v. 2, n. 18, 2022

Journal of
Engineering
Research

INTERNET OF THINGS TECHNOLOGY SYSTEM AND CLOUD COMPUTING TO INCREASE PRODUCTIVITY IN AGRICULTURAL AREAS

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Article of Course Completion Work, Graduation in Electrical Engineering, EE, UPM, São Paulo, 2021.

Abstract: Over the years, agriculture has been a fundamental part of the composition of Brazil's gross domestic product. Due to digital transformation, it is expected that there will be strong technological growth in this segment. The internet of things or IoT has the potential to help this process through the monitoring of physical data allowing the practice of precision agriculture, however the devices IoT have the characteristic of low data processing capacity. Cloud computing has virtually unlimited processing power. The integration of IoT to Cloud Computing constitutes a versatile and important tool for the growth of the Brazilian agricultural sector. This work focuses on the development, design and optimization of a system IoT and cloud computing for monitoring small and medium farmers' plantations. All aspects of the development tools used, costs and performance analysis are evidenced, which enable the correct decision criteria of potential approaches.

Keywords: IoT, Cloud Computing, Agriculture, LPWAN, Sigfox, MQTTS, HTTPS.

INTRODUCTION

The Cloud Computing or Cloud Computing, and the IoT (Internet of Things), Internet of Things), are two independent systems, which when combined become an important tool for the future (SADEEQ et al., 2021).

The Internet of Things can be defined as a network of objects, whether physical or logical, that can interact and communicate with each other over the internet. The term "things" makes up the acronym IoT, due to the various objects and devices that can integrate the network, as an example we can mention sensors, cars, residential devices (MASCARENHAS et al., 2021).

Cloud Computing (CC) is defined as follows (PIERLEONI et al., 2019, p.1):

> CC is a model that allows access to a set of shared and configurable computing resources (eg networks, servers, storage structures, applications) offered as services. These resources can be quickly requested, managed, and used on a pay-as-you-go model, so the user pays for the amount of actual usage of a resource. CC is also location independent, allowing user access to cloud services from any location and with any device via internet connection.

The study of McKinsey Global Institute requested by the National Bank for Economic and Social Development (BNDES) in partnership with the Ministry of Science, Technology and Innovations and Communications (MCTIC), regarding the use of the IoT, estimates that in Brazil the economic impact will reach 200 billion dollars by 2025 (MCKINSEY, 2017).

For 41% of study participants, the main focus of IoT must be on how to increase agricultural productivity and for 24% economic growth (MCKINSEY, 2017). In this study, the verticals for the use of IoT applications in Brazil were pointed out.

The Rural vertical received a score of 7.4 for the criterion of Competitiveness in Brazil in the IoT application environment, and a score of 10 for the criterion of Ease of developing Innovation and Business Environment.

According to the ranking of the Economic Complexity Observatory of MIT (Massachusetts Institute of Technology), in 2019, Brazil obtained about US$ 230 billion from exports (MIT, 2021).The items with the highest contribution to the value obtained from exports were soybeans (11.4%), corn (3.21%) and coffee (2.05%) (MIT, 2021).

Given Brazil's export matrix, developing applications in sectors in which it is a world reference, such as agribusiness, in fact becomes strategic.

According to projections by Gartner consultancy, the expectation is that the global market for Cloud Computing services will move US$ 362.263 billion in 2022 (GARTNER, 2020).

With the context and data presented, it is observed that the Agriculture sector has great relevance for the Brazilian economy. With a high potential for productive growth and a favorable environment for the development of technological innovations, Brazil can benefit from solutions that integrate Cloud Computing and IoT.

The study by the Brazilian Agricultural Research Corporation (EMBRAPA) highlights the biggest challenges for the agriculture sector in Brazil, namely the collection and processing of data on humidity, air monitoring and sunlight (EMBRAPA, 2017 apud MCKINSEY, 2017).

Given the limited level of processing of an IoT device and the high processing power found in CC, the integration between the two tools becomes strategic (NGUYEN et al., 2020). To this integration, this author calls Cloud of Things, cloud of things.

In 2020, EMBRAPA carried out a survey with more than 750 participants, such as rural producers, companies and service providers in the field, to map the portrait of Brazilian digital agriculture (EMBRAPA, 2020).

According to the survey, for 40.9% of rural producers, the lack of knowledge about the most appropriate technologies is a difficulty. Also, according to the study, there is a view that these new trends are accessible to large producers and high investment capacity.

GENERAL OBJECTIVE

This work comprises the analysis of the best Cloud Computing solutions in terms of cost and usability, and IoT in terms of availability and energy efficiency, which contribute to improving the productivity of the main agricultural crops of small producers in Brazil. By main crops, understand those that make up the relevant export items: soybeans, corn and coffee (MIT, 2021).

SPECIFIC OBJECTIVES

In order to achieve the objective of this work, it is necessary to develop the following specific objectives:

1 - Specify best agricultural computing practices in terms of cloud and edge computing.

2 - Given the dimensions and location of an agricultural property, it is important to determine the telecommunications devices that enable the implementation of sensors and actuators with great energy efficiency and low cost.

3 - Analyze and determine what devices are needed to interface and integrate devices with the cloud computing environment.

4 - Development of an IoT prototype, or identification in the market of an appropriate solution (cost, functionality), with cloud processing to validate the characteristics and estimates items 1, 2 and

METHODOLOGY

The work methodology is divided into stages that meet the objectives detailed in Subsection 1.2.2. Below, these are presented.

Step 1- Understanding the three largest platforms for Cloud Computing in Brazil, and its typical IoT market solutions.

A study is carried out of the three largest platforms of Cloud Computing n Brazil, namely: Amazon Web Services, Microsoft Azure and Google Cloud Platform (INFONOVA, 2021). Through published scientific articles, books and blogs, a documentary research is carried out, in search of understanding and presentation of typical solutions of these companies and their respective platforms for the IoT market. In addition, as each platform can meet the basic requirements of smart farms such as: cost, load capacity, ease of implementation, maintenance and system operation. For small farmers, there are still minimum requirements: intuitive use, low operating cost required without losing reliability and efficiency.

After identifying which platform solutions meet the requirements, comparative analyzes are made between them, to identify which solution could best meet implementations of IoT solutions for the small Brazilian producer.

Stage 2 - Study of possible viable telecommunications solutions in low consumption Brazil (LPWAN). Survey of sensors, actuators, microcontrollers with low energy consumption.

This step consists of researching information, studying, understanding and surveying the operating characteristics of low-energy telecommunications networks, available for implementations of IoT devices. The collection of information is carried out by searching on the Internet, in technical materials available in scientific bases such as that of the IEEE (Institute of Electrical and Electronics Engineers) (2021). A mapping of viable networks approved by ANATEL (National Telecommunications Agency) (2021), territory coverage, existing operating costs, consumption of radio transmitters and their reliability is carried out. The costs, ease of acquiring radio transmitters for device assembly IoT and operation are surveyed, studied, described and classified. For this, it is intended to use materials available on Internet bases, such as the IEEE (2021) and manufacturers such as Sigfox (2021).

The list and study of sensors, usual in IoT applications for monitoring and supporting agriculture (EMBRAPA, 2017), is carried out with manufacturing or import companies, with information available on the Internet, for example MOUSER (2021), or through direct contact with them.

The usual microcontrollers for application in IoT are also studied through scientific and technical materials available in the consultation bases, the latter such as GIALELIS et al. (2020). Within the telecommunications availability adopted for greater coverage of the national territory, the viable microcontroller is determined, considering acquisition costs in Brazil, energy consumption and programming possibilities.

Step 3 – Devices interface and integration with the cloud computing environment.

From the results obtained in Steps 1 and 2, and based on articles and technical and scientific collections presented in Section 3, it is intended to understand and describe the best architecture of the environment that will need to be implemented. Two aspects need to be addressed at this stage: the security of communications and, if necessary, the gateways with the IoT devices in the field. For the treatment of security, solutions that preferentially respect the principles of MQTT, a protocol presented in Section 3, are worked out. The survey of possible internet infrastructure can be identified by the address of the rural location, using maps from the CGI, Internet Manager in Brazil, such as SIMET (2021).

Step 4 - Development or market identification of an IoT solution with cloud processing, suitable for agricultural areas in Brazil

This step consists of the development or identification in the market of an IoT prototype, gateway, with cloud processing to validate the metrics, characteristics and estimates worked on in the methodological steps. The processing of the prototype or solution found in the market must use the platform of the three largest cloud computing service providers in Brazil, sensor and actuator solutions, microcontrollers and identified/ detailed integration software. The practical or laboratory test allows validating the metrics and calculations raised in the other stages of the study/project.

LITERATURE REVISION

INTERNET OF THINGS

The Internet of Things or Internet of Things (IoT) is an Internet-based paradigm and can be defined as a network of objects, whether physical or logical, that can interact and communicate with each other over the Internet (MASCARENHAS et al., 2021).

According to research carried out by EMBRAPA, the most interesting areas for the use of new digital technologies are: planning activities, property management and control of soil nutritional deficiencies (GALINARI et al., 2021). Within these strands, IoT devices have the potential to help the farmer.

CLOUD COMPUTING

Due to the limitations of the IoT, and the virtually unlimited processing and storage capacity of the Cloud Computing, the integrations between CC and devices IoT constitute a robust complementary tool among themselves (PIERLEONI et al., 2019).

The term Cloud Computing or Cloud Computing became popular in 2006, after being used by Eric Shmidt, CEO of Google in that year, in a conference to explain how the management of the company's data centers is done (DARWISH et al., 2017).

In 2011, the National Institute of Standards and Technology of the United States defined Cloud Computing (NIST, 2011):

> Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or interaction with the service provider. This cloud model is made up of five essential characteristics, three service models and four deployment models.

PROTOCOL MQTT

Created and developed by IBM in the late 90's, the MQTT (Message Queuing Telemetry Transport), is an open messaging protocol with support for performing asynchronous communication (IBM, 2017).

The protocol MQTT defines two entities in the network: a message broker and the customers. The broker it is a server that receives all messages from clients and then distributes these messages to the target clients.

According to the work of PIERLEONI et al., (2019), MQTT obtains the best results in terms of end-to-end delay and bandwidth consumption.

According to Yuan (2017), the MQTT is a flexible and lightweight network protocol. The lightness characteristic allows the implementation in hardware and networks of limited bandwidth and high latency.

PROTOCOL HTTPS

The HTTPS protocol (Hypertext Transfer Protocol Secure) is a communication protocol, designed for handling web messages securely, which can also be used in IoT communication networks (BALBINOT, 2019).

Making use of the request and response method and methods previously defined in the protocol, the HTTPS client makes a call and obtains a response file with the success or error status of the call, as well as the desired response in the message body.

RESULTS AND DISCUSSION

Following the steps described in Section 2, the following activities were carried out:

ARCHITECTURE DESIGNED FOR CLOUD ENVIRONMENTS

In accordance with step 1 described in

the methodology, a documental study of the platforms of cloud and identification of which of these solutions meet the mentioned requirements.

A comparative analysis was made between the resources and services to identify which solution could best meet the implementations of IoT solutions for the small Brazilian producer.

For a better understanding, a generic system was proposed to represent the items that make up a solution using an IoT and integrated with clouds.

Figure 1 shows said generic system.

Table 1 contains the services used for the generic system and their respective description.

It was listed that the three observed cloud service providers have similar solutions for use with IoT.

Table 2 contains the categories of similar services offered by providers Amazon Web Services, Microsoft Azure e Google Cloud Platform.

Table 2 shows the category and type of services delivered by the three platforms, as well as the services that are equivalent to each other, from a conceptual point of view.

TECHNOLOGIES LPWAN

Referring to step 2 of Subsection 2, according to the study carried out on the main technologies LPWAN the Sigfox and Lorawan network stand out (MEKKI, K. et al., 2019).

The study carried out by Teleco Inteligência em Telecomunicações (TELECO, 2021) shows the evolution of municipalities and percentage of population covered by LPWAN technologies in Brazil in September 2021.

According to the study, the Sigfox network covers 492 municipalities, covering 51.3% of the population, while the Lorawan network covers 262 municipalities, covering 50.0% of the national population.

Table 3 describes the operating characteristics of the LPWAN solutions observed by the author.

Among the two solutions, we chose to use the Sigfox network due to the greater coverage radius in the rural environment, ranging from 10 to 40 km, robust backend that allows the integration of the device with the cloud environment in general without the need to use a physical gateway.

Sigfox network technology can be described as a network protocol aimed at wireless IoT applications working at low power (DATEM, 2021).

Some of the advantages of using this technology are: low energy consumption and standardized price worldwide - the annual subscription for sending two messages per day per device is US$0.50 (NOVIDA, 2019).

GATEWAY

The function of an IoT gateway is to communicate between devices and thus form a network, for sharing resources, information and making possible the intercommunication of equipment that has different communication protocols (RAMÍREZ et al., 2019).

The gateway is the bridge that performs the flow of data between wireless sensors and local communications networks or the Internet (JUNIOR et al., 2018). A possible use scenario for a physical gateway in the context of this work would be the use of Sigfox devices in environments outside the coverage zone informed on the site. Using the gateway, it is possible to create a network repeater to cover this location. For the Sigfox network there are ready solutions available for their implementation, as described in MATURIX (2021).

PROTOTYPE IOT

In line with step 4 of Subsection 2, after completing the research for the development

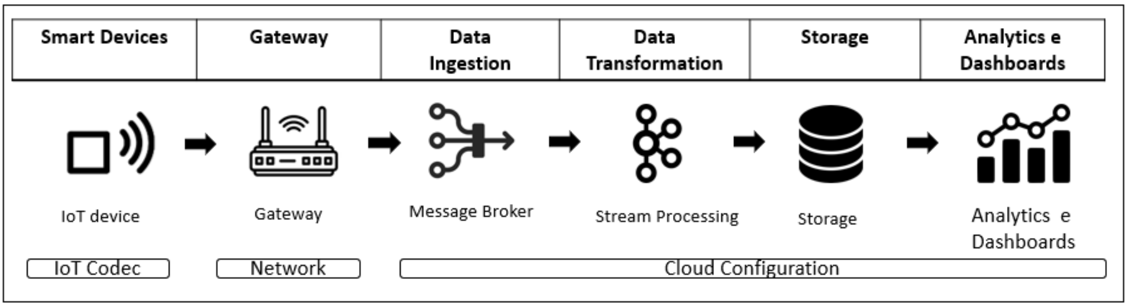


Figure 1 - Generalized System

Source: Author himself

Service	*Smart Devices*	*Gateway*	*Data Ingestion*	*Data Transformation*	*Storage*	*Analytics* e *Dashboards*
Description	IoT devices	Communication between environments	Service that receives messages	Orchestrates the data in the infrastructure	store the data	Data analysis and display

Table 1 - Description of generalized system services

Source: Author himself

Service category	**Service type**	**AWS Offer**	**Offer** *Microsoft Azure*	**GCP offer**
Data analysis	*Business Intelligence*	*Amazon QuickSight*	*Microsoft Power BI*	*Looker*
Internet of Things (*IoT*)	Platform *IoT*	*AWS IoT Core*	*Hub IoT do Azure*	*Cloud IoT*
Database	Data storage	*Amazon DynamoDB*	*Azure Cosmos DB*	*Datastore*
Data analysis	Open source processing	*Amazon S3*	*Azure Data Lake*	*Dataproc*
Data analysis	Data flow orchestration	*AWS IoT Analytics*	*Azure Stream Analytics*	*Dataflow*
Compute	*Serveless*	*AWS Lambda*	*Azure Functions*	*Cloud Functions*

Table 2 - Similar Services Offered by Cloud Providers

Source: Modified from GOOGLE CLOUD PLATFORM (2021)

	Sigfox	**Lorawan**
Modulation	**BPSK**	**CSS**
Frequency	Unlicensed ISM bands (868 MHz in Europe, 915 MHz in North America and 433 MHz in Asia)	Unlicensed ISM bands (868 MHz in Europe, 915 MHz in North America and 433 MHz in Asia)
Bandwidth	100 Hz	250 kHz e 125 kHz
Maximum data rate	100 bps	50 kbps
Bidirectional	Limited / Half duplex	Yes / Half duplex
Maximum messages/day	140 (UL), 4 (DL)	Unlimited
Maximum payload length	12 bytes (UL), 8 bytes (DL)	243 bytes
Network coverage	10 km (urban), 40 km (rural)	5 km (urban), 20 km (rural)
Immunity to interference	Very tall	Very tall
Authentication and encryption	not supported	YES (AES 128b)
Adaptive data rate	Not	Yes
Handover	End devices are not joined to a single base station	End devices are not joined to a single base station

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.3172182219084

Geo Location	Yes (RSSI)	Yes (TDOA)
Allow private network	Not	Yes
Norms	The Sigfox company is collaborating with ETSI on the standardization of the Sigfox-based network	LoRa-Alliance

Table 3 - Comparison of LPWAN services

Source: MEKKI, K. et al. (2019)

Figure 2 - List of Materials Used

Source: Author himself

Figure 3 - Prototype

Source: Author himself

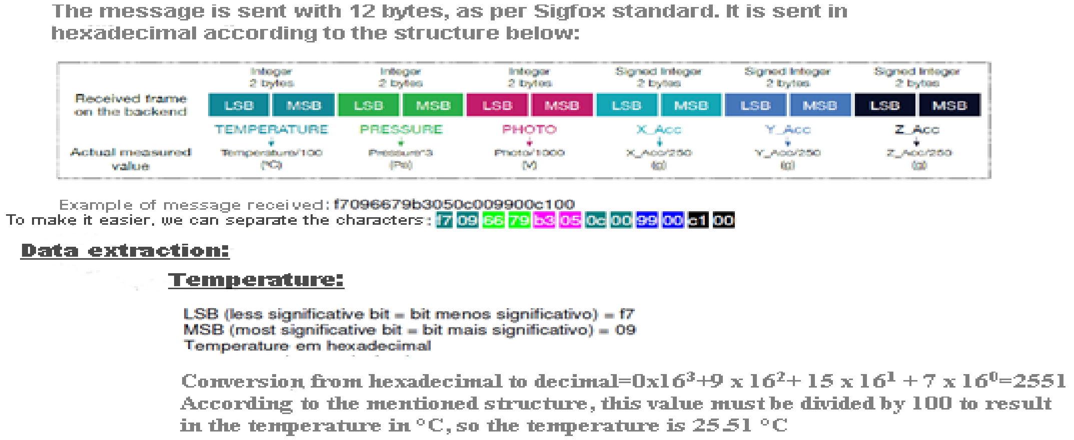


Figure 4 - Manual decoding

Source: THINXTRA (2021)

or identification of an IoT prototype in the market, it was decided to acquire and use a product found in the market. Such a product has the best cost found in the national territory, allows development on several platforms and with several sensors and has the technical characteristics described below.

CHARACTERISTICS OF THE PROTOTYPE USED

The solution for use in this work was the Sigfox development devkit with Wisol Thinxtra module, or Sigfox Developer Xkit (THINXTRA, 2021).

The development kit consists of the following items:

a- Shield supporting Sigfox RCZ2 networks (Brazil, USA and Mexico);

b- Arduino board uno r3.

c- Temperature, pressure, brightness, magnetic (reed switch) and 3-axis accelerometer sensors;

d- 1 year Sigfox connectivity license, Sigfox Platinum package, 140 upload and 4 download messages.

The Arduino uno r3 board that comes with the devkit is preloaded with a demo application that sends information from the temperature sensor, photoelectric sensor output voltage, pressure value and accelerometer.

This data is sent under the following conditions:

a- Every 10 minutes;

b- If the SW1 button of the Sigfox module is pressed;

c- If a magnet is close to the magnetic sensor (reed switch).

Aiming at developing the prototype for the agricultural environment, the DHT 22 humidity sensor was added and the original code preloaded to the devkit was modified accordingly.

A 4.8 Ah Lithium Ion battery for use with the IoT was used to power the device.

To accommodate the IoT hardware, a physical case was created and 3D printed in the laboratory of the School of Engineering of Universidade Presbiteriana Mackenzie.

Figure 2 shows the list of materials used to develop the project

In Figure 3, we have a photograph of the finished hardware project.

DATA DECODING

Data measured by the devkit sensors is displayed in hexadecimal basis (Sigfox, 2021).

For more user-friendly reading of the data, it is necessary to perform the decoding of the payload from the hexadecimal base to the decimal base and adapt the unit to the international system (S.I).

As the devkit documentation states, the payload decoding can be performed manually (THINXTRA, 2021).

Figure 4 shows the manual decoding process.

To perform the decoding of the payload, there is the possibility of creating a function in a certain programming language for operation in serverless services such as AWS Lambda, Microsoft Azure Functions and GCP Functions (GIL, 2021).

Functions were developed for this purpose and the code can be found in the Github repository (DOI:10.5281/zenodo.5648126) (RODRIGUES, 2021).

In order to make the implementation simple for users with a lower technical level, a research was carried out on which tools would have the capacity to facilitate the decoding process.After documental research based on forums, an application of SaaS - software as a service called Bitdecoder provided by the data monitoring company, Paessler (PAESSLER BITDECODER, 2021). The version used in the current work is the free beta.

Using the highlighted tool, it is possible to decode the data coming directly from the

Sigfox environment and deliver this data, already converted, to the cloud of interest.

According to the tool manual, the decoding process within the platform can be carried out via code or visually (PAESSLER BITDECODER, 2021).

Inside the platform Paessler Bitdecoder there is the possibility of direct integration with the environment AWS IoT Core e Microsoft IoT Hub (PAESSLER BITDECODER, 2021).

For the use of other clouds, such as GCP, there is the possibility of using the MQTT Broker.In Figure 5, there is a representation of the operation of the highlighted tool, with the arrival of data from Sigfox Cloud, packet conversion and data delivery to required clouds.

ENVIRONMENT OF CLOUD COMPUTING

Each cloud computing environment and their respective operating scenarios are described below.

SIGFOX CLOUD

The data collected by the sensors are sent to base stations of the Sigfox network and after this process, the data is uploaded to the Sigfox network cloud and after this step, the integration with the clouds can be carried out (LAVRIC et al, 2019).

Sigfox Cloud can automatically forward to other clouds, using callback services, called callbacks (SIGFOX, 2021). This service uses HTTPS protocol.

Figure 6 illustrates the Sigfox network architecture.

It is possible to configure callbacks for AWS and AZURE in a simplified way and the creation of customized callbacks for integration with other clouds (SIGFOX, 2021).

INTEGRATION WITH PUBLIC CLOUDS

In order to simulate the use of integration with public clouds, two scenarios were developed: one following the provider's basic recommendations and the other one of security, increased through the MQTTS protocol and improvement of the dashboard.

FIRST SCENARIO

Using native callbacks and HTTPS protocol: the data read by the sensors is sent from the Sigfox cloud to the AWS, Microsoft Azure and GCP clouds.

When the data arrives in the cloud environment, it is still stored in its original format (hexadecimal), which is the simplest scenario.

The integration with AWS and AZURE is carried out through wizard (assistant) present in the backend Sigfox cloud.

The integration with the GCP is performed through a callback developed to connect the Sigfox cloud backend.

The providers of the AWS, AZURE and GCP environments have documentation that helps in the described process (GARCIA, 2017; LIU, 2018; LEPISTO, 2020a, 2020b).

Figure 7 shows the callbacks used for this work.

SECOND SCENARIO

Data read by IoT sensors is sent from the Sigfox backend to the Paessler Bitdecoder tool and MQTTS protocol. After the conversion, the payload with the converted data is forwarded to the endpoint services of AWS clouds and Microsoft Azure. As endpoints, understand the Message broker services whose graphical representation is shown in Figure 1.

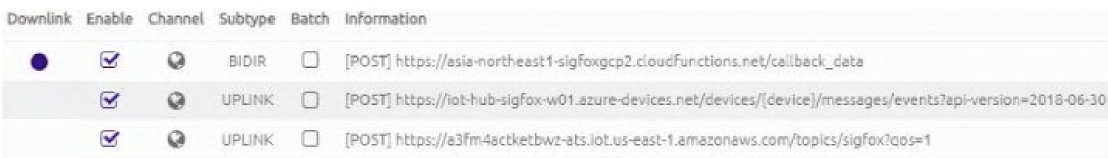
For Google Cloud Platform, it was decided not to develop the 2nd scenario at work due to connection complexities for the development

Figure 5 - Operation Paessler Bitdecoder

Source: PAESSLER BITDECODER (2021)

Figure 6 – Sigfox Network Architecture

Source: SIGFOX (2021)



Downlink	Enable	Channel	Subtype	Batch	Information
●	☑		BIDIR	☐	[POST] https://asia-northeast1-sigfoxgcp2.cloudfunctions.net/callback_data
	☑		UPLINK	☐	[POST] https://iot-hub-sigfox-w01.azure-devices.net/devices/{device}/messages/events?api-version=2018-06-30
	☑		UPLINK	☐	[POST] https://a3fm4actketbwz-ats.iot.us-east-1.amazonaws.com/topics/sigfox?qos=1

Figure 7 – Callbacks

Source: Author himself

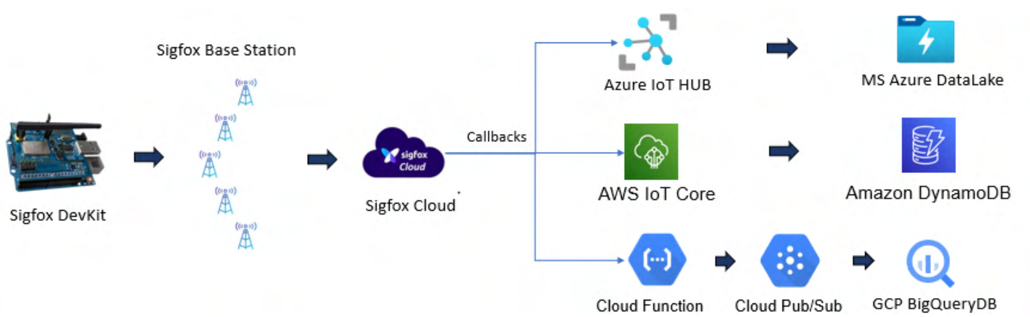


Figure 8 – Sigfox integration architecture and Clouds for 1st scenario

Source: Author himself

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.3172182219084

of a gateway.

INTEGRATION ARCHITECTURE

Figure 8 shows the elements relevant to the integration architectures between the Sigfox cloud backend and the AWS, Microsoft Azure and GCP clouds for the first scenario, in which the data travels through the HTTPS protocol and is stored without decoding.

Figure 9 shows the elements relevant to the integration architectures between the Sigfox cloud backend and AWS clouds, Microsoft Azure in the second scenario. In this scenario, the data travels through the MQTTS protocol, is decoded by Paessler Bitdecoder, stored in databases and later displayed in dashboards,

SYSTEM OPERATION

As the operation as a whole depends on numerous application layers, in addition to this Subsection, an explanatory video is proposed in RODRIGUES (2021).

In order to document the data flow process of Scenario 1, the relevant steps are presented in Figures 10, 11, 12 and 13. Figure 10 contains an example of a sequential message presented in the Sigfox environment cloud.

Figure 11 shows a record of the DynamoDB database, as shown in the AWS environment interface. You can observe log information such as date, message sequence number and a hexadecimal number that represents the values measured by the device sensors and transmitted to the cloud.

Figure 12 contains an image of a CosmosDB database record, similar to the presentation in the Microsoft Azure environment interface. On the right, you can see the metadata and information of a record that was accessed on 10/25/2021.

In Figure 13 there is a screen print with information about the payload loaded in the BigQueryDB database, similar to the visualization in the Google Cloud Platform environment interface.

For the purpose of documenting the Scenario 2 data flow process in accordance with Subsection 4.7.2.

In Figure 14, the message with sequence number 2034 is displayed in the environment Sigfox.

In Figure 15, there is a summary of the integrations carried out between the tool Paessler Bitdecoder and the endpoints AWS IoT Core e Microsoft IoT Hub.

Next, in Figure 16, the message 2034 is displayed, stored in the AWS DynamoDB database after the decoding process. One can observe the temperature, pressure and humidity values of a package already decoded correctly using the tool.

The data stored in the database are presented in the various tools through created dashboards, which facilitates the interpretation by the user, and works with HMI issues, that is, the human-machine interface.

Copying a screen from a dashboard mounted in environment AWS is shown in Figure 17.

In Figure 18, the message 2034 is stored in another cloud environment created in Microsoft Azure with the registration in CosmosDB after the decoding process similar to the one shown in Figure 19.

A print screen of a dashboard screen mounted in a Microsoft Azure environment is shown in Figure 19.

CLOUD COMPUTING TIME

The current Subsection highlights the time metrics observed in the current job.

TIME IN SCENARIO 1

Using the tools that record the service logs of each cloud platform, the following metrics were observed regarding the time of reception of data from the Sigfox cloud and later storage in the database.

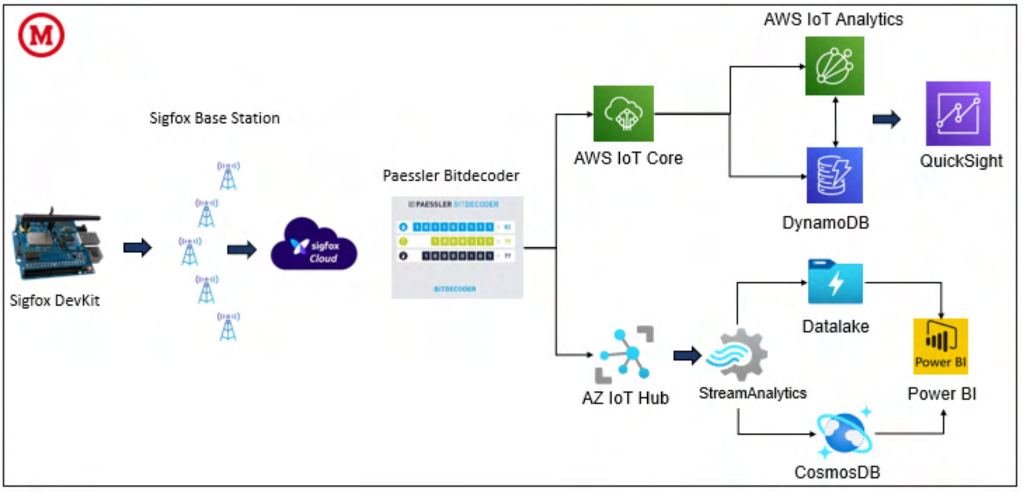


Figure 9 - Architecture of the second scenario in the environment AWS e AZURE respectively

Source: Author himself

Figure 10 – Message 2002 in Sigfox Cloud Environment

Source: Author himself

Figure 11 – Amazon DynamoDB Original Data

Souce: Próprio Autor

Figure 12– Microsoft Azure Datalake

Source: Author himself

Figure 13 - Google BigQuery

Source: Author himself

Figure 14 - Message 2034 in the Sigfox environment cloud

Source: Author himself

Figure 15 – Paessler Bitdecoder integrations with endpoints

Source: Author himself

Figure 16 – Amazon DynamoDB Converted Data

Source: Author himself

Figura 17 – AWS Quicksight com os dashboards dos dados

Source: Author himself

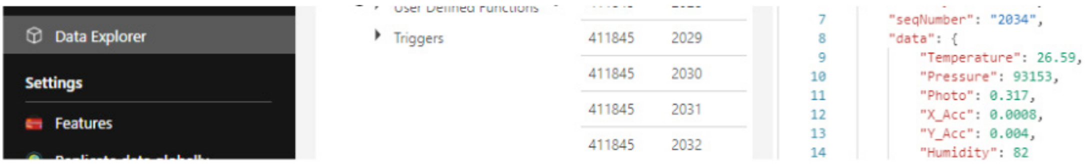


Figure 18 – Microsoft CosmosDB Converted Data

Source: Author himself

Figure 19 – Dashboards of the data in Microsoft Power BI

Source: Author himself

The log recording tools used are those available on the appropriate systems, namely: AWS CloudWatch, Microsoft Azure Monitor e Google Cloud Log.

Table 4 contains the times measured by the applications, from the arrival of the payload to the cloud environment and its storage in the database of each cloud service provider for the 2 proposed scenarios.

It can be seen that the AWS environment is 2.5 times faster in receptions for scenario 2 than the AZURE environment. As for scenario 1, the AWS and AZURE environment have similar response times, only GCP has 2.5 higher latency.

BATTERY AUTONOMY

The calculation of the autonomous is performed based on the equation in (1).

For the finished prototype, the consumption of 12.3mA was measured using the 3.7V and 4.8Ah battery.

Based on the equation presented in (1), the battery life is 390 hours or 16 days.

$$Autonomy(h) = \frac{Battery\ Capacity(Ah)}{Current\ consumed(A)} \quad (1)$$

$$Autonomy(h) = \frac{4.8(Ah)}{0.0123(A)} = 390.24h \quad (2)$$

In Figure 20, there is the display of the current reading consumed by the IoT device developed in the current work.

COSTS

The following describes all project costs, whether related to the hardware or software or development.

HARDWARE COSTS

- Sigfox development kit with Wisol module, Arduino board and XKIT1-2 sensors - R$731.40 (SMARTCORE, 2021)
- Dht22 Temperature and Humidity Sensor – BRL 25.14 (MOUSER, 2021).
- Battery 3.7v – 4.8 Ah Li-Ion Rechargeable – BRL 18.00 (MARCADO LIVRE, 2021).
- Physical case – Printed free of charge at the Electrical Engineering Laboratory of Universidade Presbiteriana Mackenzie.

The total costs related to the project's hardware were: R$774.54.

CLOUD ENVIRONMENT COSTS

For this work, only evaluation accounts were used, which allow the use of credits for the consumption of cloud services. There were no recurring costs that depend on a monthly subscription.

The costs related to each cloud computing platform below are described in Table 5.

As noted in Table 5, for the execution of this work, there were no costs related to the Google Cloud Platform. All recorded processing fell within the free tier and student account credits were not used.

ABOUT IMPLEMENTING THE ENVIRONMENT

In terms of ease of project implementation, it was evident that the operation of the Sigfox devkit proved to be simple due to the use of the Arduino board IDE and extensive documentation.

Regarding cloud computing platforms, in terms of ease and documentation, the AWS and Microsoft Azure providers are easy to handle and have good quality documentation.

As for Google Cloud Platform, it was found that it requires more technical knowledge and the documentation found on the website is less detailed compared to other platforms.

For the implementation of a cloud computing environment, it is possible to use

Time in *Cloud* (ms)		
	1° scenery	2° scenery
Amazon Web Services	195	193
Microsoft Azure	213	548
Google Cloud Platform	508	X

Table 4 - Description of services

Fonte: Próprio Autor

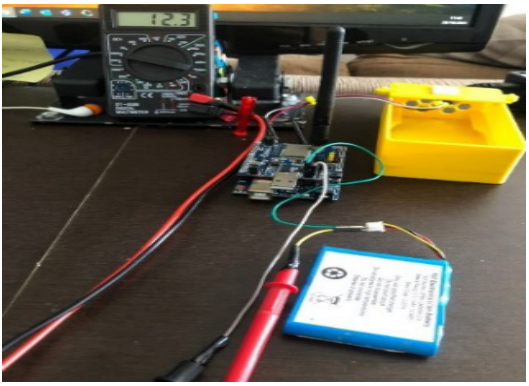


Figure 20 – Current consumed by the device IoT

Source: Author himself

Cloud costs (R$)	
AWS	6,56
AZURE	110,03
GCP	0

Table 5 - Description of services

Source: Author himself

Metrics	***Amazon Web Service***	***Microsoft Azure***	***Google Cloud Platform***
Operating time	10	8	4
Aggregate cost	9	4	10
Ease of implementation	8,5	10	5
Documentation quality	10	9	7
Total	37,5	31	26

Table 1– Performance of Cloud Platforms

Source: Author himself

IaC tools - Infrastructure as code, for this work we used the well-known Terraform tool. Such a tool allows the automation of the creation of cloud application scenarios.

CLOUD PERFORMANCE ACCORDING TO THE METRICS DEFINED FOR THE JOB

Table 1 contains the scores assigned to each cloud platform according to the metrics described in the current work.

The Amazon Web Service offered the most satisfactory service, according to the classification presented in Table 1.

O Microsoft Azure it is easy to implement and meets the demand of both scenarios, however the aggregate cost for use is a factor to be considered by small and medium rural producers.

Regarding the Google Cloud Platform, it was highlighted that in terms of cost, it has the most suitable platform for small rural producers, however, it requires greater technical knowledge for operation and more restricted documentation.

FINAL CONSIDERATIONS

In the early stages of the project, the replacement of the Arduino Uno R3 board with the Arduino Mega 2560 board was considered to increase the number of digital ports (ALL3DP, 2020). With the Arduino Mega board and the sensors specified in the bill of materials, the electrical current consumption of the project at 80 mA was measured. Such consumption generates the battery life time to 60 hours. Due to this factor, it was decided to definitively use the Arduino Uno R3 board, with this board the consumption observed was that described in Subsection 4.8.

For future improvements, works aimed at battery optimization and energy consumption are indicated.

There is the possibility of integrating the databases allocated in the cloud with voice assistants such as Amazon Alexa or Google Assistant, which can facilitate use for the end user (DZONE, 2020).

With the stored data and using data analysis techniques, one can make predictions and find correlations that interest the user (REDHAT, 2021).

As estimated by the Ministry of Agriculture, Livestock and Supply - Mapa, through the use of technology, the Gross Value of Production (GVP) of Agriculture will grow 9.6% - equivalent to an increase of R$ 101.47 billion over the current R$ 1.057 trillion (MAPA, 2021).

CONCLUSION

This work aims to highlight the best possible solution for the development of an IoT device and its respective integration to the cloud environment, aiming at the lowest cost and best performance in order to benefit the small and medium rural producer in Brazil.

According to studies by companies such as EMBRAPA and institutions such as the Ministries of Agriculture, Communications and Science and Technology, the use of these solutions will increase the performance of the Brazilian crop and optimize the use of resources in the field.

According to our best studies until the end of this article, the developed device presents performance that could help the small and medium rural producer with a low cost given the capabilities of return of gain through the practice of precision agriculture.

As for cloud computing platforms, it was observed that each platform provides an access point to the cloud through which physical devices can connect securely and privately. After authorized connection, the devices can start sending their data to the cloud: the most used protocol is the MQTT.

The results show how the platforms, even with different service times, act uniformly with satisfactory performance levels. The analysis made in relation to the costs of the platforms, gives the reader another element of comparison to make his choice, although it is possible to carry out the same work with the AWS, Microsoft Azure and GCP.

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