IoT System for Smart Bekeeping

Petar Lukovac
Faculty of Organizational Sciences
University of Belgrade
Belgrade, Serbia
petar.lukovac@elab.rs
[0000-0003-4561-8886]

Milica Simić
Faculty of Organizational Sciences
University of Belgrade
Belgrade, Serbia
milica.simic@elab.rs
[0000-0002-6870-2303]

Božidar Radenković
Faculty of Organizational Sciences
University of Belgrade
Belgrade, Serbia
boza@elab.rs
[0000-0003-2111-7788]

Abstract—This article tackles the problem of creating an IoT (Internet of Things) system for smart beekeeping. The goal is to propose an infrastructure that could provide necessary information to prove the organic origin of honey and other honey-based products. The infrastructure includes multiple sensors which are gathering data about the location of the hive, air quality, production process and other essential data. The system also includes streaming collected data to cloud database and blockchain network. This article analyses different solutions and proposes a model of the IoT system for smart beekeeping. The article also shows an implementation of the prototype for the described system.

Keywords - IoT, smart agriculture, data streaming, blockchain

I. INTRODUCTION

Usage of IoT devices is getting more applications in different areas of economy [1]. Smart environments enable easy access to the data, overlooking key process activities and wide range of information that can later be used to predict future behaviors [2].

IoT-based ecosystems in agriculture can be divided into three key types: system for monitoring, system for tracking product origin, and system for managing greenhouses [3]. The goal of this paper is to monitor honey production and gather essential data. This includes data about the location of the beehive, air quality, possible pollution of the land, etc. Interconnected and efficiently located IoT devices gather data from different sensors in real time. This helps to create a more efficient system, with minimum requirements for human interaction and barely any room for error [4].

Conventionally, IoT systems send all data to cloud server [5]. This enables a simple way of accessing information for all stakeholders and setting up an uncomplicated web application. But one of the problems with this approach is that all data is stored on a centralized server managed by a third party. The solution to this problem can be found in using blockchain network. As decentralized character and immutability of data are some of the key qualities of a blockchain network, we can use that to our advantage to solve shortcomings of a cloud database. Critical data gathered using IoT can be stored on the blockchain network to prove that data has not been manipulated at any moment. Additional data will still be stored using centralized cloud databases.

II. RELATED WORK

Different authors have explored similar areas related to smart environments and their usage in agriculture and beekeeping more specifically.

Authors from [6] implemented an automated IoT based system for beekeeping. The prototype is specifically designed to provide data about the conditions inside the beehive. Noises, temperature, and humidity data are monitored in real time. This data is accessible to farmers through a mobile application.

Other authors highlight un-controlled temperature, humidity and traditional beekeeping management as main issues in maintaining bee populations [7]. They propose creating a self-powered monitoring system that can use energy from ambient sources to run, rather than needing to be connected to the power grid.

Authors Fitzgerald et al. emphasize the weight of the colony as one of the key metrics for tracking a beehive. They state that weight data relates to health, conditions, and productivity of the beehive [8].

Developing IoT systems usually implies communication between heterogeneous wireless devices. A gateway is needed to convert different types of data through parsing and re-encapsulating [9].

One of the problems when implementing IoT systems outside urban areas is transferring data over long distances. Traditionally used cellular networks are high on power consumption and hence not applicable in these scenarios. The solution can be found in low-power, wide-area (LPWA) technologies. LoRa technology is considered one of the leading emerging technologies [10]. Key advantages of LoRa are ability to transfer data over long range and low interference with its signal [10].

III. MODEL PROPOSITION

Having in mind similar problems and solutions from other articles, in this paper a model of the IoT system for smart beekeeping is proposed.

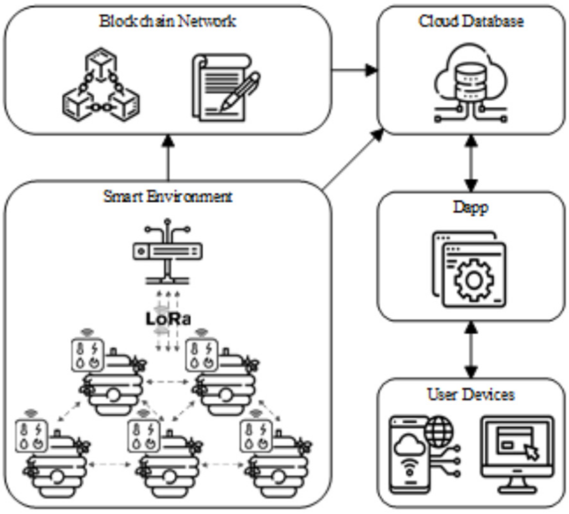

Fig. 1. Software architecture of the IoT system for smart beekeeping [11]

Figure 1 shows the software architecture of the IoT system for smart beekeeping. Every beehive is equipped with a device that gathers sensory data from the beehive and its surroundings. Sensors measure air quality including levels of carbon monoxide, carbon dioxide, oxygen, and chemical pollutants in example NO_2, H_2, NH_3. Sensors also collect data about temperature, humidity, and changes in location of the beehive. Since sensory devices can be spread over a wide area, a gateway is needed to collect and aggregate data and pass it further to the system. Communication and sending data over long distances is applicable use case for implementation of LoRa technology. Data is then collected using a gateway and passed further to the system.

All collected data is passed to a cloud database. Critical data that can be used to prove origin and organic qualities of honey is first passed through blockchain network to ensure truthfulness and immutability. Algorand blockchain platform is used to send data quickly and at a low price. Algorand relies on Pure Proof of Stake algorithm which enables security, scalability and decentralization at the same time [12], [13]. A web-based distributed application is used to provide real time access to information to the beekeeper, but also other stakeholders such as distributors, wholesalers, and end customers. Collected data can be used for future analysis and predictions.

The goal of the proposed system is to provide real-time data to beekeepers, but also make the IoT system for smart beekeeping efficient. Considering these two opposing conditions, frequency of getting data from sensors is an important factor. Providing data in shorter periods results in a more precise system and more data for future analysis. On the other hand, large amounts of data can be difficult to transfer and expensive to store. We need to bear in mind that when moving from a controlled environment to a real environment, power consumption can become an important factor. Putting sensors to sleep can make the system more power efficient. Considering that some sensors need at least 30 seconds to warm up and prepare before outputting reliable data, an interval of logging data should be no less than 60 seconds.

Many gas sensors react to different gases, a term known as cross sensitivity. For example, MQ-2 sensor can detect propane, hydrogen, methane, carbon monoxide, etc., but we cannot be entirely sure if the detection of the targeted gas is affected by other gases. Using multiple different types of sensors and combining their output to differentiate between targeted gas and others can improve quality as well as reliability of data [14].

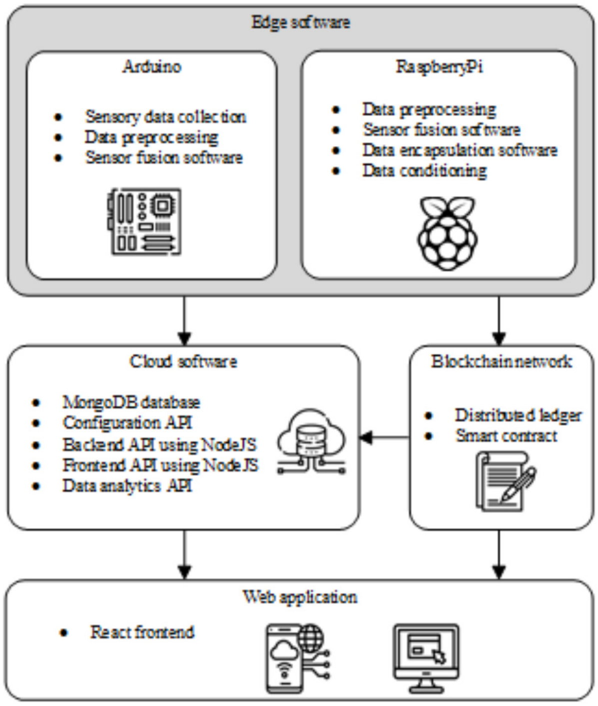

Fig. 2. Software components of the IoT system for smart beekeeping

Figure 2 shows proposed software components for the IoT system for smart beekeeping. Traditionally, IoT systems relied solely on the computation power from external sources, sending all data to cloud. In this case, cloud infrastructure is not very efficient, due to the long latency [15]. Implementation of edge computing reduces the amount of data that is being sent through the system, partly relying on computational power of IoT devices. This way, tasks are only partly transferred to the cloud network.

Arduino microcontroller contains software for gathering sensory data as input, but it is also used as a part of edge computing infrastructure. One Arduino gathers data from sensors attached to one beehive. Data is then preprocessed to an appropriate format. For example, if a sensor outputs temperature in degrees Fahrenheit, we can translate it to degrees Celsius right at the source. Multi-sensor data fusion software is used to combine large volumes of data into single output [16]. Sensory data fusion software is needed in the proposed IoT system for smart beekeeping to aggregate air quality data from multiple sensors into a more accurate and useful output. Another advantage of this approach is that it enables us to avoid usage of precise sensors with high power consumption and instead use multiple low power consumption sensors, which combined can give accurate information [17].

Similar processes are also executed on Raspberry Pi microcomputer. Here we use data fusion to combine data from multiple hives and transform them to the needed format that can be sent further through the system to the cloud database and blockchain network.

On the cloud, MongoDB database is used. Using a document-based database enables writing data in looser format than SQL databases, which is beneficial for writing sensory data. Multiple APIs are also deployed on the cloud for configuration, writing sensory data to database, implementation of operations used on the web application, etc. Configuration API is implemented for determining how the system operates and for making future changes. It enables us to change configuration settings without modifying the code. For example, we can change reading intervals on sensors used in the system and make the system more dynamic. Implementing configuration API can help to set up security and authorization restrictions. Backend API is tasked with gathering sensory data and writing them to the database. It is also used for performing data processing operations. Frontend also needs its own API. This API will mostly deal with reading data from database and sending them to the web application. It also involves implementation of data analytics that will help beekeepers notice trends in the beehive environment.

Essential data for proving the origin of honey is uploaded to a distributed ledger. On the blockchain network, a smart contract is deployed to check if all conditions that prove the origin of the honey are fulfilled. The smart contract will also form a part of the backend of our web application. Availability of smart contract data increases trust in the system.

All data is available to beekeepers through a web application implemented using React library. The proposed design of a web application used by beekeepers is shown in Figure 3.

Beekeeper receives scheduled daily notification about the state of the hives. In case there is an indication that parameters are out of desired scope, beekeeper will get an alert with an appropriate information. Using the application, beekeeper is also able to schedule maintanance of the beehives and important dates, such as checking the beehives, moving the beehives, collecting honey, etc. Data analytics is also available with a goal to help beekeeper understand trends in the environment where beehives are located.

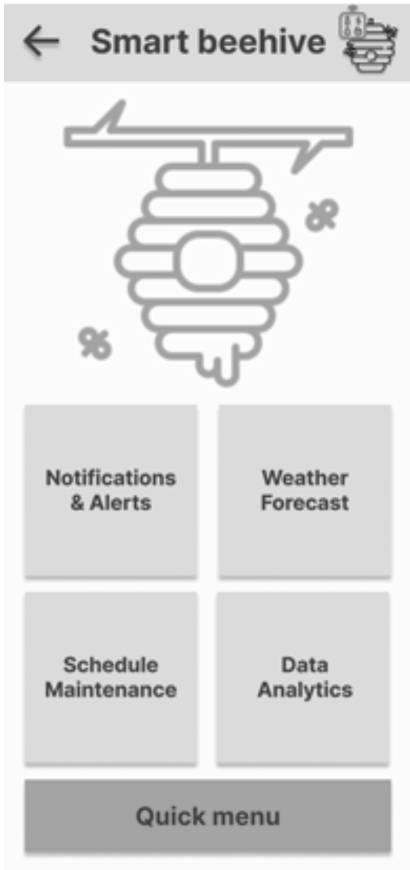

Fig. 3. Web application design

IV. IMPLEMENTATION

The implementation phase includes the development of a prototype for a smart beehive. For collecting data about air quality, we propose using MQ-135 and MQ-2 sensors to detect gases such as ammonia (NH_3), carbon dioxide (CO_2) and carbon monoxide (CO). For measuring levels of temperature and humidity, DHT11 sensor can be used. All sensors are connected to Raspberry Pi microcomputer which sends data further to the network.

Communication between devices is performed using LoRa wireless modulation, which enables easy and cheap transfer of data over long distances with low power consumption. On top of LoRa, LoRaWAN protocol is used to define way of transmitting and formatting of the messages [18].

Considering that large amounts of data are expected from IoT system with numerous writing operations, NoSQL databases are chosen for storing data on the cloud [19]. Bulk insert of data enables inserting multiple records in a single operation improving writing performance. For this scenario, best results are expected from MongoDB according to the experiment from [20].

The prototype of the smart beehive will be tested in a controlled environment to check for problems in implementation and potential improvements.

V. CONCLUSION

Implementation of the IoT technology in traditional industries, such as beekeeping, automates gathering of essential information and thus improves efficiency of processes [21]. Having real-time information enables fast response time in case problems arise. Sensory data helps beekeepers, but also provides additional information to other stakeholders. Information about origin, location, air quality etc. are significant to final consumers. Proving the high quality of the honey helps final consumers make fact-based decisions when buying final product. This is especially important considering the fact that according to newly organized EU action "From the Hives", 46% of honey tested on the EU market proved to be mixed with sugar sirup [22][23].

Considering the large amounts of data that can be gathered using IoT, future work in this field could include developing a cloud infrastructure for managing data streaming.

In the future, the IoT system can be expanded to collect data from other stakeholders such as distributors and wholesalers. This would allow tracking honey through the whole supply chain providing fast and open access to data.

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