Towards a Milk Quality Recording and Monitoring System Based on Blockchain and Long-Range Internet of Things

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Abstract. *The milk production chain in Brazil requires continuous monitoring of physicochemical parameters to ensure quality and prevent adulterations. We present a decentralized system based on IoT, long-range networks, and blockchain, enabling traceability from the beginning of production. Implemented in rural areas without internet access, this solution ensures transparent and secure quality control. The proof of concept demonstrates technical feasibility, serving as a crucial foundation for future testing and advancements in the field. In summary, our system provides effective traceability in milk production, maintaining rigorous quality control and auditability.*

Resumo. *A cadeia produtiva do leite no Brasil demanda monitoramento constante dos parâmetros físico-químicos para garantir qualidade e prevenir adulterações. Apresentamos um sistema descentralizado baseado em IoT, redes de longo alcance e blockchain, viabilizando a rastreabilidade desde o início da produção. Essa solução, implementada em ambientes rurais sem Internet, assegura controle de qualidade transparente e seguro. A prova de conceito demonstra a viabilidade técnica, sendo fundamental para futuros testes e avanços na área. Em resumo, nosso sistema proporciona rastreabilidade eficaz na produção de leite, mantendo rigoroso controle de qualidade e auditabilidade.*

1. Introduction

Milk production is one of the main milk intake activities in Brazil, placing the country in the third position in the global milk production ranking [FAO et al. 2021]. Milk production involves more than one million producers in Brazil, promoting a significant impact on the generation of jobs and income for Brazilians.

The milk production chain can go through different stages from collection to the final product. In this process, several factors can influence the quality of milk, such as hygiene conditions in handling and storage or even intentional adulteration with the aim of increasing volume, or changing the physicochemical characteristics of milk [Handford et al. 2016].

In this scenario, traceability becomes a strong ally in controlling the quality of milk, promoting transparency and integrity of the information inherent to the process. In addition, traceability facilitates the location of problems, allowing the quick identification of the stages in which these problems occurred [Aysha and Athira 2020].

Blockchain is a technology that has been proving to be promising for the traceability of production chains, as it has the premise of immutability of data, thus increasing the level of trust with the registered information [Centobelli et al. 2022]. Furthermore, the application of blockchain in a traceability context allows the integration with automation systems and/or IoT (*Internet of Things*) devices, so that the data collected by these systems is sent and registered in different nodes of a decentralized network.

The literature presents different works [Abrantes et al. 2014, Gregorio 2019, Yim et al. 2018, Mendonça et al. 2020] aimed at monitoring and recording milk quality through embedded systems. Work proposals are also presented for the traceability of the milk production chain based on blockchain. However, such approaches have a greater focus on the horizontal integration of the production chain. Unlike other works, the system proposed in this article has a decentralized approach that aims to record and monitor in real time the quality of milk in places without Internet access through long-range wireless network technologies.

More specifically, in this article, we present an architecture and operation of an embedded system for continuous remote monitoring of milk quality. Such a system is implemented directly at the primary collection/storage sites, monitoring the main variables of milk. These locations are rural environments without Internet connectivity, and therefore, long-range IoT networks are used. The collected data is transmitted to a base station that records the entire history on a blockchain network, allowing direct monitoring by cooperatives, dairies and regulatory bodies.

These characteristics of the proposed system result in traceability from the beginning of the milk production chain, in addition to simplifying auditing and inspection processes. Finally, the system has an automated and decentralized operation for the generation of milk production quality stamps. For this, the system benefits from the creation and implementation of smart contracts based on compliance with previously established tolerances, for each variable monitored.

The proposed system can bring additional benefits beyond traceability and transparency. With data recorded immutably on the blockchain, audits and inspections become more effective and agile. Regulatory bodies can access accurate information to ensure compliance with quality standards.

Furthermore, by automating the monitoring process and recording transactions on the blockchain, the system reduces opportunities for tampering and fraud. This safeguards the interests of producers, consumers, and the entire production chain.

Another noteworthy point is the efficiency in decision-making, as real-time data availability allows for quicker and more informed decision-making. Producers, cooperatives, and dairy companies can respond promptly to events and conditions affecting the quality of milk, such as diseases, logistical issues, and unfavorable weather conditions.

The remainder of this article is organized as follows: The Section 2 presents the background to this work, composed of related works and fundamental concepts related to this work. The Section 3 presents in detail the architecture and functioning of the proposed system. The Section 4 presents the proof of concept, the implementation of the system in a real milk production environment, and a discussion of this experience. Finally, the Section 5 presents the conclusions and future work.

2. Background

The IoT can be defined as a network of connected physical devices that collect, process and exchange information between themselves and other systems, without the need for human interaction [da Rosa Righi et al. 2020]. IoT devices are generally made up of sensors, microprocessors and wireless communication, components that enable the collection, treatment and transmission of data through a network in the which these devices are connected.

The advancement of technology and the reduction in the cost of hardware and components allowed these devices to be integrated into the most varied equipment, from home appliances to industrial devices. In this way, IoT has been transforming the world through smart devices that enable process automation, monitoring of production chains, in addition to providing important data that can be used as a basis for decision-making.

There is a challenge in IoT, which is the transmission range. For IoT application domains such as smart positioning system and smart agriculture, high energy efficient sensor nodes that can communicate over long distance are required. In this context, LoRa (*Long Range*) is a new family of wireless IoT connectivity that has recently evolved and is gaining popularity in low-power battery-operated embedded systems that need to transfer a small amount of data at short intervals over long range [Devalal and Karthikeyan 2018].

2.1. Milk Production Chain in Brazil

In Brazil, milk production plays a crucial role in the economy, standing as one of the main agricultural activities in the country. The milk production process is complex, involving various stages from the breeding and management of animals to the distribution of the final product.

The milk production chain begins on rural properties, where dairy cows are raised and nourished for production. Proper management, balanced nutrition, and good hygiene practices are essential to ensure the quality of milk from the outset of the process.

Milking is carried out hygienically using suitable equipment. The milk is stored under controlled conditions, typically in refrigerated tanks, to preserve its quality before transportation. Many milk producers are associated with cooperatives, which play a significant role in organizing and aggregating production. The transportation of milk to cooperative facilities is a crucial step, necessitating adequate refrigeration to preserve the product's quality.

In cooperatives or dairy industries, milk is processed to produce various derivative products, such as pasteurized milk, cheese, butter, among others. After processing, these products are distributed to regional and national markets.The commercial relationship between cooperatives and producers is based on contracts that establish supply conditions, prices, and quality standards. Cooperatives play a vital role in providing technical, logistical, and commercial support to producers, strengthening the milk production chain.

Regulatory bodies, such as the Ministry of Agriculture, Livestock, and Supply (MAPA) and the National Health Surveillance Agency (ANVISA), are fundamental in ensuring the quality and safety of dairy products. They conduct regular inspections on properties, cooperatives, and industries to ensure compliance with established norms and standards.

Milk production in Brazil is a dynamic and structured process involving producers, cooperatives, industries, and regulatory bodies. The pursuit of quality and food safety is evident throughout the production chain, with the ultimate goal of offering excellent dairy products to consumers.

2.2. Blockchain Network Technologies

Blockchain is a ledger implemented in a distributed system that records tamper-proof digital transactions, without the need for a central authority. In this way, when a transaction is published on the network, it is automatically replicated among all the nodes that compose it, so that this transaction cannot be altered or deleted after its publication [Monrat et al. 2019].

The blockchain is used in financial transactions through cryptocurrencies. This is mainly due to the strong security and high scalability of the system. Another important point about blockchain is that transactions can be verified from anywhere and at any time, enabling the generation of an immutable and secure history. These characteristics justify the use of this technology in a traceability context, such as production chains in different sectors, thus facilitating audit and inspection processes.

A blockchain network can consist of multiple nodes, with each node typically containing the following elements [Garrocho et al. 2020]:

- Rest API (*Representational State Transfer Application Programming Interface*) that receives requests from decentralized applications to request states;
- Ledger key/value based for storage;
- Smart Contract to define access and control to the states of the *Ledger*;
- Consensus Engine that runs a consensus algorithm to maintain trust between nodes;
- Validator which is the node central element and mediates the communication with blockchain network.

2.3. Milk Quality Control

Milk is an excellent combination of all macronutrients, such as carbohydrates, proteins and fats together, in excellent proportion with each other, but it also offers several important vitamins and minerals for the body. Milk, therefore, is a priceless and irreplaceable liquid that offers considerable long-term benefits for people of all ages and for society [Lambrini et al. 2021].

Milk must be produced under hygienic conditions, covering dairy cattle management and milking, conservation and transport procedures [Júnior and de Lourdes Oshiro 2017]. Still on the rural property, after each milking process, the milk produced must be immediately stored in refrigeration tanks, which can be for individual or community use, at a temperature of up to 4°C.

The collection of milk must be carried out in the place of refrigeration and storage. The process of collecting refrigerated raw milk on the rural property consists of collecting the product in a vehicle with an isothermal tank (shown in Figure 1), through a sanitary hose and pump, directly from the cooling tank, in a closed circuit [MAPA 2018].

The establishment is responsible for guaranteeing the identity, quality and traceability of milk, from collection on the property to reception at the establishment, including transport. For traceability purposes, when collecting milk using an isothermal tank car, a sample of milk must be taken from each producer or community tank prior to collection, identified and kept until reception at the industrial establishment [Júnior and de Lourdes Oshiro 2017].

The person responsible for the milk collection procedure must: have training on hygiene and collection procedures; be properly uniformed; carry out milk selection and measurements, recording the results, date and time. Compliance with these measures ensures the quality of milk.

Figure 1. Cooling tank that stores milk

2.4. Related Work

In the context of milk production, the work [Abrantes et al. 2014] discusses the most common types of fraud in milk production, as well as the main techniques for detecting them. In addition, the study also assesses the implications of fraud in the life of the final consumer.

In [Gregorio 2019] the author develops and validates an electronic system of sensors to measure physicochemical characteristics of milk through data processing to identify fraud. The study proposes the use of alternative and low-cost technologies, such as the Arduino platform, in order to reduce analytical time and cost of analyses. In [Yim et al. 2018], a study on the implementation of a LoRa network in a tree farm is presented. The authors seek to demonstrate how physical factors, configurations and different distances can influence the performance and reliability of the LoRa network in the context of Agriculture.

In their article, [Goswami and Dangi 2021] propose a milk quality monitoring system based on Arduino. The system employs sensors such as pH, gas, and temperature to detect adulterants. An Arduino is utilized to regulate the system, providing fast and reliable results, standing out for its efficiency compared to previous studies. Analyzing milk consistency is crucial to prevent adulterations, and the article emphasizes the importance of portable adulteration detection tools for farmers. The proposed system aims to monitor milk quality on the farm by detecting pH, fat, odor, and other adulterants.

The objective of the work of [Padma et al. 2023], is to develop a solution based on blockchain and IoT for managing milk acquisition and detecting adulteration. It emphasizes the need for complete traceability of milk, from production to consumption, to establish trust in delivering quality milk to society. The authors highlight the lack of transparency and traceability in the dairy supply chain as a challenge. The proposed solution involves the use of blockchain to ensure integrity and automation through IoT to track the milk.

Finally, the work [Mendonça et al. 2020] presents a technological solution related to tracking the supply chain of the dairy industry. The authors present a distributed architecture based on blockchain, that would enable the design of a traceability application for dairy production, allowing the consumer to know the entire route taken by the final product.

The work in this article seeks to integrate technologies and approaches from related works into a single system aimed at remote monitoring of milk characteristics, directly at production sites, via IoT devices connected to the LoRa network. The collected data is persisted on a blockchain network, thus increasing the degree of reliability and traceability of this information.

3. Proposed system architecture

The system architecture can be seen in Figure 2. The sensing module is strategically attached to the reservoirs where milk is stored immediately after production. A rural property may have several milk reservoirs, scattered along its length. Thus, each reservoir must have its own sensing module attached, but the collected data will be transmitted to a single receiver module.

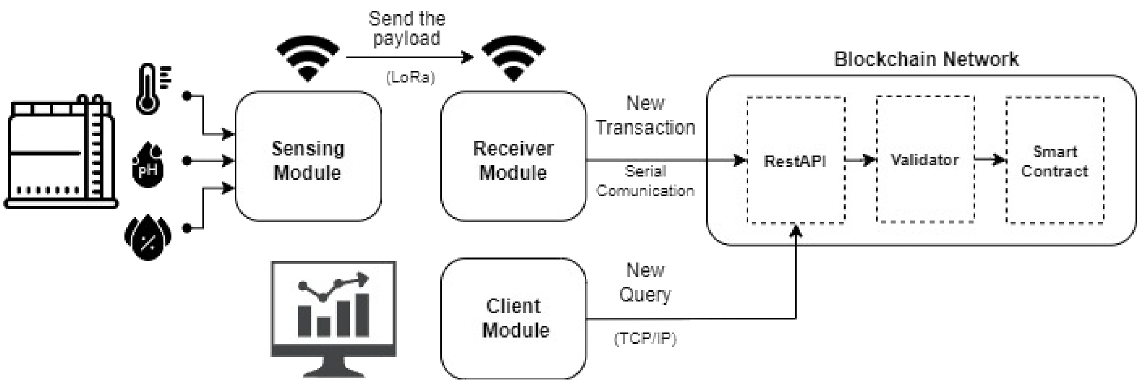

Figure 2. Proposed system architecture. The arrows represent the data being transmitted between the different components of the architecture.

In this sense, the system architecture (shown in Figure 2) is represented by the following components:

- *Sensing Module*: It is the device directly attached to reservoirs and storage tanks, in environments where milk is produced. Sensors integrated into this device allow the acquisition and initial treatment of data, referring to the physicochemical characteristics of the milk. The *Sensing Module* transmits data via wireless communication, using LoRa modulation, so it is not necessary for this device to have an Internet connection;

- *Receiver Module*: It is the device responsible for receiving the data sent by the *Sensing Modules* and publishing them on the blockchain network. The payload received is validated and converted to JSON (*JavaScript Object Notation*) format. The *Receiver Module* forwards the received data to the machine (node) that is part of the blockchain network, through serial communication;
- *Blockchain Network*: It is the distributed network that allows the immutable recording of milk quality data. This network basically has three components:
  - *Rest API*: acts as an interface, receiving requests from the *Receiver and Client Modules*, and forwarding them to the Validator;
  - *Validator*: receives these requests, identifies whether they are of the Query or Transaction type, and forwards them to the Smart Contract and other blockchain nodes. Queries are resolved by the Validator with access to the local database;
  - *Smart Contract*: only executed when the Validator receives a new transaction. Data is extracted from the transaction, validated and stored in a database.
- *Client Module*: The module refers to the application that allows viewing the data recorded on the blockchain network. It is through this module that interested parties, such as inspection bodies and cooperatives, for example, will be able to view the data of each producer that uses the monitoring system. Access to this application must be authenticated.

3.1. Milk Production Environment and System Operation

The proposed system was designed to be used in rural properties where milk is produced. In this scenario, it is common for the Internet connection to be limited, especially at the points of the property where the milk is collected, such as corrals, sheds or cattle confinement environments. Generally, these structures only have the essential components for handling the animals, without Internet connectivity.

Generally, the cooling tank, responsible for storing and cooling all the collected milk, is installed in these environments or nearby. The tank, shown in Figure 1, it stores and maintains the temperature of the milk within established limits, until it can be collected by trucks, which transport it to the dairies or factories for processing. In this system architecture, the *Sensing Module* is attached to the tank lid.

The Figure 3 presents the sequence diagram of the functioning of the system. The *Sensing Module* installed in the tank monitors the variables inherent to the quality of the stored milk, via sensors integrated into the device. The data is represented by a payload, which is generated following the JSON format. The payload (see Listing 1) consists of: collection date/time; device identification; and the data measured by the sensors.

The *Receiver Module*, in turn, has the function of receiving data from the *Sensing Module* and send them to a network node blockchain. In this step, it is necessary that there is an Internet connection in the place where the *Receiver Module* is installed. The Rest API component of the blockchain node receives the data and forwards it to the Validator to replicate the transaction with other nodes and activate the Smart Contract to validate the data and store it.

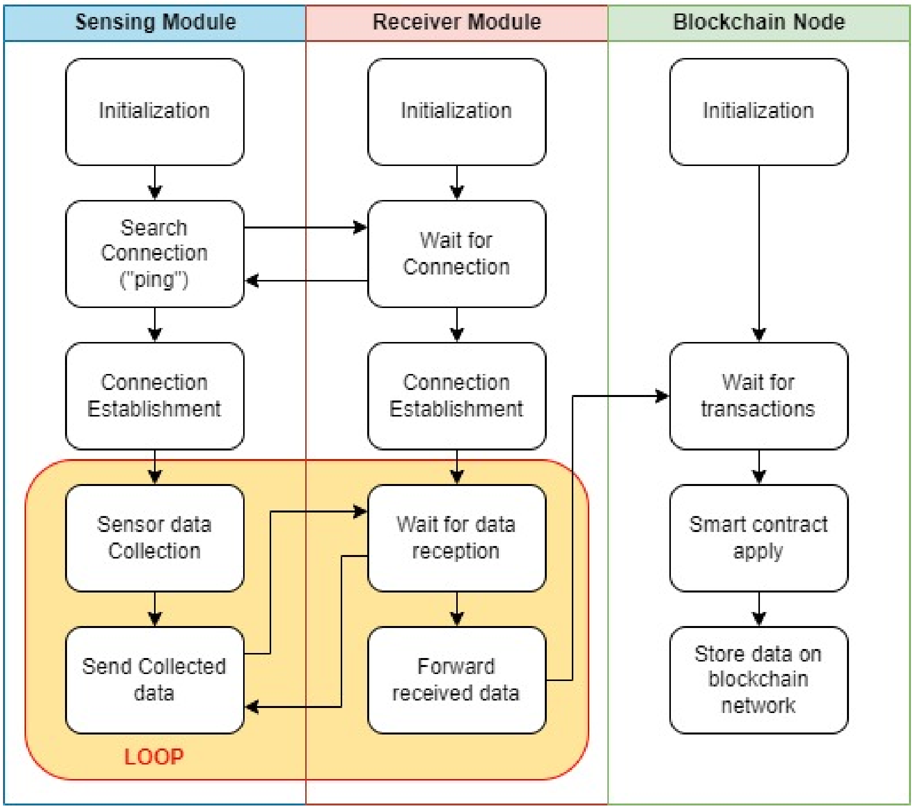

Figure 3. Sequence diagram of the proposed system. The arrows represent state changes, while inside the Loop they also represent sending data.


```
{
    "timestamp":"2023-05-27T05:13:38+00:00",
    "deviceId":12345,
    "ph":6.14,
    "temperature":20.05
}
```


Listing 1. Payload created and transmitted by the Sensing Module.

The implementation of the proposed system would make the milk production process safer and more transparent. Next, we present some algorithms to represent the collection, sending, validation, and storage of measurements. Algorithm 1, executed in *Receiver Module* presents the function MAKESENDTX which receives the key and connection with the *Sensing Module*. This algorithm has a loop consisting of the repetition of receiving measurements to create the transaction with Function MAKETX. After creation, the transaction is submitted to a Rest API from a blockchain node with the SENDTX function. Next, the transaction ID (*tx_id*) is returned with its status of processing on the blockchain network.

Algorithm 1 Collecting and sending measurements to the blockchain node.

```
function MAKESENDTX(key, conection)
    do
        measurement ← conection.receiveData()
        transaction ← MAKETX(key, measurement)
        SENDTX(transaction)
    while conection.connected
end function
```

3.2. Smart Contract and Virtual Stamp

The Smart Contract plays a fundamental role, as it has the function of validating the data received by the *Receiver Module*, mainly those referring to the values measured by the sensors of the *Sensing Module*. In this way, it is possible for producers, dairy products and inspection bodies to establish minimum and maximum values for each monitored variable, based on legislation. These agreed values will be used by Smart Contract to validate each measurement received.

Algorithm 2 declares the main operations of a Smart Contract for validating and storing new measurements. The APPLY function is performed every time the Smart Contract is triggered by the Validator component. Generally, the APPLY function performs three operations: extracting information (identification, data, keys, etc.) from the transaction received with EXTRACT; validation of measurements and generation of a stamp with VALIDATEOPERATION; and storing a new stamp in Ledger from key and system context.

Algorithm 2 Smart Contract for data validation.

```
function APPLY(transaction, context)
    key, measurement ← EXTRACT(transaction)
    stamp ← VALIDATEOPERATION(measurement)
    context.set_state(key, stamp)
end function
```

At this point, we propose the implementation of a *Virtual Stamp* consisting of a set of data that includes information on the producer, tank and location where each measurement was carried out, and measurement data. In addition, a field referring to the status of the measurement can be used to signal when the measured values are respecting or not the limits agreed in the Smart Contract. Listing 2 presents an example of the structure of the *Virtual Stamp* that is generated and stored in the blockchain network.

The *Virtual Stamp* is a non-fungible token, a proprietary digital certificate that anyone can see and confirm authenticity, but no one can change. Thus, the *Virtual Stamp* is a communicable object digitally signed by the sender (*Receiver Module*) that wants to validate the measurements collected by the *Sensing Module*. In addition to the information shown in Listing 1, the *Virtual Stamp* has a digital signature represented by the public key of the *Receiver Module*.

Furthermore, it is important to note that each blockchain node receives the payload, triggers the Smart Contract, generates the *Virtual Stamp*, and stores it in its local database. In this way, it is possible to guarantee greater reliability and decentralization in the data evaluation process regarding milk quality. This decentralized validation process ensures greater agility and transparency, as the stored stamps can be accessed by producers, consumers, and auditors.

3.3. Virtual Stamp and Use of Collected Data

The implementation of the system requires not only emerging technologies but also effective validation and traceability mechanisms. In this context, we propose the introduction of a Virtual Stamp as a digital certificate, aggregating crucial information from the measurement and validation process. It is important to highlight that for the system to function, prior configuration is necessary with the registration of producers and sensors.

3.3.1. Functionality of the Virtual Stamp

The Virtual Stamp is a non-fungible token that ensures authenticity and immutability to the associated data. Each label contains detailed information about the producer, property, reservoir, and the status of the measurement performed. The example presented in Listing 2 illustrates the label's structure, including data such as the measurement timestamp, the identification of the device used, and pH and temperature values.

```
{
    "producer": "Thulio␣Fernando␣Andrade␣Fonseca",
    "producerId" : "prod001",
    "property" : "prop001",
    "tankId" : "tk001",
    "status" : "disapproved",
    "measurement" : {
        "timestamp" : "2023-05-27T05:13:38+00:00",
        "deviceId" : dev001,
        "ph" : 6.14,
        "temperature" : 20.05
    },
    "causeOfDisapproval" : "temperature"
}
```

Listing 2. Stamp generated by the Smart Contract.

3.3.2. Validation on the Blockchain Network

The Virtual Stamp is generated by the Smart Contract, which validates the data received from the sensors. This validation can be implemented according to business needs and rules, such as the maximum and minimum limits for temperature and pH readings established by current legislation.

By adopting the Virtual Stamp, regulatory bodies can directly access the labels stored on the blockchain, enabling efficient and reliable audits. Complete traceability from production to storage facilitates the identification of potential issues and the implementation of corrective measures.

Cooperatives and dairies adopting the proposed system can use the Virtual Stamp to optimize the management of the received milk's quality. The label provides a detailed view of each measurement, allowing informed decisions on the acceptance or rejection of batches and strengthening consumer trust in the origin and quality of the product.

Moreover, dairies, cooperatives, and/or regulatory bodies could be notified when milk outside the standards is detected on any property using the system. In this case, the Virtual Stamp would be crucial to justify the measures taken after detecting out-of-specification milk on the respective property. Additionally, the decentralization of the validation process, with each blockchain node verifying and storing the label, ensures transparency and reliability.

Thus, the Virtual Stamp represents an essential innovation in ensuring milk quality, providing an effective tool for monitoring and validating measurements taken in remote locations. This approach not only strengthens transparency but also empowers different stakeholders in the milk production chain in the pursuit of excellence in the quality of the final product.

4. Proof of Concept

Aiming at testing and deployment in a real milk production environment, we developed a proof of concept based on the architecture proposed in this work. As illustrated in the Figure 4, the proof of concept is composed of two main embedded modules:

- *Sensing Module*: responsible for collecting milk data in locations without Internet connectivity. Consists of a development board based on the ESP32 Microcontroller, a LoRa communication module (ebyte e220-900t22d), an RTC-DS1307 clock module, a DS18B20 temperature sensor and a PH4502C pH sensor;
- *Receiver Module*: is positioned in strategic locations on rural properties and intermediates the communication between the *Sensing Module* and the blockchain network. Consists of a development board based on the ESP32 microcontroller and a LoRa communication module.

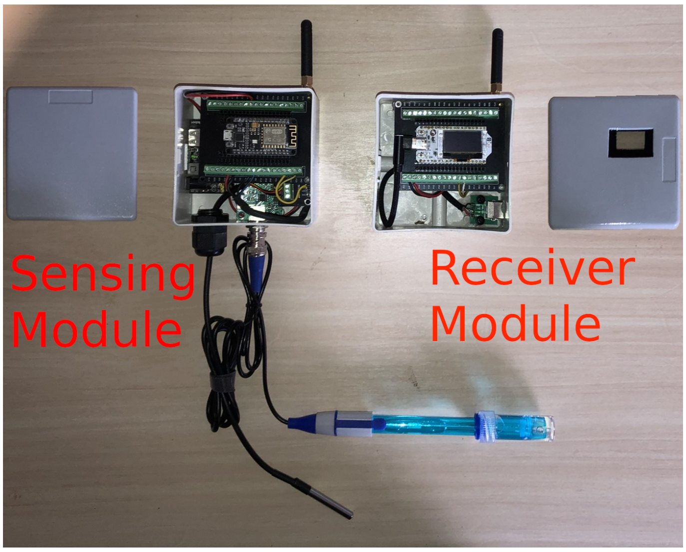

Figure 4. Sensing and Receiver Modules.

For blockchain network configuration, we adopted HyperLedger Sawtooth[1] for the following reasons: highly modular platform that separates the core system from the application level; supports permissioned and permissionless infrastructure; allows parallel processing of transactions; Ethereum contract compatibility; pluggable consensus mechanisms; multilingual support (Python, JavaScript, Rust, C++ and Go); and Byzantine fault-tolerant. For our proof of concept, we define Sawtooth as an allowable infrastructure and PoET (*Proof of Elapsed Time*) is used as a consensus algorithm.

Our implementation presents a test environment that can be built using Docker Compose[2], a tool for defining and running Docker applications from multiple containers. We build a container for each actor in the scenario shown in Figure 2. The Rest API, the Validator and the consensus mechanism run in separate containers and are assembled from images provided by Sawtooth organization. Sawtooth Clients (referring to the *Receiver Module*) and Transaction Processor (referring to the Smart Contract) were developed exclusively for this proof of concept.

In addition to Sawtooth's three blockchain nodes, we also deployed a monitor node to collect real-time Sawtooth network performance metrics using InfluxDB[3]. The GitHub repository[4] contains the source code (with network configuration blockchain, *Receiver and Sensing Modules*, Smart Contract, etc.) used as the basis for this proof of concept, which we named *EspLoraChain*. All choices and definitions (platforms, consensus algorithms, and others such as placement of blockchain nodes) presented in this section, follow a step-by-step methodology for defining, deploying and monitoring blockchain networks [Garrocho et al. 2021].

5. Final considerations

The implementation of the proposed system make the milk production process safer and more transparent. The use of a blockchain network associated with the continuous collection of data inherent to the quality of milk, through IoT devices, would allow the monitoring and monitoring of these characteristics by interested parties, such as: producers, dairy products, factories and inspection bodies.

5.1. Deployment and Challenges

For successful deployment, modules need to be located at points with effective and stable communication with each other. For the sensing module, an installation close to the cooling tank would be necessary in order to allow the collection of data through the sensors incorporated in the module.

A challenge would be the implantation of these sensors in existing tanks, since access points to the product stored in the tank would be necessary. One possibility would be to use the access points of the sensors already integrated into the tank, used to control the temperature of the tank.

Another important challenge to be faced would be to define which sensors would be most adequate and relevant for the milk quality monitoring process. This implies a

[1] `https://sawtooth.hyperLedger.org/`
[2] `https://docs.docker.com/compose/`
[3] `https://www.influxdata.com`
[4] `https://github.com/ThulioFonseca/EspLoraChain`

deeper study of the needs of the process and market options, in addition to the criteria established by the current legislation of each country in which the system was applied.

In this regard, it would also be necessary to implement procedures and routines for cleaning, calibrating/gauging the sensors, in order to guarantee the reliability of the collected information. Regarding the receiver module, it is essential to have Internet connectivity at the point of installation, only then will the data stored in the node be distributed over the blockchain network.

5.2. Conclusion and Future Works

The integration of technologies such as IoT, wide area networks and blockchain in agribusiness represents an important advance for the sector. The combination of these technologies for the development of innovative solutions can bring many benefits in addition to directly impacting the quality of field products.

This work presented a technological and innovative solution to assist in the management of milk quality, focusing on the initial stages of production. The IoT enables the continuous collection of data, which can become valuable information regarding the monitoring and monitoring of milk quality parameters. In addition, the use of LoRa modulation in the transmission of collected data represents greater flexibility for system implementation, reducing infrastructure costs and expanding usage scenarios.

Furthermore, the blockchain technologies, with its ability to track and verify the origin and authenticity of the data collected, enables greater transparency in terms of how milk quality is treated, in addition to optimizing inspection steps by regulatory bodies, thus building a solid base of trust among producers, suppliers and consumers.

As future works, we hope to carry out performance tests of the proposed system, seeking to evaluate more forcefully the efficiency of the system. In addition, we hope to carry out a more in-depth study of the specific needs of the sector and ways of implementing them. It is important to highlight that the proposed solution is not restricted to monitoring milk quality. This solution has modularity and flexibility that would allow its use in several sectors, such as Industrial, for example.

Given this scenario, we believe that the use of technologies such as IoT, smart contract, and blockchain in agribusiness is a promising path that opens doors to the modernization, transparency and growth of this essential sector for society.

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