International Journal of Advanced Engineering Research and Science (IJAERS)
Peer-Reviewed Journal
ISSN: 2349-6495(P) | 2456-1908(O)
Vol-8, Issue-10; Oct, 2021
Journal Home Page Available: https://ijaers.com/
Article DOI: https://dx.doi.org/10.22161/ijaers.810.23

Conceptual model of IoT architecture for poultry farming

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Received: 14 Sep 2021,

Received in revised form: 10 Oct 2021,

Accepted: 20 Oct 2021,

Available online: 25 Oct 2021

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***Keywords*— Internet of Things, Poultry Farming, User experience.**

***Abstract*— The data connection between machines and people is one of the pillars of Industry 4.0 and the Internet of Things, boosting productivity in healthcare, manufacturing, logistics and smart cities. However, in the case of agribusiness, projections indicate a lower diffusion of these technologies, mainly due to the difficulty of their access by rural producers, especially in cases of smaller scale production. For rural producers who have access to this type of technology, there may be a difficulty in the usability of existing IoT applications, that is, users in the rural context may not feel familiar with the available graphical interfaces and end up not using the applications. This work aims to propose a data management architecture based on the IoT paradigm for small producers in the poultry sector, presenting a mapping of needs and priorities among stakeholders. As a result, an IoT architecture model in three layers was proposed, being the physical layer, the software layer and the data analytic layer. It is concluded that with the use of this tool, small producers will be able to make better decisions, identify poor performance and act quickly, economically, simply and ergonomically in meeting the requirements of international competitiveness, when compared to other producers in the same region.*

I. INTRODUCTION

Digital transformation is important for the performance of the agribusiness production chain as a whole, however, in Brazil, these evolution of industry 4.0 lead to a process of social selectivity [1]; the growing complexity of rural management, coupled with the difficulty that most small producers have in appropriating adequate technological knowledge, and the condition of implementing a digital architecture in their properties is causing some small rural producers to give up on maintaining themselves in their traditional production activities and migrate to the production of commodities aimed at the foreign market.

Brazil is the third largest poultry producer in the world (10.90% of world production in 2020), behind only China (16.94%) and the United States (17.15%), it is estimated that less than 1% of 180 thousand producers have some kind of automation and real-time control in their aviaries [1][2]. Paraná, the largest poultry producer in Brazil (33.4% of the national total), has about 921 aviaries (6% of the total slaughterhouses) with some type of automation [1].

Technologies used in smart agriculture include low-cost hardware devices, sensors and actuators that, when installed in specific locations, monitor and act in accordance with the objectives defined by the business rule, supporting their decision-making and providing greater efficiency in management [2]. However, there are still barriers in the implementation of IoT systems aimed at rural activities, whether due to the costs of implementation and maintenance or the lack of local infrastructure such as, for example, internet access, resistance on the part of producers and even difficulties in obtaining of credit lines destined for these projects. Another obstacle, which touches the adhesion of technological solutions, is the lack of identification of the user with the existing applications [3][4][5]. What happens is a large number of applications with non-useful or non-intuitive resources, which lead to discouragement [5]. In this context, user experience elements became relevant for the development of applications, understanding their audience and their demands, not only meeting the business rules [6][7].

In this context, this research aims to propose a low cost and open source IoT data management architecture model for small producers in the broiler production chain, considering the user experience and usability aspects.

II. AGRIBUSINESS 4.0

The evolution of agriculture and livestock is closely linked to industrial revolutions. In a historical context prior to the first industrial revolution, all rural work needed the support offered by animals for the strength and traction of implements such as the plow. Around the 18th century, with the first industrial revolution in progress, it was possible to give more flexibility to some manual and craft tasks with the use of steam engines [8].

Only in the 19th century, with the second industrial revolution, it was possible to mechanize agricultural activity by replacing animal-drawn machines with combustion engines. It is noteworthy that fertilizer and crop protection biotechnologies and their spraying methods could also be boosted [9][10]. The 20th century witnessed the third industrial revolution, accompanied by information and communication technologies, with software capable of optimizing field management and allowing more accurate measurements of productivity, in addition to process automation [10][11], also known as agriculture of precision. Precision agriculture is the predecessor of digital agriculture (Agriculture 4.0) and is mainly characterized by the use of machines and technologies.

This new agriculture, until then, was characterized by making available a series of resources that involved biotechnology, corrective fertilization, pesticides, management techniques, GPS and increasingly modern and automated agricultural machines [8]. In summary, it is possible for the farmer to control the harvest through information and treat each area as unique, recognizing the differences in each region. The fourth industrial revolution [9] was also characterized by hyperconnectivity between those involved in the real-time agribusiness production chain, known as Agribusiness 4.0; this new scenario makes it possible to be present in the field without the need for an on-site worker, thanks to the intelligent automation of rural data collection and monitoring.

Pragmatically, “agriculture 4.0 is a set of innovations aimed at advanced technology, which aims to improve, optimize and monetize productivity in the field” [10]. The demand for optimization in the use of natural resources and inputs made farms migrate from agriculture 3.0 to agriculture 4.0, that is, it began to be monitored and massively automated. One of the first adaptations is the dissemination of sensors dispersed throughout the property and interconnected to the Internet, generating data in large volumes that need to be stored, processed, analyzed and made available for decision-making in rural areas [11].

III. POULTRY FARMING

Activities related to the process of production and marketing of agro-industrial products are named according to the perspective used. The term production chain or agro-industrial production chain defines activities based on a particular final product [12]. Among the various activities in poultry production, the highlight is the fattening of poultry for slaughter, especially broilers; therefore, this research includes the chicken production chain that falls under the poultry category, which also includes the production of fertilizers, eggs and other chickens [12][13]. The historical panorama of the broiler production chain begins in the mid-1950s, when poultry farming was basically a subsistence activity. Poultry farmers and agribusinesses started the integration process, which sought to improve the process from breeding to slaughter [12][14]. With this, agribusiness was able to schedule its annual production, obtain greater use of facilities and reduce costs [13][14].

Later, in the 70s, the agricultural sector underwent a process of modernization introduced in the technical bases of production and production processes. During this period, the poultry agroindustry stood out as a modern segment, which invested in the activity and established partnerships with foreign genetic improvement companies [12].

However, it was from the 1990s that the chicken meat production chain gained greater visibility in the Brazilian and world agribusiness scenario, thanks to the diversity of technological resources and effective management [14]. In the 2000s, the strong growth of Brazilian production was noticeable due to the improvement of processes and the sanitary quality of the herds and also to the significant improvement in the income of the Brazilian population, which brought a significant growth in domestic consumption [13][14] and led to the conquest of the foreign market.

IV. INTERNET OF THINGS

The concept of the Internet of Things is related to a physical entity of individual interest (thing) - an object such as a bicycle, an industrial machine, an air conditioner in a room, security cameras triggered by motion detection, lamps with control of lighting, etc. [15]. Depending on the nature of the "thing" (device), different technologies are used to connect them to the internet, such as identification devices (RFID, tags or barcodes), monitoring devices such as sensors (temperature and other sensors, cameras in vehicles, door locks or window openings) and actuators. According to [15][16][17], the IoT consists of a global network of billions of uniquely identifiable (and addressable) objects, embedded with sensors, actuators and controllers) and these are wirelessly connected to the Internet. The International Telecommunications Union determines the IoT as a dynamic global network infrastructure that can self-configure using interoperable standards and protocols where things (physical and virtual) have identities, attributes and personalities, use intelligent interfaces and can integrate seamlessly with the network [16][17]. IoT technologies are classified into three types: i) Detection and data collection technologies: they are responsible for detecting and collecting information about the physical environment (such as temperature, humidity or light sensors) or about objects (identity, status, energy level). ii) Data communication technologies: configure the way data transmission occurs in a given application. They can be classified into two main categories: wired or wireless. Wired technologies require an adequate physical infrastructure to run cables, which can be expensive and unfeasible in some cases. Wireless technologies require fewer physical hardware connections, making it easier to deploy in hard-to-reach locations or scarce electrical resources. Wireless communication means include wi-fi, Bluetooth and mobile data communication. iii) Data storage and analytics technologies: these encompass IoT applications, data analytics and management, and application platforms. In general, it can be said that IoT applications are running software that coordinates the interaction between people, systems and devices in the context of a certain purpose [15][16][17].

Over the years, several projects related to the Internet of Things (IoT) have specified their own architectural versions, based on the specific requirements that the projects were addressing [18][19][20]. Depending on the project scope or problem domain to be addressed, architectures were focusing on different aspects or on a subdomain of the IoT without a consolidated and always adaptable architecture [21]. According to [22], due to a great heterogeneity of application domains and, consequently, of requirements, the approaches to specify the architecture differed among the projects, resulting in more or less different architectures, composed of a series of components and protocols. Also, according to the author, this resulted in limited interoperability between systems, which also hampered discussions between domains. A survey by [23] indicated that the opinion of the IoT community is that IoT reference models are needed and the main goals of a common model are to enable interoperability between solutions, promote common understanding of IoT and facilitate integration with other systems. The most important components of an IoT reference model are terminology, interface, interaction model, standards, communication model and information security models.

V. USER EXPERIENCE

The concept of User eXperience (UX) can be commonly understood as subjective and context-dependent [24][25], UX is defined as "The perceptions and responses of a person that result from the use of a product, system or service". With the development of new technologies, users not only seek to perform a task, but also to have fun [26].

Usability from an interface design point of view is not enough to define the quality of a software and obtain user acceptance [25]. The product can be useful in technical matters, but unpleasant and not acceptable by most users [26]. It is in this context that UX and usability fit, covering details about the interactions between users and the product, from the perception of how the product works and whether their goals, needs and expectations are met in any context in which they use the product [27]. According to [25], UX is focused on meeting human needs beyond the instrumental, that is, beyond task-oriented aspects, to enrich product quality and create a holistic interaction [28][29]. Garrett's method for designing digital products that enhance the user experience requires elements that must be taken into account.

In the site objectives and user needs layer are business goals, creative goals, or other goals that originate internally for the site, along with the strategy of meeting the user's needs. The second layer: content requirements and functional specifications, requires the definition of the content elements needed by the website to meet the user's needs, as well as the detailed set of functionalities that the application must contain to meet the users' needs [28]. Information design is the presentation of information to facilitate understanding. Information architecture, on the other hand, refers to the structure of information on the screen to facilitate intuitive access to content. The information design refers to how the information will behave on the screen in order to facilitate the user's understanding, in this element are the navigation design: interface elements to facilitate the user's movement through the information architecture [29]. The interface design aims to facilitate user interaction with system functionalities. Finally, visual design refers to the visual treatment of text, GUI elements and navigation components [27][28].

VI. METHODOLOGY

The research is exploratory and qualitative in nature, and the procedures to meet the research objective are described below: Data collection through interviews with stakeholders in the poultry production chain. The data analysis step used the "Needs Matrix" to rank stakeholder needs and priorities for an efficient IoT architecture. Finally, the conceptual model of the proposal is presented, meeting the requirements identified in the interviews and contemplating the technologies for the development of IoT applications.

VII. MAPPING PRIORITIES AND NEEDS

The information was collected through interviews with four poultry farmers, a poultry slaughtering agroindustry manager, a cooperative coordinator and a municipal server from the Agriculture and Environment department, totaling seven respondents. As for the issues of the relationship between producers and agribusiness, respondents mention that they receive advice from agricultural technicians, veterinarians and zoo technicians with information about birds, diseases, feed, animal welfare and other technical information on production [13].

Respondents mention that the partnership with agribusiness, also known as integration, takes place through the provision of services, agribusinesses provide chickens with up to three days of life to poultry farmers, who provide their labor and physical space (farm) for the carrying out the growth and fattening work. The complete cycle takes 45 to 50 days. For remuneration, the elements listed by respondents were: mortality rate, feed conversion rate, occurrence of diseases and inspection after slaughter, which calculates the average size and weight of chickens per batch [15]. Thus, the remuneration for the producer, in this partnership, depends on the good management of the aviary [13] [14].

These elements of remuneration are directly related to practical issues of production and management, being the greatest opportunity for the implementation of IoT devices, since the growth and fattening phases of the chickens are the most relevant for increasing the productivity and profitability of the producer [10][12][15][16].

To identify technological gaps, the researcher addressed the questions about which information technologies have access. Immediately, respondents responded that they have an application developed by the cooperative to request feed and other inputs for production; through the application it is possible to estimate the cost of raw material and check your purchase history; they also have access to the daily quote for chicken, corn and soy through the app and can consult the weather forecast [10][12].

Asked which IoT technologies exist for real-time management of handling processes, the poultry farmers mentioned that they are services offered by outsourced companies, but none of them contracted the services and the mentioned impediment was the high cost of implementation; one respondent mentions that he does not feel the need, as his production is small and his family is able to manage, but he stressed that he is interested in modernizing his farm, thinking of expanding production in the future [11][8]. Although none of the producers interviewed have a system in place, two of them mentioned the name of two companies that provide this type of service and claim to know neighboring producers who contracted this technology.

VIII. IoT CONCEPTUAL PROPOSAL

For the modeling, the layered model was adopted, since for the context of the broiler production chain the layered IoT architecture is appropriate because users already have their financial/accounting control systems, and the purpose of the architecture it is not to overwrite existing systems [16][17], but to include in the production routine another application to support in-situ production control. Furthermore, with the layered architecture, it is possible to update technologies or electronic components from the physical layer, keeping the interfaces (back-end and front-end), as the communication and service modules do not need to be changed. The architecture contains five layers: physical layer, communication layer, collection, treatment and storage layer, services layer, and visual layer. In addition to these five vertical layers, the proposal also includes three horizontal layers parallel to the vertical, namely: data quality, interoperability and security. The objectives and elements present in each layer are discussed below [18].

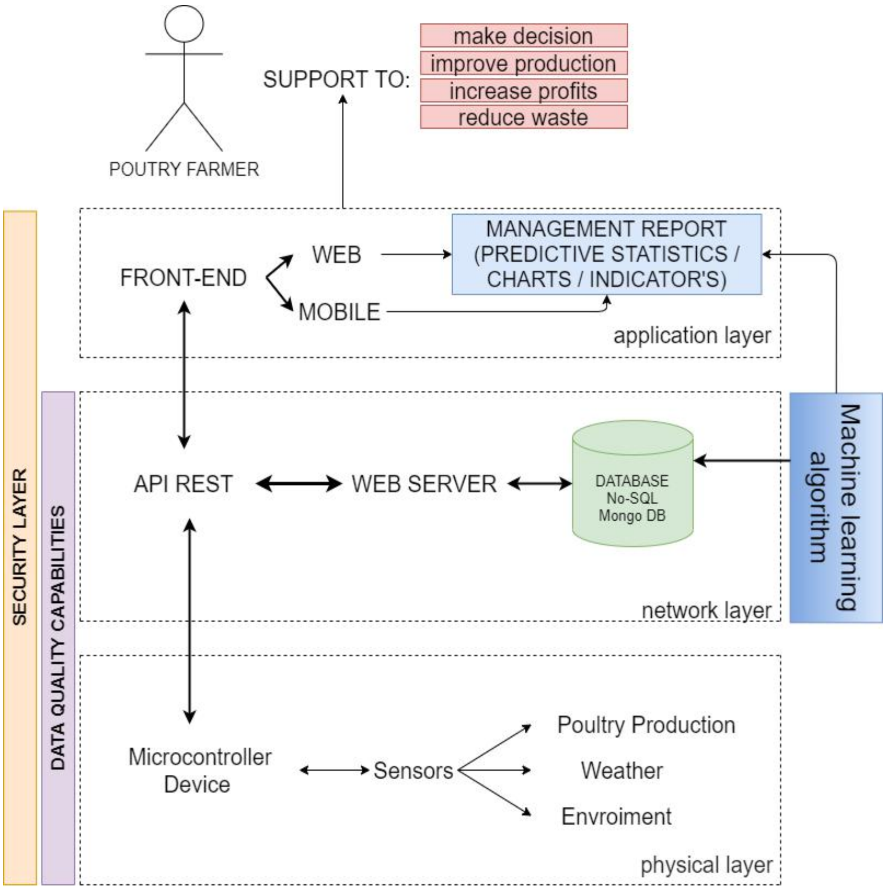

Fig. 1: IoT proposal Architecture

Physical Layer: The physical layer is the first (architectural basis), its objective is the physical presence of the Data Logger on the farm, it is the hardware that provides the data sources (sensors). Through the internet it is possible to establish communication between the physical layer with the others (ensuring the interoperability of the system); the importance of sensor calibration is related to the vertical layer of "Data Quality", that is, that the data is reliable and valid to be persisted, processed and visualized in the following layers; security, on the other hand, concerns the guarantee that the data sent by the microcontroller to the server is not maliciously injected by external sources. Hardware is uniquely identified; given the large number of "things" that can be interconnected, a unique identifier will allow you to track/monitor each item in the physical environment, ensuring accuracy in the management process, preventing a user's hardware from being identified as belonging to another user. Services layer: The services layer is the one that allows users to communicate between the server and the actuators, via WebSockets protocol, the connection between the Data Logger and the Server is established for actions without the need for requests from the client. Visual layer: can be considered the layer closest to the users who make use of the IoT architecture. This layer is responsible for making data and information available to system stakeholders through web and mobile platforms. It is also in the visual layer that the application requests information from data previously stored and processed in the application's routes, in order to provide graphics and indicators of what is happening in real time on the farm. Component responsible for facilitating data visualization and user decision-making: the data analysis module, on the web layer, also provides a control panel using the Shiny library of Software R, with statistical methods that aid in mapping production behavior and also generate forecast of the future behavior of poultry production.

IX. CONCLUSION

This research, which proposes an architecture based on IoT, is able to guide and support the management of small broiler producers, placing them in the context of Agribusiness 4.0, in order to improve their decision-making processes; identifying low performance and acting quickly, cheaply, simply and ergonomically, to meet the requirements of international competitiveness compared to large producers in the same region. Although there are other architectures that use the IoT paradigm in the context of agribusiness, at the end of the development of this thesis, the objective is to contribute with the presentation of a scalable architecture that encompasses security, quality and data interoperability issues in an integrated manner. Furthermore, using the "Needs Matrix" tool, the methodological procedures used allow a thorough investigation of the needs and priorities of stakeholders in the chicken production chain to model the application that covers the user experience.

ACKNOWLEDGEMENTS

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001.

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