

# Architecture and Organizational Protocol of a Connected Medical Monitoring Device

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## ABSTRACT

This article presents the design and implementation of a biomedical remote monitoring system intended for the real-time acquisition, processing, and transmission of physiological data. The system is based on a modular architecture structured in a star topology, integrating several biomedical sensors (electrocardiograph, stethoscope, thermometer, pulse oximeter, blood pressure monitor, and heart rate sensor). Data collected by these sensors is processed locally using an Arduino MEGA 2560 board and transmitted via an Ethernet Shield module configured as an HTTP server, enabling real-time display on a web interface hosted on a computer. This setup allows for reliable remote monitoring of vital signs, paving the way for applications in telemedicine, home care, and emergency response. The results highlight the relevance of this solution in resource-constrained settings, while emphasizing the importance of incorporating robust security features and advanced connectivity in future developments.

**Keywords:** Biomedical monitoring, Arduino MEGA 2560, physiological sensors, Ethernet Shield, HTTP server

## INTRODUCTION

The rapid advancement of Internet of Things (IoT) technologies and embedded systems has enabled the development of medical remote monitoring solutions that allow continuous, long-distance patient supervision. These systems rely on well-structured architectures, integrating acquisition, processing, and transmission units to ensure effective care of patients with chronic conditions [1]. A connected medical monitoring device typically consists of several core components. The acquisition unit gathers physiological signals using biomedical sensors, while the processing unit applies algorithms for analysis and filtering to extract meaningful information [2]. Finally, the transmission unit forwards the processed data to a host computer or a monitoring platform, using wireless communication technologies such as Bluetooth, Wi-Fi, LoRaWAN, or optical wireless communication [3]. However, designing such systems

poses several challenges, particularly in terms of interoperability, energy efficiency, and data security. Organizational protocols play a crucial role in structuring communication between modules, ensuring secure and reliable transmission of medical data [4]. Additionally, the integration of artificial intelligence and cloud computing is increasingly leveraged to enhance decision-making and data analysis in telemonitoring systems [5]. This article provides an in-depth study of the architecture and organizational protocol of a connected medical monitoring system. It highlights key technological choices and implementation challenges, supported by case studies and practical experiments.

## METHODS

The development of a connected medical monitoring system follows a rigorous methodological approach involving system architecture design, functional unit development, and implementation of the

**Relevant conflicts of interest/financial disclosures:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.



organizational protocol. This section outlines the main steps taken to ensure the reliability and efficiency of the proposed system.

### System Architecture Design

The architecture adopts a modular structure composed of three main units: physiological data acquisition, signal processing, and data transmission. This design follows best practices in the field of telemonitoring systems, aiming for seamless communication and enhanced interoperability [6]. The acquisition unit integrates biomedical sensors selected based on their accuracy, low power consumption, and compatibility with existing communication standards. These sensors monitor vital signs such as heart rate, blood oxygen saturation, and body temperature [7]. The processing unit uses embedded system architecture with signal processing and anomaly detection algorithms. To optimize both energy efficiency and computational robustness, the system employs low-power microcontrollers and efficient digital signal processing techniques [8]. The transmission unit leverages wireless communication technologies suited to medical use cases, including Bluetooth Low Energy (BLE), Wi-Fi, LoRaWAN, and optical wireless communication. These technologies are chosen to ensure secure, low-latency data transfer with minimal energy usage [9],[10].

### Development of the System's Organizational Protocol

The organizational protocol is designed to manage communication between the system's various units, ensuring data synchronization and consistency. It follows a hierarchical model in which the acquisition unit sends data in real-time to the processing unit. This unit filters and classifies the data before forwarding it to the host computer or cloud platform [11]. A "publish-subscribe" communication paradigm is adopted to

streamline integration with digital health platforms and to enhance scalability [12]. Moreover, encryption protocols such as AES-128 are implemented to ensure the privacy and security of transmitted medical data [13].

## RESULTS

### Organizational Protocol of the System

The main objective of the project is broken down into a set of operational actions aimed at ensuring the functional coverage of the telemedicine system. To this end, the organization of telemedicine services, based on the identification and interconnection of various types of links between actors, enables the design of organizational models adapted to the specific constraints of a given region. A preliminary analysis of the medical procedures that can be performed remotely helps determine the types of telemedicine relationships to be established between the various stakeholders (health professionals, patients, care facilities). Once combined, these relationships give rise to different organizational models depending on the type of care provided (teleconsultation, tele-expertise, remote monitoring, etc.). The definition of the organizational model therefore involves [14]:

- Identifying the actors involved for each type of telemedicine act;
- Determining the locations where these acts are to be performed;
- Describing the modes of interaction between the stakeholders.

The development of a formal organizational protocol, followed by its dissemination to all stakeholders, is an essential step to ensure the adoption of the system and guarantee its coherent and efficient functioning.

**Table 1: Process for Implementing a Medical Teleconsultation**

Step	Associated Actions
1. Telemedicine Act Request	- Preparation of the medical record - Request submission to the specialist physician - Validation of the request (scheduling a timeslot) - Informing the attending physician
2. Preparations Before the Session	- Informing and obtaining consent from the patient (or legal representative) - Preparing the medical file and the teleconsultation room - Informing relatives and healthcare staff - Checking equipment and network connections

	<ul style="list-style-type: none"> <li>- Welcoming and settling the patient</li> <li>- Launching the telemedicine software</li> </ul>
3. Teleconsultation Session	<ul style="list-style-type: none"> <li>- Introducing the participants</li> <li>- Medical interview conducted by the specialist physician</li> <li>- Possible additional examinations (performed by on-site staff)</li> <li>- Clinical discussion between the specialist and the local team (with or without the patient/family, depending on the case)</li> <li>- Closing the consultation by the specialist</li> </ul>
4. After the Session	<ul style="list-style-type: none"> <li>- Possible debriefing</li> <li>- Drafting and sending the consultation report</li> <li>- Reporting on the telemedicine session</li> <li>- Evaluating the quality of the service</li> </ul>

## System Architecture

### Overall Diagram

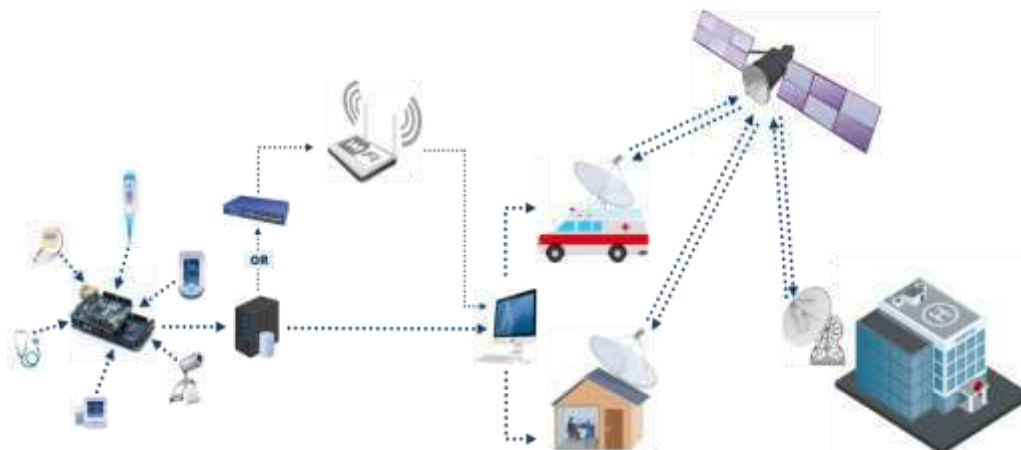
The overall system architecture is presented in a summarized form before the detailed description of each functional unit. The system is structured around four main components: a data acquisition unit, a processing unit, a transmission module, and a host computer responsible for data management and the user interface. The data acquisition unit collects information from various biomedical sensors. All sensors are interconnected in a star topology, converging to a central collection node. The acquired data are then transferred to the processing unit for analysis, filtering, or transformation according to the specific needs of the application. Once processed, the data are transmitted to a local HTTP server via an Ethernet Shield module. This module can be connected to the host computer either directly using a crossed RJ45 cable, or through a local network using a router and a Wi-Fi connectivity module. In the latter case, the data are transmitted wirelessly, facilitating integration into mobile or remote clinical

environments. Real-time data visualization and management are ensured by a web platform hosted on the host computer. This interface allows the user to access measurements, interact with the system, and monitor the overall state of the device.

Communication between the requesting station (transmission site) and the target site (expert center) is based on satellite communication. This infrastructure comprises two distinct segments :

- The space segment, consisting of the satellite, equipped with RF transmission and reception devices, directional antennas, as well as high-gain broadband amplifiers.
- The ground segment, composed of fixed or mobile stations located on the surface, integrating transmission and reception equipment and auxiliary devices required to operate the link.

The ground stations include both DTH-type home receivers (Direct-To-Home) and mobile terminals integrated into the medical device, enabling robust and continuous communication even in areas with low terrestrial network coverage.



**Figure 1: System Architecture**

## Data Acquisition Unit

### Electrocardiograph

#### Electrodes

The frontal electrodes detect the electrical impulses generated by cardiac activity. This prototype uses three frontal electrodes to record potential variations in the frontal plane, in accordance with standard limb leads [15].



Figure 2: Frontal Electrodes

The AD8232 module is a signal conditioning IC designed for biopotential measurements such as electrocardiography (ECG). It extracts, amplifies, and filters weak signals in noisy environments [16]. It integrates high-pass and low-pass filters, as well as a quick recovery function to minimize signal stabilization time after electrode placement.

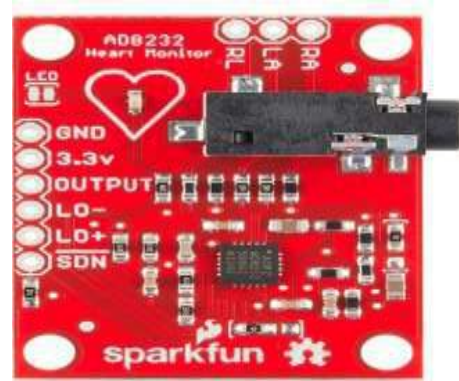


Figure 3: AD8232 Module

AD8232 Module

Schematic

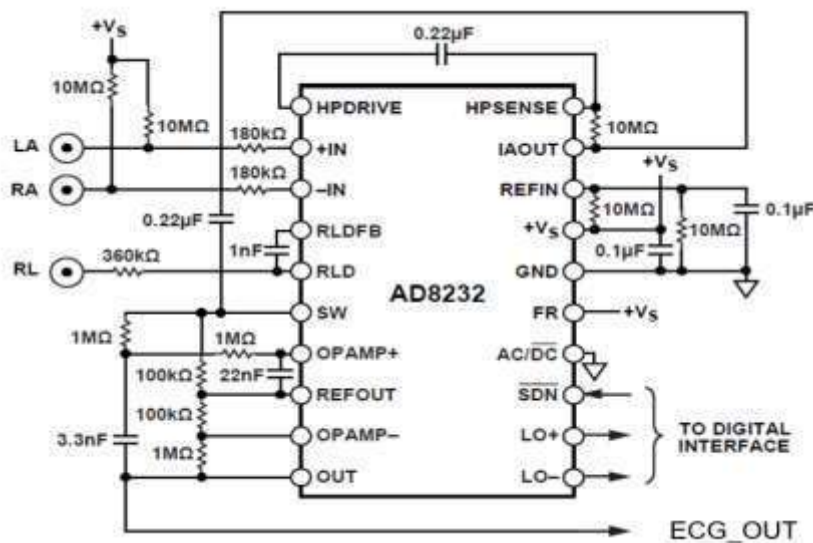


Figure 4: ECG Module

Stethoscope

Chest Piece

The chest piece, placed on the auscultation zone, captures sound vibrations transmitted through the tubing to an acoustic sensor.

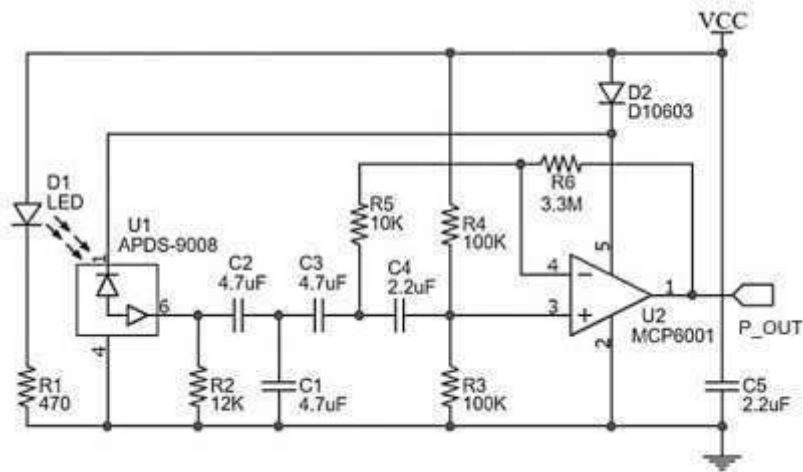


Figure 5: Stethoscope Chest Piece

KY-038 Module

The KY-038 module is based on an acoustic sensor coupled with an amplifier adjustable via a





**Figure 11: Heartbeat Module**

Pulse Oximeter

MAX30100 Module

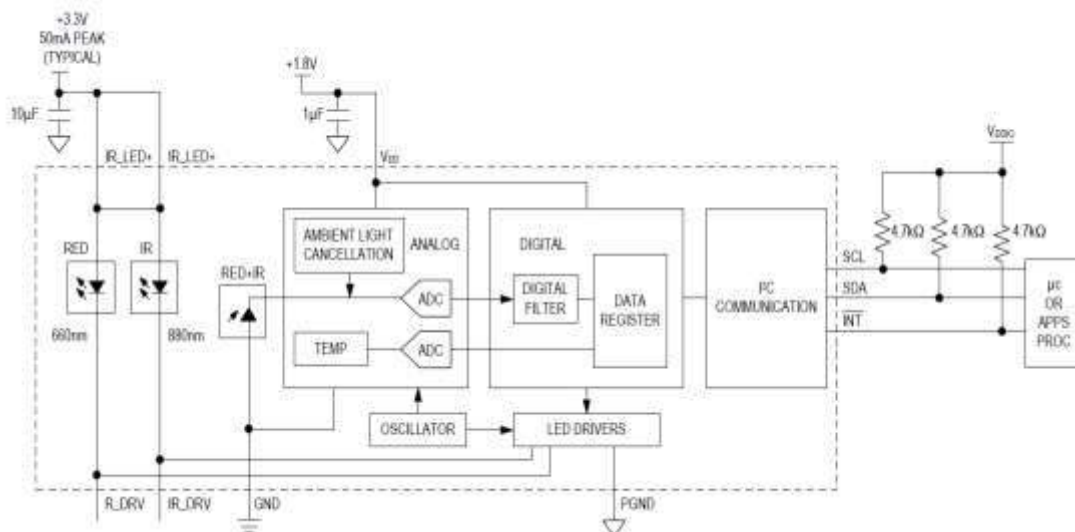
The MAX30100 module integrates an optical system for measuring blood oxygen saturation (SpO<sub>2</sub>) and

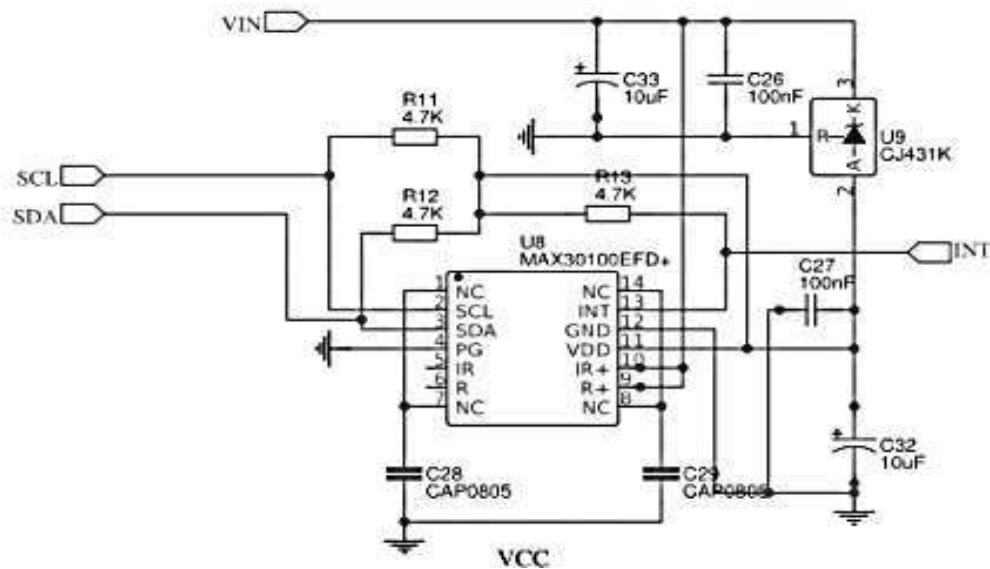
heart rate. It includes dual LED emitters (red and infrared), a photodetector, a 16-bit ADC, an active filter, and a temperature compensation algorithm [20].



**Figure 12: MAX30100 Module**

Schematic





**Figure 13: Pulse Oximetry Module**

### Blood Pressure Monitor

#### Pneumatic Unit

The cuff is inflated using a pump to a pressure above the systolic pressure. By decreasing the pressure via a micro solenoid valve, systolic and diastolic pressures are identified based on blood flow return <sup>[21]</sup>.



**Figure 14: Cuff**



**Figure 15: Rolling Pump**



**Figure 16: Micro Solenoid Valve**

#### Measurement Module

The module uses an **MPX2010DP pressure sensor**. The analog signal is amplified and filtered to isolate the AC component, crucial for interpreting arterial pressures <sup>[22]</sup>. Two successive band-pass filters extract the useful signal between 0.3 and 19 Hz.

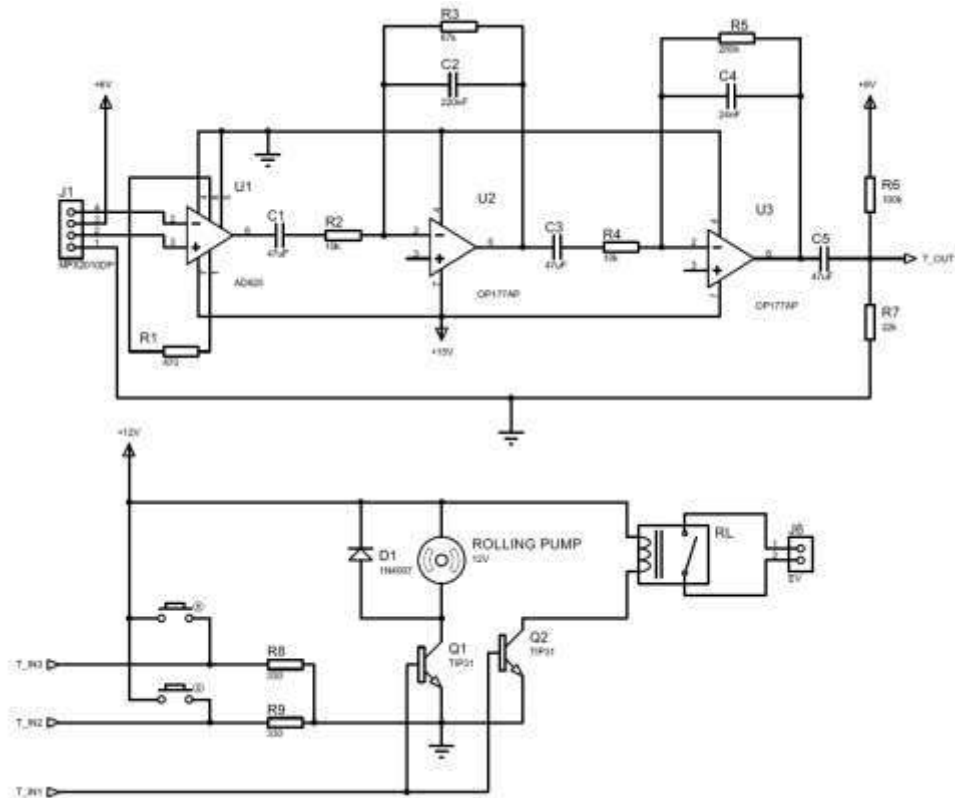


Figure 17: Blood Pressure Module

PCB

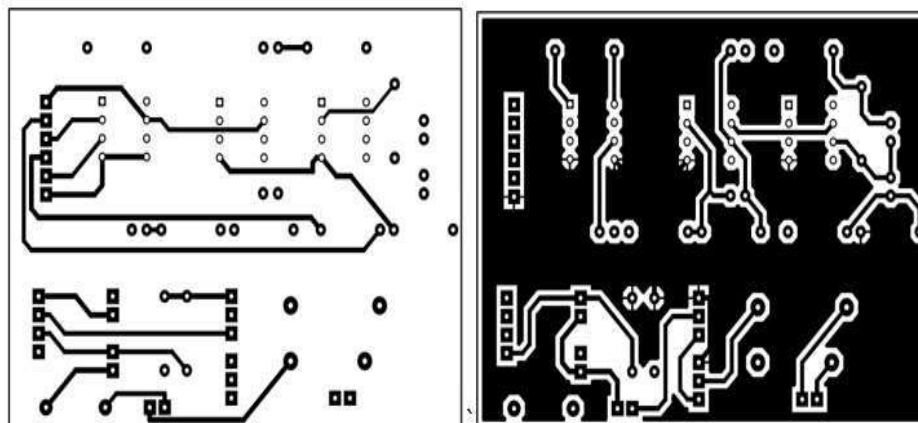


Figure 18: Blood Pressure Module PCB

### Data Processing Unit

#### Module Description

To analyze, synchronize, and transmit data from various biomedical sensors, a **processing unit** was developed around the **Arduino MEGA 2560** development board. This board serves as the **central node** of the star topology used in the acquisition system, with each sensor individually connected to it. The Arduino MEGA 2560 is based on the ATmega2560 microcontroller, clocked at 16 MHz. It

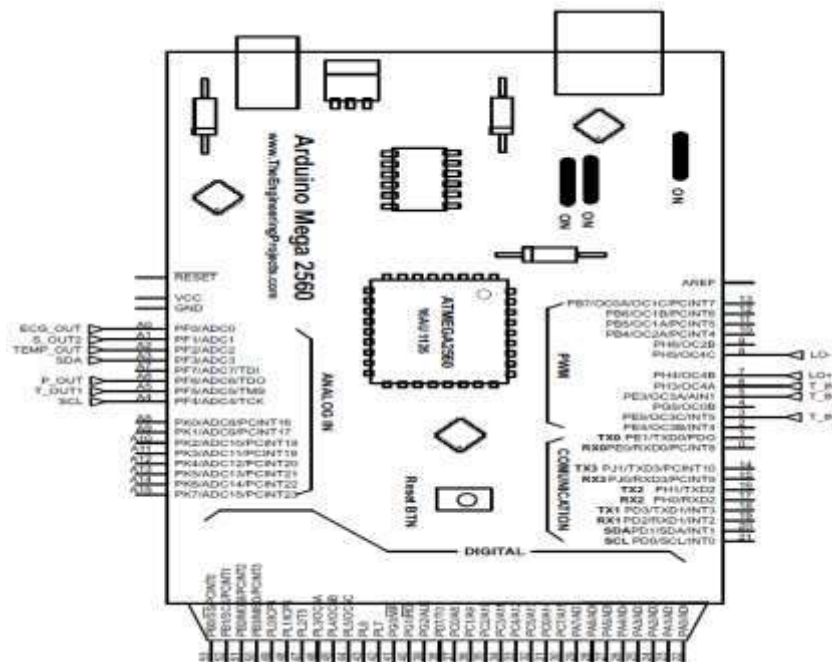
offers 54 digital I/O pins (14 with PWM capability), 16 analog inputs, and 4 UARTs for serial communication. It also features a bootloader for reprogramming via USB without an external programmer [23]. Thanks to its extended memory capacity (256 KB Flash, 8 KB SRAM, 4 KB EEPROM), it is well-suited for handling multiple biomedical sensors and managing communication protocols with network or server interfaces [24].



**Figure 19: Arduino MEGA 2560**

Connection Diagram Between Acquisition and Processing Units The following diagram shows the architecture linking the sensor modules with the central processing unit represented by the Arduino MEGA 2560. Each sensor transmits data as analog or

digital signals, read either by analog pins (e.g., LM35, XD58C) or handled via interrupts or serial communication (e.g., MAX30100, blood pressure monitor).

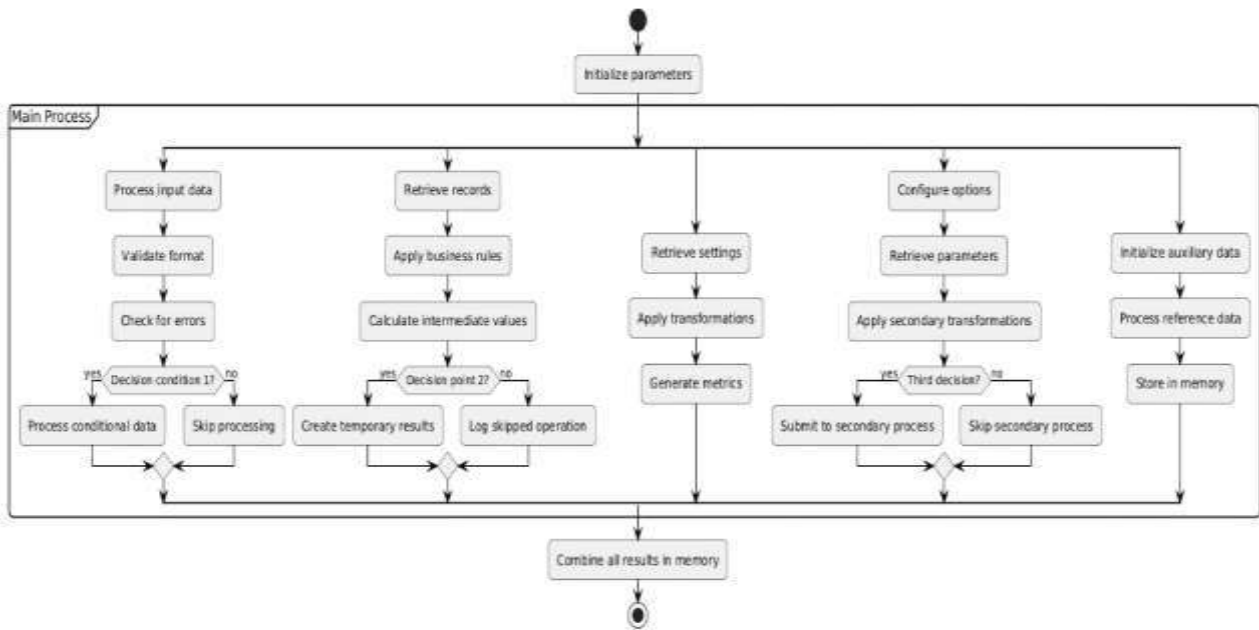


**Figure 20: Sensor Module Connections**

### Data Processing Algorithm

The processing workflow is structured around a **cyclic loop algorithm**, typical of embedded systems in the Arduino ecosystem. The algorithm performs **sequential sensor readings**, preprocessing (filtering, averaging, validation), and structuring/sending data to

the local server via a network interface (Ethernet Shield or Wi-Fi module). Each module is polled at a specific sampling rate, with **priority given to critical data** (e.g., ECG, SpO<sub>2</sub>). Validated data are formatted as structured frames (e.g., JSON or CSV) and transmitted to the local server via HTTP requests.



**Figure 21: Processing Algorithm**

Data Transfer Unit Between Equipment and Host Computer

Module Description

The data transfer unit enables communication between the Arduino MEGA 2560 and the host computer, using an Ethernet Shield. This module establishes a wired network connection (10BaseT/100BaseTX standard), facilitating the transmission of biomedical data to a local monitoring interface via HTTP [25]. The Ethernet Shield is based on the Wiznet W5100 IC, supporting TCP/IP and up to four simultaneous connections. It also includes a microSD card reader for local data storage or transfer. The module has several indicator LEDs:

- **TX** : Data transmission,
- **RX** : Data reception,
- **COLL** : Network collision,
- **FULLD** : Full-duplex mode,
- **LINK** : Active network connection,
- **100M** : 100 Mbps connection,
- **PWR** : Power status.

This device enables a **local human-machine interface (HMI)**, essential for data visualization and system interaction.



**Figure 22: Ethernet Shield**

**Configuring the Module as an HTTP Server in a Local Network**

The Ethernet Shield can be configured as an HTTP server, hosting a local web page to display real-time

measurements. This can be done in two ways: via a direct RJ45 crossover cable connection to the host computer, or through a router using a straight RJ45 cable. In the direct connection scenario, a network

bridge between the Wi-Fi and Ethernet interfaces must be configured on the host computer<sup>[26]</sup>.

Configuration steps include:

1. Connecting the Ethernet Shield to the Arduino board via the SPI bus;
2. Setting up the IP address, subnet mask, and gateway on the host computer to match the Shield's network;

3. Connecting the Shield to the computer using the appropriate cable (crossover or straight);
4. Uploading a configuration sketch to the Arduino to run the **HTTP server**, respond to incoming requests, and send measurement data.

The embedded HTTP server enables lightweight interaction without third-party software, accessible via any **web browser on the local network**.

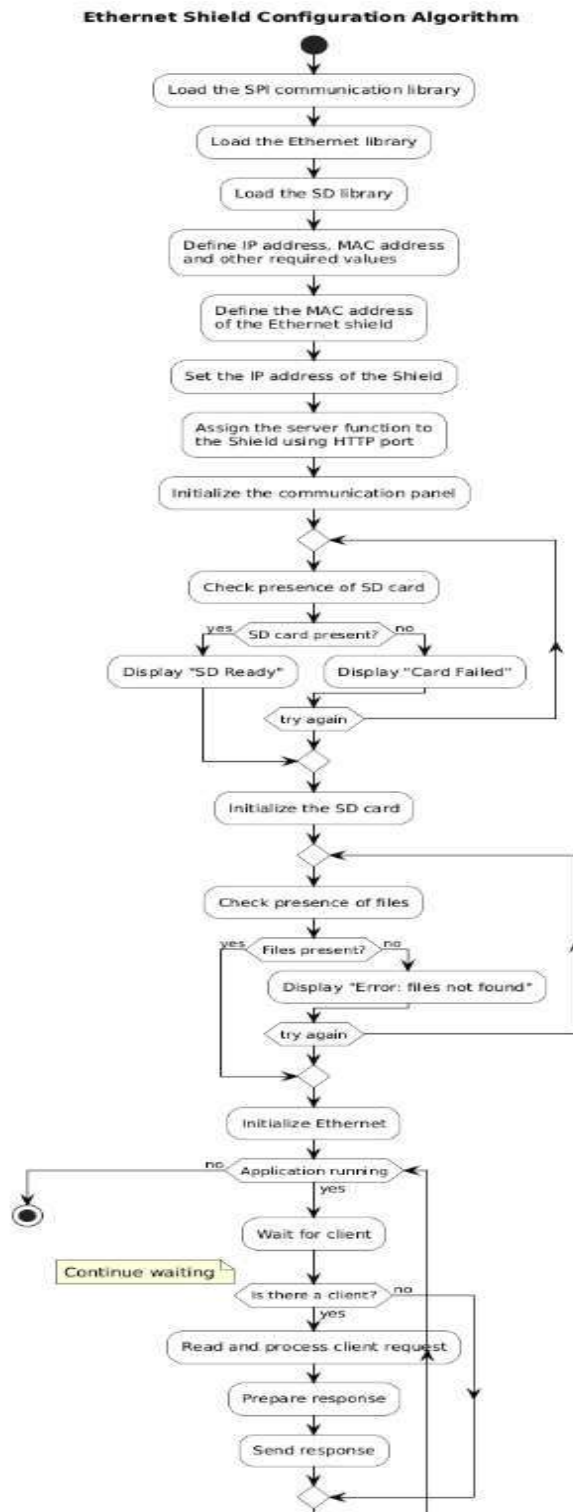


Figure 23: Configuration Algorithm

## DISCUSSION

The medical remote monitoring system developed in this work is based on a coherent modular organization, where each unit plays a critical role in the chain of data acquisition, processing, and transmission of physiological parameters. A star topology was adopted to ensure centralized communication between sensors and the processing unit, simplifying the overall architecture while enhancing system reliability. This configuration is widely recognized for its robustness in embedded biomedical applications, particularly due to its ability to easily accommodate additional modules. The system's hardware architecture is divided into distinct functional units, reflecting a well-established approach in the design of connected medical systems, emphasizing flexibility, modularity, and low power consumption. The data acquisition unit integrates specialized sensors such as the AD8232 module for electrocardiography, the MAX30100 for oxygen saturation and heart rate measurement, and the LM35 for body temperature monitoring. These sensors incorporate built-in signal conditioning circuits that help reduce interference and improve signal quality even in noisy environments. Data processing is handled by the Arduino MEGA 2560 board, selected for its ability to manage multiple sensors simultaneously due to its extensive array of analog and digital I/O pins. Although limited in computational power, this platform has proven effective in basic remote monitoring scenarios and offers a scalable solution for more complex systems if needed. For data transmission, the W5100 Ethernet Shield module was used in HTTP server mode, enabling local access to the data through a standard web browser. This approach avoids the privacy concerns associated with cloud-based platforms while maintaining direct control over data streams. The module's support for TCP/IP protocols ensures stable and fast communication, and the integrated SD card slot allows for optional local data storage. Despite its simplicity, this solution aligns with IoT standards in medical applications by offering good network interoperability and ease of deployment. Overall, the results confirm the technical feasibility of the proposed system and open avenues for future enhancements, including wireless communication modules, integration of automatic anomaly detection algorithms, and secure remote data storage.

## CONCLUSION

This work led to the design, development, and validation of a biomedical remote monitoring system integrating multiple physiological sensors (ECG, temperature, SpO<sub>2</sub>, blood pressure, heart rate, etc.) around a modular and scalable architecture. The adopted approach is structured around a star topology, centered on a main data processing unit (Arduino MEGA 2560) responsible for acquiring, preprocessing, and transmitting data to a visualization interface hosted on a local computer via Ethernet. The results obtained demonstrated the technical viability of the system and its ability to reliably collect physiological data, establishing a strong foundation for potential applications in telemedicine. The design highlighted the importance of seamless integration between the different functional units (acquisition, processing, communication), while also pointing out the limitations inherent to the use of low-cost components and restricted connectivity. In light of these findings, several improvements can be envisioned: integrating wireless communication modules (Wi-Fi, GSM, LoRa), implementing security protocols to ensure medical data privacy, and adding decision-support algorithms for early anomaly detection. These advancements would bring the system closer to real clinical requirements and enable its deployment in low-resource or remote settings. Thus, this prototype represents a significant step toward the development of accessible and adaptable technological solutions tailored to the growing demands of remote healthcare monitoring, particularly in the context of chronic disease management, home care, and emergency response.

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