.5%. Despite the generalization of prenatal consultations and delivery assisted by qualified personnel, regional disparities are still notable, with maternal mortality varying from one to two depending on the region. In addition, a relatively high proportion of infant mortality is observed during the perinatal period [4].

The causes of neonatal mortality and morbidity, like those related to maternal mortality, are largely preventable and are essentially related to the quality of care and to dysfunctions linked to the health system in general. According to the Ministry of Health (MOH) epidemiological report, it appears that one of the main factors of maternal deaths is the dysfunction of the health system. This dysfunction is characterized by the following three delays [4]: delay in the decision to use health services, mainly at the time of delivery, delay in referral to an appropriate health service, and delay in receiving care after arriving at health services.

Thus, nearly one hundred women still die each year in Tunisia from complications related to pregnancy or childbirth. Maternal mortality is primarily a problem for women in the most difficult social situations and in the least endowed areas [5], [6]. UNICEF estimates that "For every woman who dies from complications related to childbirth, twenty more suffer injuries and infections that are often ignored and untreated and can lead to severe disabilities, chronic pain, and social and economic exclusion. Most of these risks of complications can be detected and prevented." [7].

The problem of neonatal mortality thus requires the development of strategies for the identification and management of complications of pregnancy and childbirth, including spontaneous prematurity, maternal hypertensive disorders, and birth asphyxia. Today, we know that the shortcomings of safe motherhood initiatives in many countries are not due to a lack of knowledge or technology. They are generally due to the lack of a clear, concise, and feasible strategy [8].

Maternal and child health, in particular the reduction of maternal and neonatal mortality, still represents a major challenge for our country. The national strategy for maternal and newborn health 2020-2024 [9] is focused on some strategic areas for the period of 2020 to 2024 are: Improving access (geographic, financial, psychological) along the continuum of Maternal Newborn and Child Health (MNCH) services and care; Strengthening the quality of MNCH services; Strengthening governance, national leadership and accountability of the different actors in the system; Integrating the social determinants of health for MNCH services and multisectoral collaboration; Development of community participation and social mobilization to build individual, family and community capacity to improve MNCH; Improved monitoring/evaluation data on the implementation of the MNCH strategy 2019-23 for decision making and accountability.

2.2. 5G mobile networks in Tunisia

The population of Tunisia is 11,972,169 in 2024 [10] and three public 2G/3G/4G mobile telecommunications network operators are present on the market: "Tunisie Télécom," "Ooredoo," and

"Orange." In December 2024, Tunisia officially entered the 5G era with the allocation of licenses to the three public telecommunications network operators [11]. 5G promises to unlock new opportunities for both businesses and consumers.

2.3. Overview of the IoT

The term "Internet of Things" was first introduced by Kevin Ashton in 1998-1999 [12]. It is a recent technology that enables machines and devices to communicate and exchange data with each other via the internet [13] with capabilities of collecting and sharing various types of information at any location, time, media, and environments [14], [15].

It can also be defined as an interconnection between people, animal or objects that has the ability to exchange data over a network without involving human-to-human or human-to-computer interaction [16]. The IoT is recognized as one of the most important areas of future technologies in fields related to smart cities, military, education, hospitals, agriculture [17]. In the last few years, we have observed a growing interest in IoT applications [17]. The IoT is enabled by the latest developments in radio frequency identification (RFID), smart sensors, communication technologies, and Internet protocols [18].

2.4. Applications of IoT in telemedicine

The IoT was initiated in 1959, but the significant development in this field was in the last 8–10 years. It is the interconnection of physical objects, machines, people and other devices that enables connectivity and communications to exchange data for intelligent applications [19]. It enables objects to be monitored remotely via existing network infrastructure, creating the potential for integration between the physical and digital worlds [20].

It is also implemented in medical devices. IoT devices, such as wearable sensors, remote monitoring devices, and smart medical equipment, enable real-time data collection and transmission, allowing healthcare providers to monitor patients remotely and make informed decisions. IoT-enabled telemedicine platforms can also improve the overall patient experience by providing more personalized and convenient healthcare services. We can cite examples of health-care applications:

a. Sensing of Glucose: monitoring blood glucose levels involves detecting variations in glucose levels and enables physical activity and the timing of medication to be adapted in addition to diet. An m-IoT design for this purpose is presented by Istepanian *et al.* [21]. The technique examined involves connecting sensors (associated with patients) via the IPv6 network to healthcare providers.
b. Body temperature supervising: As body temperature is an important sign of the body's stability [22], monitoring body temperature is a crucial element of intelligent healthcare. One use of m-IoT [22] is the use of a sensor that monitors body temperature, implanted in the TelosB.
c. Electrocardiogram (ECG) Supervision: The ECG is the inspection of the recording of electrical activity related to the human heart, which incorporates an approximation of the direct pulse and the determination of vital rhythm, as well as the finding of complex arrhythmia, delayed QT intervals and myocardial ischemia [23].
d. Blood pressure monitoring: Blood pressure monitoring involves detecting the pulse and pressure signal using sensors, such as electronic pressure and pulse sensors, and providing the result in digital form. In [24], a system for collecting blood pressure statistics and sending them over an IoT-based network was presented.

2.5. Overview of Tunisia's health sector

The Tunisian authorities are preparing several national strategic plans, the latest of which is the National Plan Digital Tunisia 2020 with a budget of 5.5 billion dinars for the period 2014-2020. The strategy aims to make Tunisia an international digital hub and to promote ICT as a key vector for the country's socio-economic development. However, in 2020, only 25 of the strategic objectives were not achieved at the project idea stage [19].

Tunisia has now displayed the plan of "Digital Tunisia 2025" which intend to decrease the digital divide, promote the digitization of education, the transition to e-government, to support entrepreneurship and innovation and the implementation of the national strategy of cybersecurity [25]. The migration of medical specialists plays an important role in the current situation of the health sector in Tunisia. A program called Expresso on Radio Express FM on March 5, 2024 [26] touched on doctors' migration to Tunisia, with the presence of the general secretary of the Tunisian Doctors' Deanship, who spoke about the reasons for doctors' migration and the problems involved. He said that medical interns who are not entitled to certain specialties (they are not among the first), the state has given them the right to obtain a specialty on condition that they practice in interior areas. After training in the specialty, they did not respect the condition and did not practice. Among 200 specialists, only between 40 and 45 were working in interior areas. The general secretary of the Tunisian Doctors' Deanship explained that the number of immigrants could mean that there would be no specialists in Tunisia in the future (5.20).

2.6. Existing telemedicine platforms in Tunisia

In Tunisia, there are several examples of telemedicine platforms facilitating interaction between doctors and patients. We can cite telemedicine.tn [27], Tobba.tn [28], DocNet.tn [29], Med.tn [30], Wic-doctor [31]. They offer services that differ from one to the next. Some platforms offer synchronous services, others offer non-synchronous services, and some offer both. The challenge is to provide real-time services.

3. METHOD

We are trying to develop a modern tool that provides equal access to care, as a solution that facilitates the interaction between patients and medical specialists to fight the delay of access that causes most death cases. This is frequently noted for the poor social category. So, the idea keeps seeing how one can design a platform to monitor their daily condition. This will mainly concern solving the delay problem noted for geographically isolated zones.

3.1. System's architecture and components

The main components in the proposed system are IoT devices, a sensor-based application for gathering information, patient medical records, 5G and a telemedicine Platform. The general architecture is based on three layers: Acquisition layer, processing and transmission layer and application layer, presented in Figure 1.

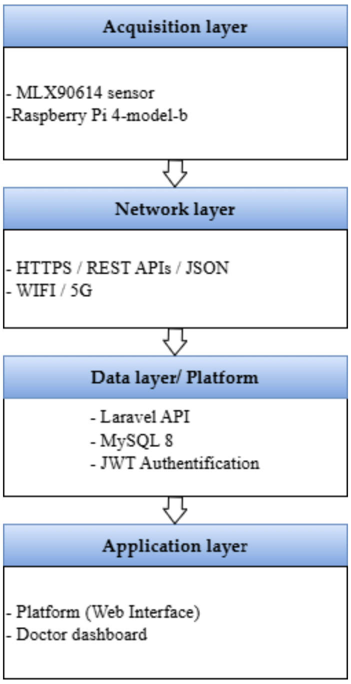

Figure 1. General architecture of our system

a. Acquisition layer: presents a temperature measurement sensor MLX90614 is a suitable and efficient infrared temperature sensor for measuring human body temperature, non-contact, low power consumption, operates with a supply voltage of 3.6 to 5 V. MLX90614 can be used with Arduino, ESP32 or raspberry Pi. Also, the Raspberry Pi 4-model-b card allows the collection, processing, analysis, and display of data from a single sensor. It has Wi-Fi and Ethernet for sending data online (cloud and web server). It can also collect data from multiple sensors simultaneously (temperature, glucose, blood pressure). The Raspberry Pi 4-model-b card requires SD card and Dupont cable which is used to connect the MLX90614 sensor to the Raspberry Pi.
b. Network layer: Ensures data transmission between the IoT gateway and the remote server. Communication is based on the HTTPS protocol, REST APIs for sending and receiving data, JSON format, and the Wi-Fi/5G network.

c. Data layer/Platform: Ensures the transmission of data between the IoT gateway and the server. In our platform, communication is based on the HTTPS protocol, REST APIs for sending and receiving data and the JSON format for structuring messages.
d. Application layer: a web interface for visualization.

3.1.1. Materials used

The integration of IoT devices into telemedicine platforms is crucial for enabling remote monitoring and data collection. IoT devices can include wearable sensors, smart medical devices, and mobile health applications [32]. These devices collect real-time data, such as temperature, blood pressure, and glucose levels, and transmit it to the telemedicine platform for analysis. The challenge is to remotely transmit data. For testing our system, we use a temperature measurement sensor, MLX90614, a Raspberry Pi 4-model-b card, and a female-female Dupont cable presented in the Figure 2. Specifically, we use a Raspberry Pi 4 Model B card as the central processing unit as shown in Figure 2(a), female-to-female Dupont cables for wiring and connectivity as shown in Figure 2(b), and an MLX90614 infrared temperature measurement sensor for data collection as shown in Figure 2(c).

(a) (b) (c)

Figure 2. IoT devices used in our system: (a) Raspberry Pi-4-model-b, (b) Dupont cable, (c) temperature measurement sensor MLX90614

The temperature measurement sensor, MLX90614, is a suitable and efficient infrared temperature sensor for measuring human body temperature, non-contact, low power consumption, and operates with a supply voltage of 3.6 to 5 V. For good performance, it must be used with a measuring distance of 5 to 10 m for good accuracy. MLX90614 can be used with Arduino, ESP32, or Raspberry Pi. The Raspberry Pi 4-model-b card allows the collection, processing, analysis, and display of data from a single sensor. It has Wi-Fi and Ethernet for sending data online (cloud and web server). It can also collect data from multiple sensors simultaneously (temperature, glucose, blood pressure). Raspbian OS on the SD card. And Dupont cable is used to connect the MLX90614 sensor to the Raspberry Pi.

3.1.2. Software used

a. Overview of our platform technologies

Our platform provides real-time services; it gives synchronous services such as video calls for patients who prefer face-to-face interaction and instant messaging for patients who prefer text-based consultations to interactive ones for reasons of confidentiality to fight against the main obstacle between the patient and the doctor which is the long time to have an appointment.

The doctor will be notified following a request from a patient. Only doctors can initiate a video call, if necessary, depending on the patient’s condition for further organization. To realize these options, we use such development technologies that we will detail below.

The platform harnesses the power of Laravel 11, Laravel Reverb for real-time communication and PHP 8.2. In the next paragraph, we’ll dive deep into the architecture, features, and benefits that make this platform with the services below a standout solution in the market.

– Backend

The backend of our platform is built on Laravel 11, a feature-rich PHP framework that provides a sturdy foundation for our server-side logic. By using the latest version of Laravel, we’ve been able to take advantage of its cutting-edge features, improved performance, and enhanced security measures.

Laravel 11 framework offers powerful features for creating modern, high-performance applications. These include its controllers, which enable business logic to be managed in a structured, modular way. Routes facilitate the management of URLs and corresponding actions. Migration also simplifies database management.

One of Laravel 11's main strengths is its expressive syntax and modular structure, developers can code faster and more efficiently. What's more, security is a major concern for any company. Laravel 11 incorporates security mechanisms, session ID management, and secure queries capable of handling increased workloads without compromising performance. Scalability is another major advantage of Laravel 11.

– Real-time communication

We've integrated Laravel Reverb, a powerful real-time communication package, to facilitate seamless real-time communication between our users. This allows our application to deliver instant updates, live notifications, and interactions, creating a dynamic and engaging user experience. Laravel Reverb's advantages for real-time Communication are: i) Instant messaging: Laravel Reverb enables us to build real-time chat functionality, allowing our users to communicate instantly and effortlessly within the application, fostering a more engaged and connected user base. ii) Live notifications: With Laravel Reverb, we can deliver live notifications to our users, keeping them informed about updates, events, and important information without the need for page refreshes, enhancing the overall user experience. iii) Collaborative experiences: The real-time capabilities of Laravel Reverb enable us to create collaborative features, such as real-time document editing, whiteboarding, and shared workspaces, fostering seamless teamwork and productivity among our users.

– Database and scripting

The latest version of MySQL 8, coupled with the advanced capabilities of PHP 8.2, powers our data storage and processing. This combination provides unparalleled performance, scalability, and reliability, ensuring that our application can handle even the most demanding workloads with ease. Our platform allows such services: Real-time Video, Instant messaging, live notifications, Vital Signs Monitoring, and electronic health record (EHR) Access.

The platform provides functionalities such as Appointment Scheduling, so that patients can send an appointment request with a chosen specialist by choosing the desired date. Then, file sharing, the platform allows for the sharing of medical images, test results, and other relevant documents between healthcare providers and patients. And secure Messaging so healthcare providers and patients can communicate securely through the platform, ensuring privacy and confidentiality.

b. Overview of our IoT integration technologies

The software technologies that are used for these functions after connecting the IoT components shown in Figure 3 are mentioned in the following section and are summarized in Figure 4. For communication between the Raspberry Pi Model B board and the sensor, we used a serial communication protocol, inter-integrated circuit (I2C), which enables the various electronic components to communicate with each other using two wires: serial data (SDA), which carries the data, and serial clock (SCL), which carries the clock signal.

To read data via I2C, we used Python as the language and the Python library Adafruit_Python_MLX90614. To transmit data to Laravel, we used the API REST method (POST JSON), with the Python script periodically sending data via HTTPS POST to a Laravel API.

c. Communication infrastructure

5G is a major innovation in the healthcare field [2]. It enables the transfer and processing of large amounts of data and the connection of many highly reliable communication devices. 5G connects people, objects, data, applications, networks, transportation systems, regions, and much more. It divides the latency (response time) by 10 and multiplies the connection density by 10 compared to 4G [3]. In our system, latency plays a critical role in ensuring patients benefit from the services offered by our platform.

Figure 3. Connecting IoT components: Raspberry Pi 4 board, Dupont cable, MLX90614 sensor

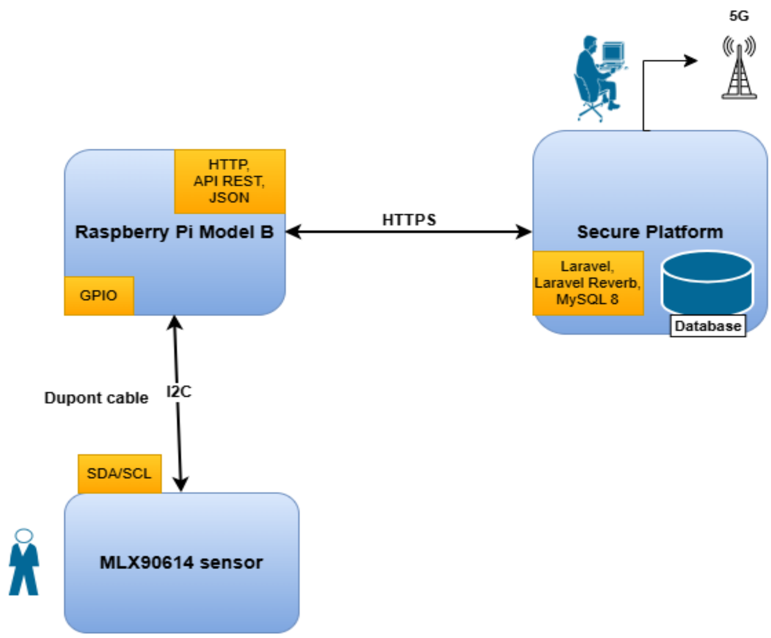

Figure 4. Communication between different components

3.1.3. Implementation of the system

Our system works in the following four steps, summarized in the sequence diagram in Figure 5. The first step is that the patient, who is the source of the data, is occupied by sensors or medical devices. The accuracy of the measurements taken by the sensors is the most important parameter in our system. Then, after a demand by the user, the gateway reads data via the I2C protocol. The third step data collected in step 2 are transmitted to the remote server via a REST API in JSON format. The Laravel server stores data in the database. Data is transmitted at the highest transmission rate to healthcare providers using 5G services. A high data transmission rate translates into a faster response time, which is efficient in the healthcare system. In step four, the doctor, who is the final user of our system, receives the captured and stored data via the platform to assess the patient's condition. He plays an important role in the proposed system.

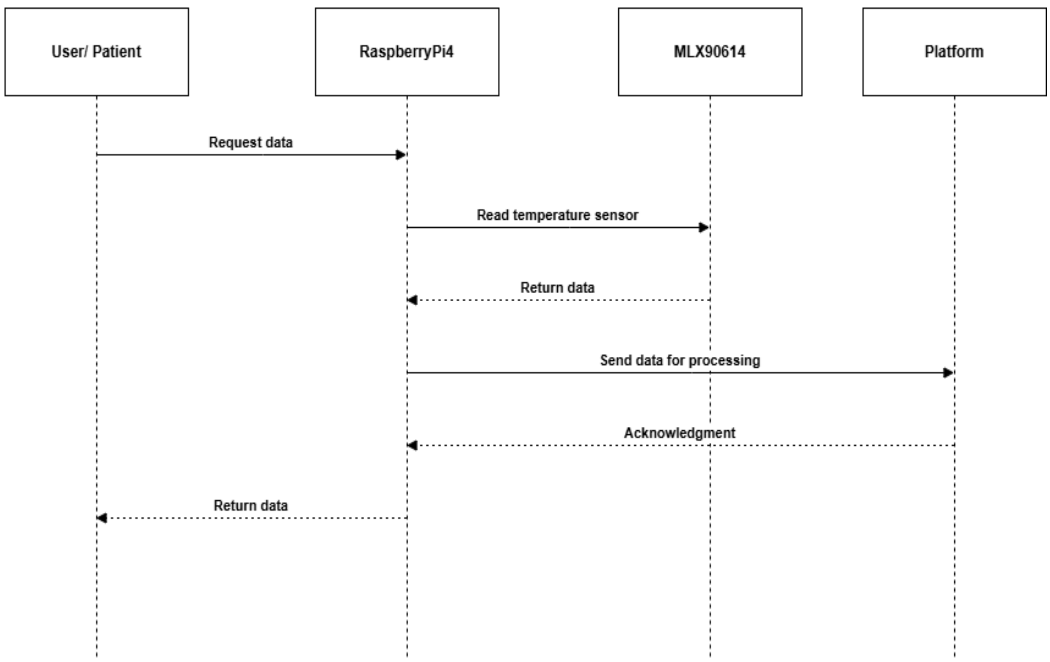

Figure 5. The sequence diagram of our system

4. RESULTS AND DISCUSSION

Connected devices have become an essential means of collecting sensory physiological data in healthcare IoT. Figure 6 indicates the result shown in doctor's interface in the platform.

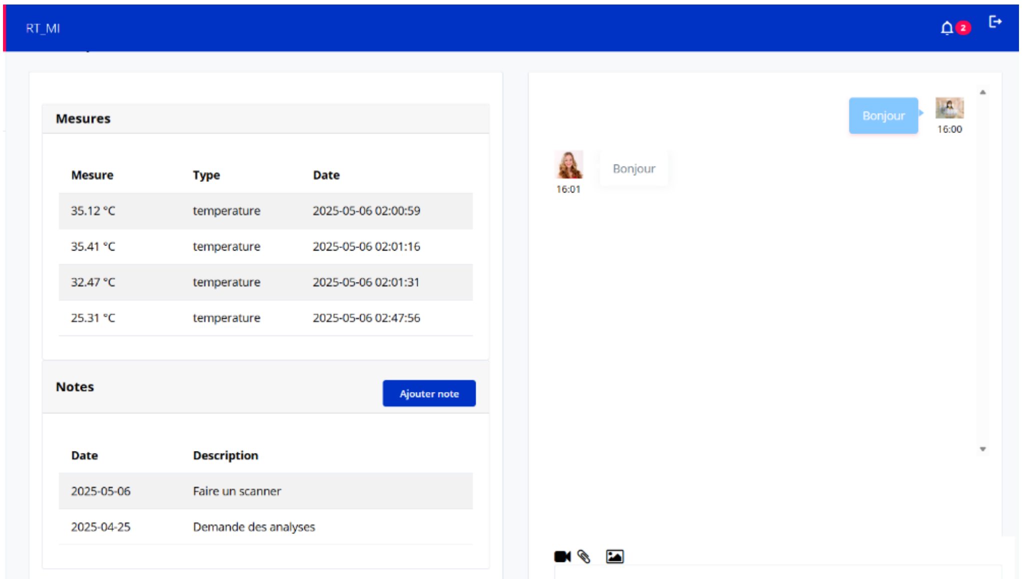

Figure 6. Experimental results shown in the doctor's interface

4.1. Performance evaluation and results analysis

The evaluation of the proposed platform is based on an experimental approach aimed at analyzing its actual behavior. The tests are carried out on the developed prototype under normal conditions of use. To test the proper functioning of our system, and since IoT devices are expensive, we used just an MLX90614 temperature sensor. The data is then acquired by a Raspberry Pi 4-model- b board and transmitted wirelessly via 5G mobile network using a 5G modem provided by Ooredoo operator to a remote platform. The evaluation criteria focus mainly on response time, data loss rate, system availability, and measurement reliability, as shown in Table 1.

- Response time: Response time is the delay between the collection of data by the sensor and its availability on the web interface. This indicator is used to evaluate the responsiveness of the system.
- Data loss rate: This indicator measures the percentage of data not received or lost during transmission between the IoT gateway and the server.
- System availability**:** Represents the platform's ability to operate without interruption over a given period.
- Measurement reliability: This is assessed by comparing the values measured by the IoT sensor with reference measurements.

The strengths of our system compared with existing platforms are real-time interaction between patient and doctor, ensuring the transfer of data captured by the sensor and access at the same time, real-time communications such as video calls, live notifications and instant messaging using 5G mobile network via 5G modem provided by Ooredoo operator, in addition to the integration of IoT for collecting data from patients and transferring it automatically to doctors via our platform. In comparison of our telemedicine platform RT_MI and the mentioned platforms existing in Tunisia. We can summarize the services offered by each one and our perspective on the others in Table 2.

Table 1. Experimental results from the platform

Evaluation criteria	Response time	Data loss rate	System availability	Measurement reliability
Results	The collected data is transmitted and displayed in near real time.	Tests indicate a low loss rate, demonstrating the stability of REST API communication.	The platform demonstrated satisfactory availability during the trial period. Interruptions were mainly due to network or hardware constraints.	The use of authentication mechanisms ensures an acceptable level of security.

Table 2. Comparison with existing platforms in Tunisia.

	Tunisia's Platform's name					
Services	telemedecine.tn	Tobba.tn	DocNet.tn	Med.tn	Wic-doctor	RT_MI
Instant messaging	No	Not precise	No	No	Yes	Yes
Live notification	Not precise	Not precise	Not precise	No	Not precise	Yes
Electronic prescription	Yes	Not precise	Yes	No	Not precise	Yes
Video consultation	Yes	Yes (variable)	Yes	No	Yes	Yes
IoT integration	No	No	Yes	No	No	Yes

Results obtained demonstrate that the developed platform meets the objectives set in terms of performance, reliability, and security. The integration of IoT enables automated collection of medical data, contributing to improved patient monitoring. However, certain limitations remain, such as our system has not been tested with all types of medical sensors, and it has only been tested in a local environment.

4.2. Ethical and data considerations

Laravel and Laravel Reverb offer technical tools that help comply with certain general data protection regulation (GDPR) and health insurance portability and accountability (HIPAA) standards. For data security, Laravel offers encryption mechanisms by using bcrypt or Argon2 to securely store passwords. Also, protection against common attacks via cross-site scripting (XSS), cross-site request forgery (CSRF), and SQL injection for input data validation, the validation system prevents SQL injections or malformed data by filtering server-side inputs. Laravel allows access management via Middlewares auth, can… which limits access to medical data to authorized users only, thus ensuring authentication and authorization. In addition, Laravel allows logging, which allows tracking actions, which is useful for the traceability required by GDPR/HIPAA. It also allows secure storage management with the possibility of integration with AWS-compliant solutions with encryption and secure servers for infrastructure security: it allows automatic data encryption (at rest and in transit), S3, RDS, and other AWS services ensure data confidentiality by offering automatic AES-256 encryption. In order to block attacks, monitor logs, and control access, a firewall, network security measures, and continuous monitoring are implemented using security groups, VPC, AWS WAF, and CloudTrail.

4.3. Future directions and challenges

In future work, we aim to incorporate field trials, the integration of additional sensors, the use of AI and machine learning for medical data analysis, as well as cybersecurity measures. This will enable us to better address the needs of the healthcare sector, meet patients' care needs, and overcome all the challenges faced in rural areas.

5. CONCLUSION AND PERSPECTIVES

The telemedicine system we have developed consists of a platform that manages IoT gateways and databases. It allows users to log in and view medical data. It manages IoT gateways for data logging, connection, and transmission. It receives real-time medical monitoring data and stores it in a database. Users and healthcare professionals can log in to view medical data in real time. Our primary goal is to promote health in Tunisia and address the regional disparities affecting certain areas of the country. The design and implementation of such platforms highlight their architecture through the integration of IoT devices and the incorporation of security measures. A telemedicine platform prototype was presented as a case study. This demonstrated the effectiveness of IoT technologies in facilitating remote consultations and addressing many other needs. By using an MLX90614 sensor to test the proper functioning of data transfer and store the data in the database so that the doctor can view it in real time, we achieved the desired result.

The strengths of our system compared with existing platforms are real-time interaction between patient and doctor, ensuring the transfer of data captured by the sensor and access at the same time, real-time communications such as video calls, live notifications and instant messaging using 5G mobile network via 5G modem provided by Ooredoo operator, in addition to the integration of IoT for collecting data from patients and transferring it automatically to doctors via our platform. Future works expanded to include field testing, integration of additional sensors, and the use of AI/ML for medical data analysis to better serve the healthcare sector in Tunisia.

FUNDING INFORMATION

No funding involved.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Ibrahim Monia	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	
Dadi Mohamed Bechir		✓		✓		✓		✓		✓		✓		
Rhaimi Belgacem Chibani				✓	✓	✓				✓	✓	✓	✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

No conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

REFERENCES

[1] H. Mihalj *et al.*, "Implementation of telemedicine in otorhinolaryngology," *Southeastern European Medical Journal*, vol. 5, no. 1, pp. 122–134, 2021, doi: 10.26332/seemedj.v5i1.195.

[2] A. Owen and S. Kellr, "Transforming telemedicine: Leveraging cloud enabled IoT devices for enhanced patient engagement," *ResearchGate (unpublished)*, pp. 1–19, 2025.

[3] R. Khatoon *et al.*, "Advancing healthcare: A comprehensive review and future outlook of IoT innovations," *Engineering, Technology and Applied Science Research*, vol. 15, no. 1, pp. 19700–19711, 2025, doi: 10.48084/etasr.9156.

[4] C. G. Victora *et al.*, "Countdown to 2015: A decade of tracking progress for maternal, newborn, and child survival," *The Lancet*, vol. 387, no. 10032, pp. 2049–2059, 2016, doi: 10.1016/S0140-6736(15)00519-X.

[5] Ministry of Health Tunisia, "Overview of maternal and neonatal health in Tunisia," (in French) *Ministry of Health Tunisia*, 2017. https://tunisia.unfpa.org/sites/default/files/pub-pdf/Etat_des_lieux_SMNN_tunisie_0.pdf (accessed Aug. 02, 2025).

[6] T. D. Rafla *et al.*, "National survey of maternal moprtality of 2010: data of Tunis," (in French) *Tunisie Medicale*, vol. 92, no. 8, pp. 560–566, 2014.

[7] UNICEF, "The state of the world's children 2009: Maternal and newborn health," (in French) *UNICEF*, Dec. 31, 2009. https://www.unicef.fr/sites/default/files/userfiles/4667-4(1).pdf (accessed Nov. 05, 2018).

[8] T. Boerma, C. AbouZahr, D. Evans, and T. Evans, "Monitoring intervention coverage in the context of universal health coverage," *PLoS Medicine*, vol. 11, no. 9, p. e1001728, 2014, doi: 10.1371/journal.pmed.1001728.

[9] Ministère de la Sante, "National strategy for maternal and newborn health 2020-2024," (in French) *Ministère de la Sante*, 2019. https://tunisia.unfpa.org/fr/publications/stratégie-nationale-de-la-santé-maternelle-et-néonatale-2020-2024 (accessed Oct. 01, 2019).

[10] L'Institut National de la Statistique (INS), "General population and housing census 2024," (in French) *L'Institut National de la Statistique (INS)*, 2024. https://www.ins.tn/ (accessed Aug. 02, 2025).

[11] R. T. Instance Nationale des Telecommunications, "Public consultation on 5G regulation," (in French) *Instance Nationale des Telecommunications, Republique Tunisienne*, Dec. 2024. https://www.intt.tn/upload/files/Consultation publique regulation 5G.pdf (accessed Dec. 05, 2024).

[12] A. Dasgupta, A. Qumer Gill, and F. Hussain, "Privacy of IoT-enabled smart home systems," in *IoT and Smart Home Automation [Working Title]*, IntechOpen, 2019, pp. 9–24.

[13] Y. Ismail, *Introductory chapter: Internet of things (IoT) importance and its applications*. Intech, 2012.

[14] M. Dauwed and A. Meri, *IoT service utilisation in healthcare*. Intecho, 2019.

[15] A. U. Rehman *et al.*, "Internet of things in healthcare research: Trends, innovations, security considerations, challenges and future strategy," *International Journal of Intelligent Systems*, vol. 2025, no. 1, p. 53, 2025, doi: 10.1155/int/8546245.

[16] Z. Cheah Wai, J. Jayanand, and L. Son Chee, "Exploring IoT application using Raspberry Pi," *International Journal of Computer Networks and Applications*, vol. 2, no. 1, pp. 27–34, 2015.

[17] A. Bader, H. Ghazzai, A. Kadri, and M. S. Alouini, "Front-end intelligence for large-scale application-oriented internet-of-things," *IEEE Access*, vol. 4, pp. 3257–3272, 2016, doi: 10.1109/ACCESS.2016.2580623.

[18] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, "Internet of Things: a survey on enabling technologies, protocols, and applications," *IEEE Communications Surveys and Tutorials*, vol. 17, no. 4, pp. 2347–2376, 2015, doi: 10.1109/COMST.2015.2444095.

[19] D. M. West, "How 5G technology enables the health Internet of Things," *Cyber Resilience of Systems and Networks*, no. July 2016. pp. 1–150, 2016, [Online]. Available: http://link.springer.com/10.1007/978-3-319-77492-3_16.

[20] R. Want, B. N. Schilit, and S. Jenson, "Enabling the internet of things," *Computer*, vol. 48, no. 1. pp. 28–35, Nov. 2015, doi:

10.1109/MC.2015.12.
[21] R. S. H. Istepanian, S. Hu, N. Y. Philip, and A. Sungoor, "The potential of Internet of m-health Things m-IoT for non-invasive glucose level sensing," in *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS*, 2011, pp. 5264–5266, doi: 10.1109/IEMBS.2011.6091302.
[22] S. B. Baker, W. Xiang, and I. Atkinson, "Internet of things for smart healthcare: Technologies, challenges, and opportunities," *IEEE Access*, vol. 5, pp. 26521–26544, 2017, doi: 10.1109/ACCESS.2017.2775180.
[23] S. H. Liu, C. B. Lin, Y. Chen, W. Chen, T. S. Huang, and C. Y. Hsu, "An EMG patch for the real-time monitoring of Muscle-fatigue conditions during exercise," *Sensors (Switzerland)*, vol. 19, no. 14, p. 3108, 2019, doi: 10.3390/s19143108.
[24] Z. J. Guan, "Internet-of-Things human body data blood pressure collecting and transmitting device," *Chinese Patent 202 821 362*, no. 202. p. 362, 2013.
[25] "National strategic plan digital Tunisia 2025," *webmanagercenter.com*, Jun. 2024. https://www.webmanagercenter.com/ (accessed Jun. 15, 2024).
[26] Express FM, "Expresso: The migration of doctors in Tunisia," (in French) Tunisia, Mar. 2024.
[27] "Telemedecine.tn: Telemedicine platforms," *telemedecine.tn*, 2024. http://telemedecine.tn/ (accessed Sep. 12, 2024).
[28] "Tobba: Telemedicine platforms," *www.tobba.tn*, May 2019. https://www.tobba.tn (accessed May 02, 2025).
[29] "DocNet.tn: Telemedicine platforms," *docnet.tn*, May 2023. https://docnet.tn/ (accessed May 02, 2025).
[30] "Med.tn: Telemedicine platforms," *med.tn*, May 2025. https://www.med.tn/ (accessed May 02, 2025).
[31] "Wic-doctor: Telemedicine platforms," *wic-doctor.com*, Jan. 2025. https://wic-doctor.com/Telemedecine.html (accessed Jan. 02, 2025).
[32] M. V. M. N. Sravan and K. V. Rao, "A hybrid deep learning framework for speech to-text conversion as part of telemedicine system integrated with 5G," *International Journal of Electrical and Computer Engineering Systems*, vol. 16, no. 4, pp. 333–346, Mar. 2025, doi: 10.32985/ijeces.16.4.6.

BIOGRAPHIES OF AUTHORS

Ibrahim Monia holds a B.Sc. degree in computer science and a master's degree in networks and embedded systems from the Faculty of Science in Gafsa (Tunisia), obtained in 2015 and 2017. She is now a PhD student in electrical engineering. She can be contacted at email: monia-ibrahim@hotmail.com.

Dadi Mohamed Bechir received the Ph.D. degree in telecommunication engineering. In June 2006, he received the M.Sc. degree in communications system. In June 2005, he received the B.Sc. degree in telecommunication. All from the National Engineering School of Tunis (ENIT). From September 2011, he was a graduate as an assistant Professor in the National Engineering School of Gabes (ENIG). He has taught courses in telecommunications engineering, computer networks and computer engineering. His current research interests include 5G/6G mobile communications, IoT systems, AI and Wireless system. He can be contacted at email: mohamedbechir.dadi@enig.rnu.tn.

Rhaimi Belgacem Chibani is a professor in communication systems at the Department of Communications and Networks at Eng. High School of Gabès at University of Gabès. After his Engineer's Communications Diploma, he received the M.S. degree in automatic control and PhD. degree all from University of Tunis in Tunisia. His research is focused on communications and signal processing with their applications. He can be contacted at email: abouahmed17@gmail.com.