UNIVERSIDAD TÉCNICA DE AMBATO

FACULTAD DE INGENIERÍA EN SISTEMAS, ELECTRONICA E INDUSTRIAL

CARRERA DE INGENIERÍA INDUSTRIAL EN PROCESOS DE AUTOMATIZACIÓN

Tema:

"AMPQ EMPLEADO EN PROCESOS INDUSTRIALES BASADOS EN SISTEMAS CIBERFISICOS DE PRODUCCION"

Proyecto de trabajo de Graduación. Modalidad: Articulo Académico, presentado previo a la obtención del título de Ingeniería Industrial en Procesos de Automatización.

LINEA DE INVESTIGACIÓN: Tecnología de la Información y Sistemas de Control

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AMBATO- ECUADOR

enero /2020

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En mi calidad de tutor del trabajo de investigación sobre el tema: "AMPQ EMPLEADO EN PROCESOS INDUSTRIALES BASADOS EN SISTEMAS CIBERFISICOS DE PRODUCCION" realizado por el señor Llamuca Supe Erick Santiago, estudiante de la carrera de Ingeniería Industrial en Procesos de Automatización de la Facultad de Ingeniería en Sistemas, Electrónica e Industrial, de la Universidad Técnica de Ambato, considero que el informe investigativo reúne los requisitos suficientes para que continúe con los trámites y consiguiente aprobación de conformidad con el numeral 7.2 de los Lineamientos Generales para la aplicación de Instructivos de las Modalidades de Titulación de las Facultades de la Universidad Técnica de Ambato.

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DEDICATORIA

A mis padres *quienes, con su amor, dedicación, cariño y sobre todo paciencia me educaron de la mejor manera, me enseñaron hacer responsable, me enseñaron valores y a luchar por lo que se quiere.*

Al amor de mi vida, Alejandra*, por acompañarme en este camino, de constancia, con triunfos y fracasos, por el amor incondicional que me ha brindado, demostrándome que siempre podré contar con ella.*

A mi hijo Gael, *quien, con su amor, con su inocencia y ocurrencias alegraba mis días duros, cuando quería rendirme, me enseñó a tener un motivo más porque levantarme y seguir luchando, me enseñó a no dejarme vencer por nada ni por nadie.*

A mis abuelitos*, por darme el ejemplo de superación, humildad y sacrificio, por sus consejos y por enseñarme a valorar todo lo que Dios me ha dado.*

Finalmente quiero dedicar esta tesis a toda ***mi familia, a mis amigos/as*** *que no son muchos, por apoyarme cuando más lo necesitaba, por extender su mano en momentos difíciles y brindarme palabras de aliento.*

Erick Santiago Llamuca Supe

AGRADECIMIENTO

A Dios *por darme vida, salud, paciencia, sabiduría, enseñándome que de los errores se aprende, haciéndome más fuerte cada día.*

A mis padres y a mis suegros *quienes me brindando su apoyo moral y económico, por darme palabras de aliento cuando estuve a punto de rendirme.*

A mi hermano Jairo Llamuca *por haber compartido sus conocimientos a lo largo de la preparación de mi profesión.*

A la Carrera de Ingeniería Industrial en Procesos de Automatización *quienes me formaron como una profesional con ética y valores.*

A mis amigos *quienes hicieron de la vida universitaria una experiencia única e inolvidable, por su amistad y apoyo.*

Al Dr. Marcelo García*, por guiarme y compartir sus conocimientos, para la realización del proyecto de investigación.*

Erick Santiago Llamuca Supe

INDICE GENERAL DE CONTENIDOS

RESUMEN EJECUTIVO

La presente investigación se llevará a cabo en base a la necesidad de la industria de migrar a sistemas automatizados y optimizar la información de sus procesos para lograr un sistema de control de acuerdo al segundo escalón de la pirámide de automatización, consiguiendo intervenir en los procesos de la industria. Se buscará aportar con información que ayudará con el desarrollo en la industria manufacturera e inteligente, a través de la adquisición de datos, y la comunicación entre maquinarias y sus aplicaciones de una forma fácil, fiable y segura.

Debido al reciente desarrollo en la Internet de las cosas (IoT) y las tecnologías de computación en la nube, los sistemas cibernéticos (CPPS) están evolucionando como un importante controlador durante y después del proceso de fabricación de productos, lo que genera nuevos conocimientos que pueden mejorar la toma de decisiones. Procesa y proporciona una ventaja empresarial competitiva. Este estudio trata sobre la implementación de CPPS en una fábrica real para controlar un proceso e integrar las comunicaciones en el taller utilizando el protocolo AMQP (Protocolo Avanzado de Cola de Mensajes). Finalmente, la operación de todo el sistema se demuestra a través de un panel de control de CPPS. En una era en la que la mayoría de los estudios relacionados con CPPS se realizan en modelos abstractos de alto nivel, este estudio describe marcos arquitectónicos más específicos en un proceso real.

SUMARY

This research will be conducted based on the industry's need to migrate to automated systems and optimize information about its processes to achieve a control system according to the second step of the automation pyramid, managing to intervene in the processes of the industry. It will seek to provide information that will help with the development in the intelligent and manufacturing industry, through data acquisition, and communication between machinery and its applications in an easy, reliable and safe way.

Due to the recent development of the Internet of Things (IoT), and Cloud computing technologies, Cyber-Physical Systems (CPPS) are currently used as controllers during the manufacturing process. This new approach results in new insights that can enhance decision-making processes and provide a competitive business advantage. This study deals with the implementation of CPPS using low-cost devices in a simulated factory to control the industrial process and integrate shop-floor communications using the AMQP (Advanced Message Queuing Protocol) protocol. In an era in which most CPPS-related studies are conducted on high-level abstract models, this study describes more specific architectural frameworks in a real process.

CAPITULO I.- MARCO TEÓRICO

1.1 Antecedentes investigativos

Al referirse a sistemas Ciber-físicos utilizados en procesos industriales, se establecen necesidades específicas de seguridad en la información, por lo cual las características que debe cumplir un protocolo de comunicación son estrictas. Teniendo en cuanta el objetivo general de alcanzar niveles de transmisión de información eficientes, se pueden implantar diversos protocolos, empero la síntesis, sincronización, y tiempos de respuesta de cada uno los diferenciara, determinando su funcionalidad en el campo industrial. Ya que en la actualidad se busca un entorno fiable con un método estándar que permite la comunicación [1] [2].

Los sistemas de mensajería son compatibles con diferentes modelos de comunicación, cada uno de los cuales define cómo intercambia la información entre productor y consumidor. Al momento de no existir un consumidor del mensaje, el inconveniente presentado es una complicación en la semántica requerida para manejar las colas y distribuir la información entre los diversos consumidores. Sin embargo, un protocolo que permita manejar esa complejidad interna requiere mucho desarrollo y el seleccionar la opción correcta es esencial, de tal modo que conocer los alcances de protocolos estándar para sistemas de mensajería se convierte en la clave de la eficiencia de los sistemas Ciber-físicos de producción (CPPS) [3] [4].

Hoy en día, la aplicación del Internet de las cosas se convierte en una ventaja competitiva, ya que describe un escenario en el que los objetos se identifican y se conectan a Internet; permitiendo el control remoto de situaciones críticas o relevantes para un dominio, a través de sensores y actuadores estratégicamente distribuidos (García, 2018). Sin embargo, para detectar este tipo de situaciones es necesario comunicar, almacenar, analizar y procesar de manera eficiente la gran cantidad de información generada cada día por estos dispositivos inteligentes [5].

El middleware orientado a mensajes constituye un parámetro importante en la entrega de datos. AMQP (Advanced Message Queue Protocol) es un estándar abierto, ampliamente utilizado en la Internet de las cosas (Internet of Things - IoT), que se desarrolló para facilitar el intercambio de información entre elementos del mismo sistema o en el presente caso de proceso industrial. AMQP está preocupado por los problemas de seguridad y confidencialidad sin afectar el rendimiento de la comunicación [6].

Para el uso de protocolos de comunicación orientados a mensajes como AMQP, es necesario conocer las características que mantiene. Esta es la razón para desarrollar pruebas de su eficiencia en aplicaciones de entornos industriales, enfatizando las necesidades de carga de las aplicaciones, en términos de tamaño de mensaje y tasas de comunicación [7]. AMQP finalmente ha abordado los estándares de interoperabilidad de los mensajes comerciales e industriales basados en CPPS, de una manera sencilla que le permitió trascender en el mercado [8].

La investigación propone un método de comunicación óptimo para el control industrial en los marcos de CPPS utilizando AMQP para la integración de la comunicación en el taller. Como objetivo general, se ha buscado identificar los límites de aplicabilidad de este middleware, evaluando su capacidad en términos de pérdidas de mensajes, latencias o fluctuaciones, pero las pruebas en el entorno industrial deben estar altamente desarrolladas para una aplicación confiable y eficiente, en el caso de envío de cantidades masivas que comprometen el rendimiento del sistema en un proceso dado.

1.2 Objetivos

Desarrollar sistemas Ciber-Físicos de Producción basados en el protocolo AMQP.

Analizar el protocolo AMQP y su alcance aplicativo en industria actual. Mediante la integración un método de comunicación a nivel de planta. Para comunicar la celda flexible de manufactura Festo y un servidor web basado en sistemas Ciber-Físicos de producción. Y así validar como un protocolo para diseño de sistemas CPS.

1. Recolectar información relevante del protocolo de comunicación
2. Identificar los parámetros y atributos del protocolo de comunicación
3. Analizar los atributos identificados del protocolo
4. Definir las pautas que puedan relacionarse y ser aplicadas en el protocolo
5. Diseñar un modelo adecuado para la comunicación
6. Evaluar el funcionamiento de la aplicación del modelo diseñado.
7. Registrar y presentar los resultados obtenidos en un informe.
8. Validar el uso de AMQP como protocolo para diseño de sistemas CPS

Cyber-Physical Production Systems for Industrial Shop-Floor Integration Based on AMQP

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***Abstract*—Due to the recent development of the Internet of Things (IoT), and Cloud computing technologies, Cyber-Physical Systems (CPPS) are currently used as controllers during the manufacturing process. This new approach results in new insights that can enhance decision-making processes and provide a competitive business advantage. This study deals with the implementation of CPPS using low-cost devices in a simulated factory to control the industrial process and integrate shop-floor communications using the AMQP (Advanced Message Queuing Protocol) protocol. In an era in which most CPPS-related studies are conducted on high-level abstract models, this study describes more specific architectural frameworks in a real process.**

***Index Terms*—Cyber-Physical Productions Systems (CPPS), Internet of Things (IoT), Shop-floor communications, AMQP protocol.**

I. Introduction

When referring to Cyber-Physical systems (CPS) used in industrial processes, specific information security needs are established, so the requirements that a communication protocol must meet are strict. Taking into account the overall goal of achieving efficient levels of information transmission, a number of protocols can be implemented. However, the synthesis, synchronization, and response times of each protocol can be different and determine its applicability in the industrial field where a reliable environment is currently being sought by using a standard method that allows communication. [1], [2].

Messaging systems are compatible with different communication models, each of which defines how information is exchanged between producer and consumer. When there is no consumer of the message, the inconvenience presented is a complication in the semantics required to manage the queues and distribute the information among the various consumers. However, a protocol that manages that internal complexity requires a lot of development. So, knowing the scope of standard protocols for messaging systems and selecting the right one, becomes the key to the efficiency of Cyber-Physical Production Systems (CPPS) [3].

Furthermore, since integration is sought in the communications without loss of information, knowing the characteristics of a protocol allows better use of all communication technologies at the level of industrial production [4].

Today the application of the IoT becomes a competitive advantage, as it describes a scenario in which objects are identified and connected to the Internet; enabling remote control of critical or relevant situations for a domain, through sensors and strategically distributed actuators [5]. However, in order to detect such situations it is necessary to communicate, store, analyze and efficiently process the large amount of information generated each day by these intelligent devices [6].

The message-oriented middleware makes up an important parameter in data delivery. AMQP (Advanced Message Queuing Protocol) is an open standard, widely used in the Internet of Things (Internet of Things - IoT), that was developed to facilitate the exchange of information between elements of the same system or in the industrial process, as in the present case study. AMQP solves security and confidentiality issues without affecting communication performance [7].

For the use of message-oriented communication protocols such as AMQP, it is necessary to know all of its characteristics. For this reason, efficiency tests of the protocol are developed in industrial environment applications, emphasizing on the loading needs of applications, in terms of message size and communication rates. AMQP has finally addressed the interoperability standards of business and industrial messaging based on CPPS, in a simple way that allowed it to transcend in the market [8].

This research proposes an optimal communication method for industrial control in CPPS frameworks using AMQP for shop-floor communication integration. As a general aim, it has been sought to identify the limits of applicability of this IoT protocol, assessing its capacity in terms of message losses, latencies or fluctuations. For this reason, tests in the industrial environment must be highly developed for reliable and efficient applications, in case of sending massive quantities of data that compromise the performance of the system in a given process.

978-1-7281-4886-1/19/$31.00 ©2019 IEEE
DOI 10.1109/ICI2ST.2019.00014

The content of the article is structured as follows: Section II presents a series of related studies that encouraged the development of this work. Section III provides brief concepts which will allow a better understanding of the following sections. Section IV presents the case study used for the research method. In Section V, the architecture and methodology of the communication system is depicted. While in Section VI, the implementation of the communication system is located at the Festo™ Testing station. The results obtained in the communication are presented in Section VII. Finally, the conclusions and future work are presented in Section VIII.

II. Background Literature

This section discusses research and works directly related to the areas in which messaging protocols have been used. The research made on the AMQP protocol is also consulted, by analyzing how this protocol can solve problems in communication networks used in industrial processes. Several scientific articles on the AMQP protocol have been published in recent years:

- Subramoni H. [7], with its research on the Design and evaluation of benchmarks for financial applications using the Advanced Protocol of Message Queue Server (AMQP) about InfiniBand, which aims to observe the performance of AMQP in a real-life scenario, obtaining results that indicate that in order to meet the high-scalability requirements of the high-performance computing financial applications, we need high-performance communication protocols such as AMQP.

- A study carried out by the School of Computer Science and Engineering, South China University of Technology [4], on the design of control protocols for Cyber-Physical systems, is identified as a relatively new thing with a continuous development today. But there is a lack of universal underlying support platform to integrate the underlying devices and evaluate the details of the technology. We introduce a Physical Control Framework to integrate devices from the real world to form the lower level abstraction network with complexity and heterogeneity, through protocols that meet the needs to control remote devices and exchange information from sensors.

- Luzuriaga J. [9], this publication highlights that AMQP allows almost any form of messaging, including classic message queues, Robin, storage and sending and combinations thereof. For example, some consumers can obtain copies of messages while others can come directly out of the same queue, all using different AMQP filters and also using message metadata to support user messages and message grouping.

There are different jobs where messaging protocols are used for IoT systems, one of the most analyzed protocols is AMQP that uses TCP as default transport protocol and TLS / SSL and SASL for security. Therefore, communication between the client and the agent is a targeted connection. Reliability is one of the main features of AMQP, and offers two preliminary Service Quality Levels (QoS) for message delivery: Format destabilization (unreliable) and Settlement Format (reliable). In addition, AMQP is a binary protocol and typically requires a fixed 8 byte header with small message payloads up to maximum size, depending on the / server agent or programming technology [10].

- A study conducted by Steve Vinoski [?] on AMQP, states that this protocol represents an open standard for an interoperable asynchronous messaging protocol. Summing up, AMQP is finally addressing the lack of interoperability standards for business messaging. Therefore, this relatively simple but convincingly powerful business messaging protocol is ready to open up a bright new era for business messaging.

- Another interesting article by Shaoqiang Wang et al. [11], is based on the use of the Network Protocol Analyzer with Wireshark. They mention that Wireshark "understands" the structure of the different network protocols like AMQP, so you can see the fields of each of the headers and layers of the packages being monitored, providing a wide range of options to network administrators when performing certain traffic analysis tasks.

In summary, these works coincide in the search for novel methodologies to generate communication protocols, but do not focus on the transmission of data unlike the present study. In the proposed research, the speed and loss of data transmission is verified using the communication protocol AMQP, which is used to establish connection between the low-cost devices (Raspberry Pi) and Programmable Logic Controller (PLC). Transmission data will be sent to a web interface.

III. State of the Art

A. Cyber-Physicals Systems

Cyber-Physical System (CPS) is the term coined by the American foundation NSF (National Science Foundation) which takes its name from the result of equipping the physical components or objects that we usually find in our working environment, with computing and communication capabilities to convert them into intelligent objects able to overcome the simple embedded systems in terms of capacity, security, scalability, adaptability, resilience and usability. These intelligent objects can work together to form distributed and fully autonomous ecosystems. Therefore, CPSs go beyond

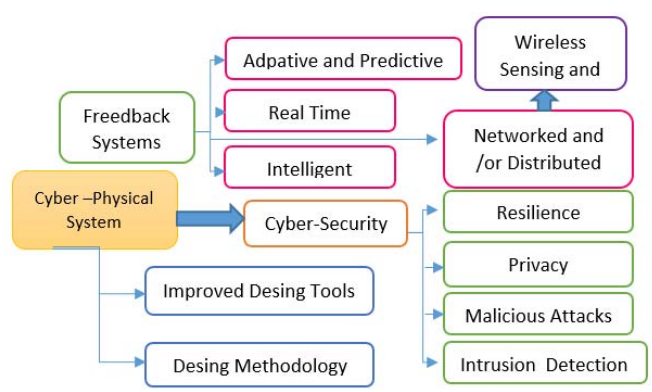

Fig. 1. Cyber-Physical Systems

individual objects by offering services over the internet as it refers to more complex systems composed of other systems and they are able to learn from the interactions that have with the physical world, so that they turn ordinary environments into intelligent ones [12]. Below, the main features of a cyber-physical system are presented in (see Fig. 1).

B. AMQP (Advanced Message Queuing Protocol)

Advanced Message Queuing Protocol was designed as an open replacement for the existing proprietary messaging middleware. Two of the most important reasons for using AMQP are reliability and interoperability. As its name suggests, it offers a wide range of messaging functions, including reliable queues, publish/subscribe messaging based on themes, flexible routing, transactions and security. AMQP exchanges path messages directly - in output form, by theme, and also based on headers [13].

The AMQP architecture is conformed by: Producer, a client application that generates AMQP messages; Consumer, a client application that receives AMQP messages generated by a Producer; Broker, a server to which client applications (Producers and Consumers) connect to send and receive messages, which represents an abstraction of a queue used to store and send messages to appropriate consumers; Exchange, the component in charge of redirecting and filtering the messages sent by the Producers [14], which is shown in (see Fig. 2).

With regard to the features of AMPQ, the most important is the acknowledgment of receipt, namely the AMQP standard, which provides mechanisms to ensure the correct reception and processing of a message. It also has durability and resistance since it indicates whether a queue or message should survive a broker restart. Priority is another feature that allows to assign a priority to each message so that messages of higher priority are sent before others in queue, having an expiration time in which a maximum duration of validity to stay in the system is assigned. In relation to the data transport used, AMQP considers that all communications are done through TCP, as well as limiting its scalability because the broker must maintain an active connection for each publisher or subscriber present in the system [15].

C. Raspberry Pi

The Raspberry Pi can be defined as a small computer with functions similar to those of a PC. It has several ports and entries, two USB, an Ethernet and an HDMI output. These ports allow to connect the mini computer to other devices, creating a correct interaction in environments that require control. Raspberry Pi uses an ARM processor architecture, RISC type (Reduced instruction Set Computer). That is, it uses a simple instruction system that allows you to perform tasks with minimal power. Also known as a single-board computer, it has a 1.2GHz, 64-bit Quad-Core ARMv8 processor, a 1GB SDRAM memory, four USB ports, low-level peripherals with a seventeen GPIO bus, 800mA and 4W power consumption. supports the following operating systems: Debian (Raspbian), Fedora (Pidora), Arch Linux (Arch Linux ARM), Slackware Linux [16].

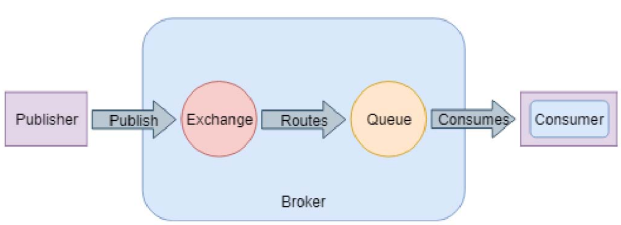

Fig. 2. Example of an AMQP routine

D. Snap7

As far as communications are concerned, industrial control systems are characterized by a large number of existing protocols, without neglecting that each manufacturer develops for its products with specific characteristics such as the S7 of Siemens. The suite called Snap7 is a multi-platform software to communicate in the same way that PLCs from the manufacturer SIEMENS would do, interfacing natively with Ethernet technology and the S7 protocol, which is oriented to functions or commands. Snap7 can work as a client, server or partner with Siemens PLCs. Snap7 does not need additional configurations once installed, it simply requires the use of C language for its use.

The main features of the Snap 7 are: its architecture, designed for 32 and 64 bits; the support it has for several operating systems; its support for several types of CPU and the management of transmission of information both synchronous and asynchronous. Today, Snap7 gives partial support to Siemens CPUs such as 1200 and 1500, without the need to use a special adapter, since it is oriented to be used in Ethernet and S7 communications. Bearing in mind that, in applications of automation it is crucial to have a message-oriented processing, the RFC 1006 application addressed to messages is used but based on TCP [17].

E. Node-Red

In today's industry, by programming sequences or simple instructions, the behavior of specific equipment connected to operational processes can be handled. The use of textual programming languages such as Assemblies, C, Python, and JavaScript, is one of the main ways to do it, so the treatment given to them must be made as simplified as possible by having the same textual code font for all the programs.

Node-Red is a visual programming tool, which allows relationships and functions and giving the user the ability to program without having to write in a specific language, in Node-Network you can add or delete nodes and connect them allowing to communicate with each other. Node-Red is a quite simple software to use on Raspberry Pi and is built on Node.js, it is driven by JavaScript, granting the possibility of writing in the function nodes within the code editor [18].

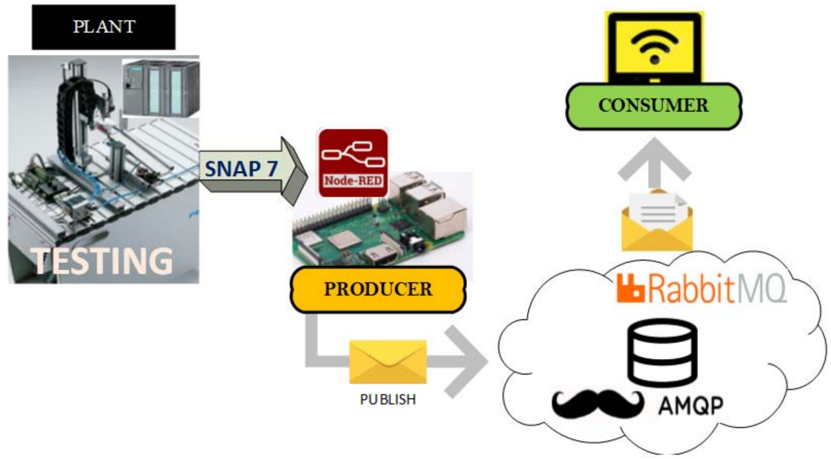

Fig. 3. Case Study Communication System Architecture

IV. Case Study

Inappropriate industry quality control methods are evidenced when there are products being exposed to errors as a result of malfunction and improper use of materials by workers during the manufacturing process. Therefore, industry quality control becomes the main constraint for improving and finding solutions. The case study is aimed to integrate shop-floor communication using AMQP protocol under low-cost CPPS in order to get a classification of the quality of the product in the Festo™ testing workstation, applying an automated defect by attribute inspection analysis model under the concept of "pass or fail". This information is sent to a server that monitors the process in real-time.

The testing station is responsible for detecting the color, material, and height of workpieces and classify certain kinds of workpieces to the next workstation within the Festo™ Modular Production System (MPS). The testing station handles the following tasks: (i) acquisition of information (test if the workpiece is red, metal or black and measure its height), comparing specified characteristics with reference values and resulting decision (reject black workpieces and pass red and metal workpieces). Besides these functions, the testing station has to be able to track the position of workpieces and move them along from the sensing module to the height measurement module using the lift module and ejecting pistons and finally to the next station via the slide module.

AMQPs automated communication system successfully covers situations where the operator cannot stay close to a process all the time to avoid workpieces imperfections, therefore, a web server is created in direct connection with the communication protocol, so that when the parts are found on the FESTO™ station, an error is detected, which will be reported by the application and the operator will be immediately alerted.

The process implemented will determine the presence of the workpieces and mainly uses the classification of them, without the presence of the operator. This in turn facilitates the methodology of quality control, reducing considerably the costs involved, since it is almost impossible to carry out this type of inspection in terms of technical and economic factors and to increase, at the same time, the assurance that there are no defective workpieces in a consignment lot.

Above, Fig. 3 shows the components used to establish communication between a plant and a computer, using a CPPS in a low-cost device like Raspberry Pi as an intermediary.

V. Communication Architecture Proposed

To have a communication frame to get real data of the current situation of a company; the system architecture for the Server-Client communication is detailed below. The CPPS system is implemented using a low-cost device as Raspberry Pi. It focuses on the integration of computational applications with physical devices, being designed as a network of interacting cyber and physical elements.

The use of Snap 7 in Raspberry Pi is used to read the status of each process variable and while the Node-Red software is used to download the variables and identify each of them, also, to act on the variables that are necessary to obtain the required data of the process. In Fig. 4 the Step 7 structure and the AMQP server that we want to use for communication are shown.

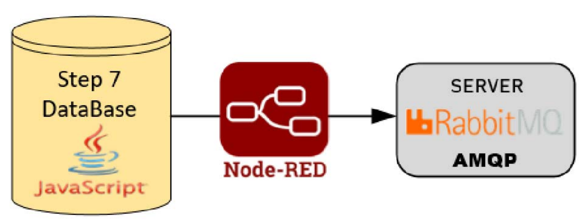

Fig. 4. Step 7 - Node Red

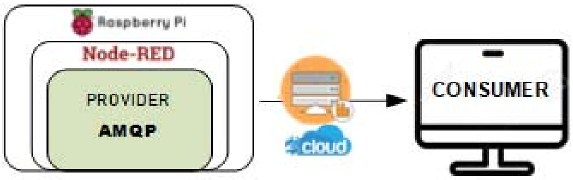

Fig. 5. Node Red Consumer

To do this, several add-ons were used, such as the Snap 7 library with version 1.4.2., for Raspberry Pi 3. It can be seen that the plot consists of two main parts, which are: Topic.- where the name of the variable is stored , and the second part called Pyload, that stores the value of the variable. Also, with the Node-red 0.19.5 software which is a platform written in javascript language, each of the libraries is configured so that they are enabled and available to use. Once the libraries are configured, it is already possible to read the variables of the PLC.

The variables recognized with the AMQP server in the Node network are used in the AMQP client in Node-Red, to create nodes that can send the data to the graphical interface designed to display these variables. In Fig. 5 the configuration used to establish a connection with the consumer is observed. The current state of the variables will be sent to the consumer only if the workpieces complies with the desired requirements.

To start communication with the established protocol (AMQP), a server that works with this protocol must be installed. In this case, RabbitMQ was installed, since it is a good broker of open-source messages that allows us to have several deploys nodes and what is better to store information in the cloud. It must be taken into account that to install the library above, you must first install the Erlang library in which the Orbit client library of RabbitMQ allows the code to interconnect with the AMQP consumers. The protocol library should be installed in the network of nodes since that is where the process variables will be read.

Finally, instances are installed in the AMQP cloud to communicate with different devices. It is very useful that the protocol used in an industrial process can be analyzed in this area and obtain the performance of the communication. And consequently we can analyze if the result is good for the industrial plant.

VI. Implementation Proposed

A. *Shop-floor Data integration on Festo™MPS Testing*

The plant designed to simulate quality control in the product detects the pieces matching different characteristics and gives a reading value according to the dimension of the pieces. These values are sent to a PLC. Data is transferred from Simatic Manager through PLC and Raspberry communication acquired by the Snap7 library. Snap7 in Raspberry allows the communication through a port, acquires all the information of the PLC and makes it available for Rasberry Pi to run an application with the ability to work with this library. For the case study in this document, the programming of the Node-RED platform carries this information through a Snap7 node configuration node developed in JavaScript. This node, once installed on the Node-RED platform, first verifies the IP address, port, rack and slot configured in the CPU.

The data received by the Rasberry Pi through Snap 7 are stored in a message flow within Node Network in the transmission of cyclically loaded values every time a variable changes. The message flow consists of a frame with two components; msg-topic, and msg-pyload.

B. *Communication flow in Node-RED*

The work platform of Node-Red is composed mainly of nodes of palettes, space of flows of messages and panels of information and debugging. And once the local IP and port are identified, you can access Node-Red through a browser.

The message flow is the abstract connection between the communication components, in this case, the Snap7 server and AMQP. The information is contained and transmitted in the payload of the message (msg-Payload), this is the most relevant action for the message transfer component, since msg-topic is used by each node differently depending on their needs. Continuing with the communication flow, once the message arrives at the AMQP server of the node, it is the only component that accepts the message load, and inside the Out node of the AMQP, msg-topic takes the value of the destination user of the message.

The Output AMQP server node in the first instance verifies that the user ID server has the appropriate JID structure and a password. Once the information server is verified, it allows making available to any client the identified data upload message.

Fig. 6 shows the implementation of Step 7 nodes in the Node Network where the state of the variables used for communication is configured. In this case, we will include two input nodes in different frames, which represent the two signals that acquire the values of the PLC memories that come from the analog sensor of the Festo™testing station. These signals are sent to nodes output servers of AMQP that provides the messages to the clients in Node Network.

Since the PLC marks deliver a Boolean value, the message to take the string values required in the message is identified. For example, the load message is processed when the (bad) mark is true; this represents a text string for an AMQP client.

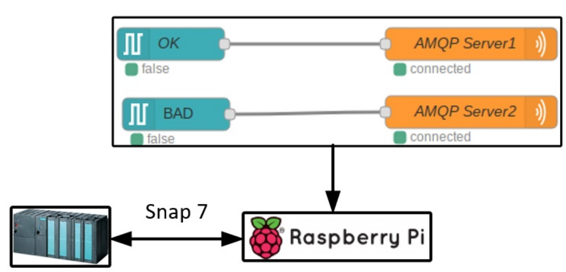

Fig. 6. Data integration on CPPS using Snap7 and AMQP server

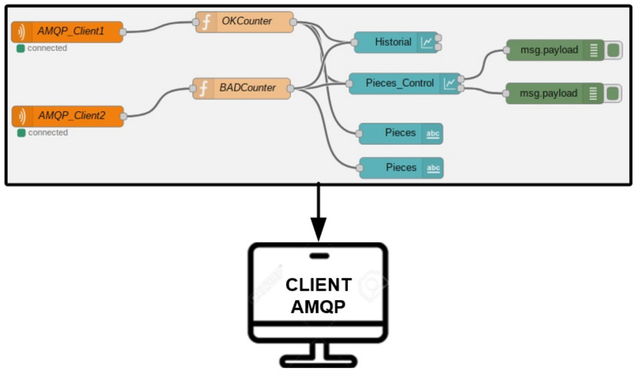

Fig. 7. Data Visualization on client side.

In Fig. 7 the nodes that are used to establish a connection with the consumer are depicted. The current state of the variables will be sent to this consumer if the piece meets the desired characteristics. In other words, the image describes two frames that will treat the two signals coming from the AMQP server nodes. The AMQP clients receive the processed signal, that is, whether the PLC marks are activated or not. For example, the M0.0 mark that corresponds to the workpieces that meet the required standards has a good signal that corresponds to being "true". If the mark is activated, the node OKCounter, will count as a unit that meets the requirements. Whereas if the other frame, the AMQP Client 2, receives a "true" signal in the "BADCounter" node, it will be counted as a part that has not fulfilled the requirements. These values will feed a statistical chart where the quantity of good and bad quality elements can be visualized. While the node "History" belongs to the memory space where the elements that pass through the process are stored in a timeline.

VII. Discussion of Results

In Fig. 8 a statistical diagram with the results obtained for a batch of 100 processed workpieces is observed. The incoming pieces are received by the sensor at the moment in which the plant is operating, its reading value is represented in each variable as elements that meet the characteristics and elements that do not meet these characteristics. Thus, in Fig. 8, the dark blue part represents the defective pieces, while the light blue part represents the non-defective pieces. In addition, a numerical result is obtained in the lower part of the graph, indicating the percentage that contains the statistical graph. Also in the "History" statistical graph, a timeline is shown on the x-axis, which represents the time to analyze the quality of each element, with the intention of knowing the existence of elements with poor quality and thus reduce time waste of the plant operators during the decision making process.

Also, Fig. 8 presents the website interface in which the operator that gets the connection IP, can access and visualize the data acquisition of the process through statistical graphs. If the user sees any difficulty in the process the operator can suggest corrective or preventive maintenance in the manufacturing processes.The figure shows a problem found in the process, in this case the operator can intervene effectively by suggesting the actions to take in the manufacturing processes.

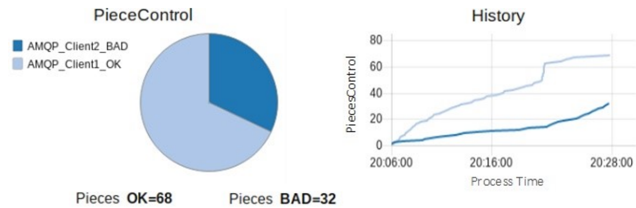

Fig. 8. Screen with statistical data

Fig. 9 corresponds to the Queued messages metric. It shows that message queues have a value of zero, this is because the message queues are generated according to the resources used by the sent messages of the AMQP server. In this case there are no messages in queue, because the messages sent do not occupy a high percentage of resources, and at that moment our process had made a quite simple commutation. It should be noted that while messages are arriving, the graph is continuously being updated. In addition, figure 9 also shows the Message rates metric for the last-minute, boths graphs represent the delivery and publishing of the process messages, obtaining as a result that the delivery was completed in a time of 0.4 sec; while the response time or publishing time of the messages was approximately of 0.2 sec, with a processing time of 15 sec.

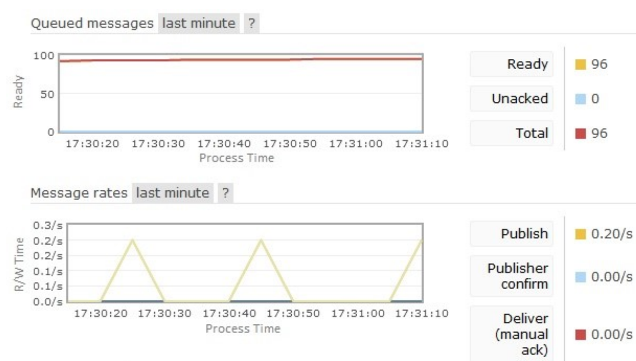

Fig. 9. Message queue in Rabbit MQ

In Fig. 10 an analysis of network message exchange is shown. The analysis was performed with the Wireshark software obtaining a real-time graph, representing the consumption of bandwidth that is occupied by the AMQP. It is evident that the communication with the protocol is efficient. In other words, a high-performance equipment is not necessary since the communication occupies a low percentage of bandwidth which is optimal to perform this type of communication and it is not exposed to a request for data.

VIII. Conclusions and Future Work

With the transmission of data via the AMQP protocol, process effectiveness and low bandwidth consumption for data

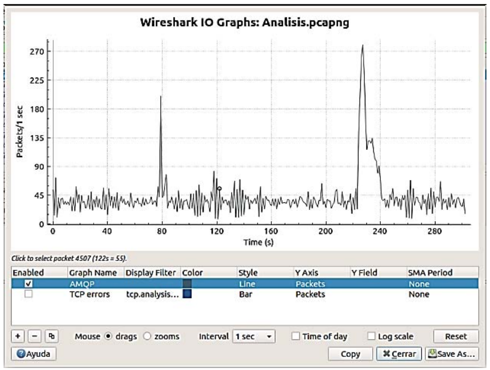

Fig. 10. AMQP analyzer over architecture proposed

transmission were achieved. In this way, the consumer obtains the results of the plant performance in real-time in a visual interface that can be accessed from anywhere in the world, and thus the quality of the plant production process can be evaluated.

The AMQP communication structure developed, creates a reliable quality control, by means of a light and secure message routing, allowing to visualize the state of each workpiece along the process in the history graph. The proposed method is able to identify the defective parts, for decision making and corrective maintenance according to the respective analysis.

The data traffic inspection shows that there are fewer reading errors because there are no messages forwarded to the system. This indicates that there is no increase on information loss using the AMQP information protocol, obtaining optimal message performance per second through a low-cost intermediary device.

As future research, it is intended to evaluate the work proposed with other application contexts and thus determine their capacity to adapt to industrial processes according to communication requirements. In addition, we aim to further implement this method with other types of communication protocols by performing a data traffic analysis, determining the speed of transfer and the protocol ability to communicate in order to improve the performance or industrial applications by applying the achieved results. .

Acknowledgments

This work was financed by Universidad Tecnica de Ambato (UTA) and their Research and Development Department (DIDE) under project CONIN-P-0167-2017.

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CAPITULO III.- CONCLUSIONES Y RECOMENDACIONES

3.1 Conclusiones

Con la transmisión de datos a través del protocolo AMQP, se logró la efectividad del proceso y el bajo consumo de ancho de banda para la transmisión de datos. De esta manera, el consumidor obtiene los resultados del rendimiento de las plantas en tiempo real en una interfaz visual a la que se puede acceder desde cualquier parte del mundo y, por lo tanto, evalúa la calidad del proceso de producción de las plantas.

La estructura de comunicación AMQP desarrollada, crea un control de calidad confiable, mediante un enrutamiento de mensajes ligeros y seguro, que permite visualizar en la historia el estado de cada producto en proceso. Pudo identificar los productos defectuosos, para la toma de decisiones y la corrección. Mantenimiento según el análisis respectivo.

La inspección de tráfico de datos muestra que hay menos errores de lectura, porque no hay mensajes reenviados al sistema. Esto indica que no se aprecia la pérdida de información utilizando el protocolo de información AMQP, obteniendo un rendimiento óptimo de mensajes por segundo a través de un intermediario de bajo costo.

Como investigación futura, se pretende evaluar el trabajo realizado con otros contextos de aplicación y, por lo tanto, determinar de acuerdo con las características de la comunicación, su capacidad para adaptarse a los procesos industriales. Para implementar aún más este método con otros tipos de protocolos de comunicación para realizar un análisis de tráfico de datos, la velocidad de transferencia y la capacidad de comunicarse para obtener ventajas en aplicaciones industriales para clasificar su utilidad en la industria de acuerdo con los resultados obtenidos.

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