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Prospective for the integration of Blockchain and the IoT for Cluster implementation

Prospectiva de Integración de Blockchain e Internet de las Cosas para una implementación en Clúster

Prospectiva para a integração de Blockchain e IoT para Cluster implementação

José Ignacio Rodríguez Molano[1]
Jhonnatan Nicolás Martínez Baracaldo[2]
Jenny Alexandra Triana Casallas[3]

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[1] Facultad de Ingeniería. Universidad Distrital Francisco José de Caldas, Bogotá, Colombia
ORCID: https://orcid.org/0000-0003-2581-277X
E-mail: jirodriguezm@udistrital.edu.co

[2] Facultad de Ingeniería. Universidad Distrital Francisco José de Caldas, Bogotá, Colombia
ORCID: https://orcid.org/0000-0002-3255-3924
E-mail: jnmartinezb@correo.udistrital.edu.co

[3] Doctorado en Informática. Universidad de Oviedo, España
ORCID: https://orcid.org/0000-0003-2943-6361
E-mail: UO268296@uniovi.es

Abstract

Introduction: The present article is the result of the investigation and approach to the applications and developments of blockchain and Internet of Things (IoT), developed during the second semester of the year 2019 and first of 2020.

Problem: Construction of environments and mediums in a cluster structure that allow companies and institutions to cooperate and compete to achieve efficiency and strengthen grouping.

*Objective***:** Integrate blockchain and IoT to develop and present a two-level architecture, from which a support environment is established and a series of functionalities are offered for a cluster implementation.

*Methodology***:** Review articles to achieve an approach to blockchain and IoT architecture, configuration and description of structural and functional levels.

Results: An architecture with a structural level constituted by a decentralized computer application based on blockchains, a sensory and response network that incorporates IoT technologies and an intermediate component of cloud computing; this, at a functional level that manages to offer users support and help in their activities from modules created with a particular specialty.

Conclusion: The structural level furthered the integration of base technologies, blockchain and IoT; on the other hand, the second level of architecture reveals the potential and versatility of these technologies.

Originality: Proposal for the implementation of blockchain, IoT and cloud computing in a cluster structure.

Limitations: The difficulty of accessing a cluster to perform a test of the architecture in a real environment.

Keywords: Cluster, Blockchain, Internet of Things, Cloud Computing

Resumen

Introducción: El presente artículo es el resultado de la investigación y acercamiento a las aplicaciones y desarrollos del blockchain e Internet de las Cosas (IoT), estudio desarrollada durante el segundo semestre del año 2019 y primero de 2020.

Problema: Construcción de entornos y medios en una estructura de clúster que permitan a las empresas e instituciones cooperar y competir para alcanzar la eficiencia y el fortalecimiento de la agrupación.

Objetivo: Integrar blockchain e Internet de las Cosas para desarrollar y presentar una arquitectura de dos niveles, desde los cuales se establezca un entorno de apoyo y se ofrezcan una serie de funcionalidades para una implementación en clúster.

Metodología: Revisión de artículos para lograr un acercamiento al blockchain e Internet de las Cosas, planteamiento de la arquitectura, configuración y descripción de los niveles estructural y funcional.

Resultados: Arquitectura con un nivel estructural constituido por una aplicación informática descentralizada basada en blockchain, una red sensorial y de respuesta que incorpora tecnologías de Internet de las Cosas y un componte intermedio de computación en la nube; y un nivel funcional que logra ofrecer a los usuarios soporte y ayuda en sus actividades desde módulos creados con una especialidad en particular.

Conclusión: El nivel estructural permitió ahondar en la integración de las tecnologías base, blockchain e Internet de las Cosas; por su parte el segundo nivel de la arquitectura deja entrever el potencial y versatilidad de dichas tecnologías.

Originalidad: Propuesta de implementación del blockchain, Internet de las Cosas y la computación en la nube en una estructura de clúster.

Limitaciones: La dificultad de acceso a un clúster para realizar una prueba de la arquitectura en un entorno real.

Palabras clave: Clúster, Blockchain, Internet de las Cosas, Computación en la nube

Resumo

Introdução: este artigo é o resultado de pesquisa e abordagem de aplicações e desenvolvimentos do blockchain e da Internet of Things (IoT), estudo desenvolvido durante o segundo semestre do ano 2019 e primeiro de 2020.

Problema: Construção de ambientes e mídias em uma estrutura de cluster que permite às empresas e

as instituições cooperam e competem para alcançar a eficiência e fortalecer o cluster.

Objetivo: Integrar blockchain e Internet of Things para desenvolver e apresentar uma arquitetura de duas camadas, a partir do qual um ambiente de apoio é estabelecido e uma série de funcionalidades são oferecidas para um implantação de cluster.

Metodologia: Revisão de artigos para chegar a uma abordagem do blockchain e da Internet das Coisas, abordagem da arquitetura, configuração e descrição dos níveis estruturais e funcionais.

Resultados: Arquitetura com nível estrutural constituído por um aplicativo computacional descentralizado baseada em blockchain, uma rede sensorial e de resposta que incorpora tecnologias da Internet das Coisas e um componente intermediário da computação em nuvem; e um nível funcional que consegue oferecer suporte aos usuários e auxiliam em suas atividades a partir de módulos elaborados com uma determinada especialidade.

Conclusão: O nível estrutural permitiu aprofundar a integração das tecnologias de base, blockchain e

Internet das Coisas; por sua vez, o segundo nível da arquitetura revela o potencial e a versatilidade

dessas tecnologias.

Originalidade: Proposta de implantação de blockchain, Internet das coisas e cloud computing em uma estrutura de cluster.

Limitações: A dificuldade de acessar um cluster para realizar um teste de arquitetura em um ambiente real.

Palavras-chave: Cluster, Blockchain, Internet das Coisas, Cloud Computing

1. Introduction

Porter defines a cluster as a geographically dense group of companies and related institutions (universities, standardization institutes, trade associations, among other entities that can be incorporated into the cluster), belonging to a specific field, united by common features and complementary to each other, thus forming a favorable environment for the members of the cluster to cooperate and compete [1]. The first element of this cluster scenario, cooperation, is directly related to the integration of different organizations and institutions in an environment of contribution and mutual benefit, either through the supply of raw materials and products in the provision of services, or in partnerships for research and development; localized competition promotes development, innovation, higher quality standards and continuous improvement to meet and exceed the requirements that the environment demands. However, to make a cluster efficient in its operation and therefore generate benefits for its companies and institutions, it is especially important to strengthen and encourage interactions, facilitating the processes where they work together to make them more fast and reliable and establish greater recognition and implementation of available resources. In order to achieve this efficiency, some technologies and paradigms of information technology and communication are identified, such as the blockchain, a decentralized data structure composed of interconnected blocks and the Internet of Things (IoT) [2], a network of interconnected objects that takes on properties of intelligence and autonomy [3] [4], where these elements are outlined with great potential to contribute to the functioning of the cluster and favor its modernization; however, it is not only a matter of considering its benefits, but incorporating these elements, a task that requires developing an adequate connection and structure to exploit their properties.

2. State-of-the-Art of Blockchain and Internet of Things (IoT) for an approach to its applications

Initially, it is necessary to go further into three elements; two of them already mentioned in the introductory section. However, due to its importance in the architecture that is presented in this document when forming the base or structure of the proposed application, it presents a specific definition for each of them.

Blockchain

It is a data structure that operates as a decentralized book, in which the transactions carried out in a network are recorded and stored in a chain [5] [6]; the chain of blocks is completely preserved from its origin until the last transaction is made. The blocks are created by a mining process that involves solving complete computational problems. Once created they are incorporated chronologically into the chain, the blocks have a unique link to the previous block, an identification number and a series of specifications [7] [8], measures that together prevent the chain from being altered, validating it and offering security and confidence to users [9] [2].

Internet of Things (IoT)

The IoT aims to integrate and connect objects with each other at any time and place, thus forming a collaborative network that interacts through the Internet and contributes to improving the rendering of services and carrying out activities in various fields of application, achieving greater levels of flexibility and reducing human intervention [10] [11] [12]. These objects, in the context of the IoT, are called intelligent objects. These are characterized by the capabilities of detection, memory, data processing, response and communication. This is achieved thanks to the incorporation of sensors, actuators, RFID tags and electronic components as key technologies that enable and allow much of the aforementioned characteristics [3] [10] [11].

Cloud computing

Cloud computing allows access through a network to shared computer hardware and software resources such as storage units, servers and programs, in turn offering users confidence, security and availability in accessing said resources [11] [13]. Cloud computing is emerging as a solution to the technological problems related to the IoT. For this reason, these two technologies are often implemented jointly, since aspects such as improvements in the flow and management of data and in the realization of the functions of the devices that are achieved thanks to the most direct connection and to facilitate the operation in real time, constitute it gradually as a complement of great interest for the applications [4].

In order to establish an approach to the developments, applications and trends originated in the context of blockchains and the IoT, a review was carried out of thirty two documents consulted in databases such as ScienceDirect, SpringerLink, Scopus and Google Scholar. This review was developed in the period from June 2018 to January 2019. The documents were selected and classified into two categories according to their relationship with these topics. The first twenty one works were related to blockchains in services, industry and logistics, where they are included [9] [2] [5] [14] [15] [16] [7] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30]; the second category, specifically designated for the IoT, frames the remaining eleven [10] [31] [3] [11] [32] [4] [33] [34] [35] [13] [36]. The documents were reviewed, implementing a matrix to extract and organize the relevant information in the development of its content, marking and indicating the topics to which the keyword blockchain in services, industry and logistics made reference. In this way, for the first category, thirty one subjects and nine groups were established; for the second category, fourteen subjects and five groups. The results for each group are presented in Table 1 and Table 2, respectively.

Table 1. Topics groups and topics for blockchains in services, industry and logistics.

Blockchains in services, industry and logistics		
Topics groups	**Topics**	**Keyword by Topic**
Management, validation and registration of information	Record keeping	3
	Registration and protection of Industrial and intellectual property	4
	Blockchains as a mechanism to provide security, transparency and trust	18
Blockchain Payment Network	Cars with connectivity to make micro payments	1
	Air delivery drones that allow you to make micro payments	2
Blockchain developments and tools	Platforms for the development of blockchain applications	1
	Platform and Ethereum blockchain	5
	Smart Contracts	16
	Digital identity	7
Applications with decentralized features	DAOs (Decentralized Autonomous Organizations), DACs (Decentralized Autonomous Corporations) and DASs (Decentralized Autonomous Societies)	2
	Dapps (Distributed/Decentralized Applications)	8
Categories of blockchain	Public blockchains	9
	Private blockchains	10
	Semiprivate blockchains	4
Traceability	Product Life cycle	2
	Traceability and Logistics Systems (Supply Chain)	5
	Traceability in the automotive sector	1
	Transparency and traceability in the food Sector	3
	RFID	4
Applications in the area of technology and computing	Artificial Intelligence supported by blockchain	1
	Applications incorporating the IoT IoT and blockchain	8
	Electronic Commerce	2
	Machine-to-machine interactions (M2M)	3
	CMfg (Cloud making)	4
Environmental Applications	Blockchain and climate change	1
Blockchain for business sectors and businesses	Blockchain and insurance companies	2
	Exchange of electricity by means of agreements supported by blockchain	5
	Construction projects	1
	Exchange and transaction of knowledge between teams and organizations	1
	Collaborative and shared economy	2
	Business Process Management (BPM)	2

Source: own work

Table 2. Topics groups and topics for the IoT.

IoT (IoT)		
Topics groups	**Topics**	**Keyword by topics**
Identification, detection and measurement technologies	RFID (passive and active)	7
	Wireless Sensor Networks (WSN)	4
	Semantic Sensor Networks (SSN)	1
Control systems	Programmable Logic Controllers (PLC)	1
	SCADA system	1
Objects and systems	Automation	3
	Smart objects and Systems (SO)	7
	Machine to machine Emerging Technologies (M2M)	3
Applications in the computer area	Data collection (Big data)	4
	Cloud computing	4
	CMfg (Cloud making)	2
Traceability	Product Life cycle	1
	Supply Chain Traceability	1
	Traceability in the food Sector	1

Source: own work

The results of the review presented in Table 1 and Table 2 were implemented in an analysis by groups of topics, processing the information. The graphs Fig. 1 and Fig. 2 were elaborated with the number of coincidences of the keyword blockchain per subject, thereby allowing for observations regarding the percentage distribution of the same developments, applications and trends that are found more frequently in the documents and some links between them. For blockchain, it can be seen that the developments and tools inherent to said data structure take on a great importance thanks to intelligent contracts [9]; as with information, it is found that security, transparency and trust are three of the main interests in its implementation [5]. On the other hand, in the case of the IoT, there are constant references to objects and systems that adopt the characteristics of these technologies and repeated mention is made of identification, detention and measurement equipment such as RFID tags and Wireless Sensor Networks (WSN) [31] [3] [33] [35] [10] [14] [36]. For categories such as blockchains in services, Industry and logistics and the IoT, there are some topics that commonly appear between the two, such as information, product traceability, RFID tags, machine to machine interactions (M2M) and the systems and operations supported in the cloud.

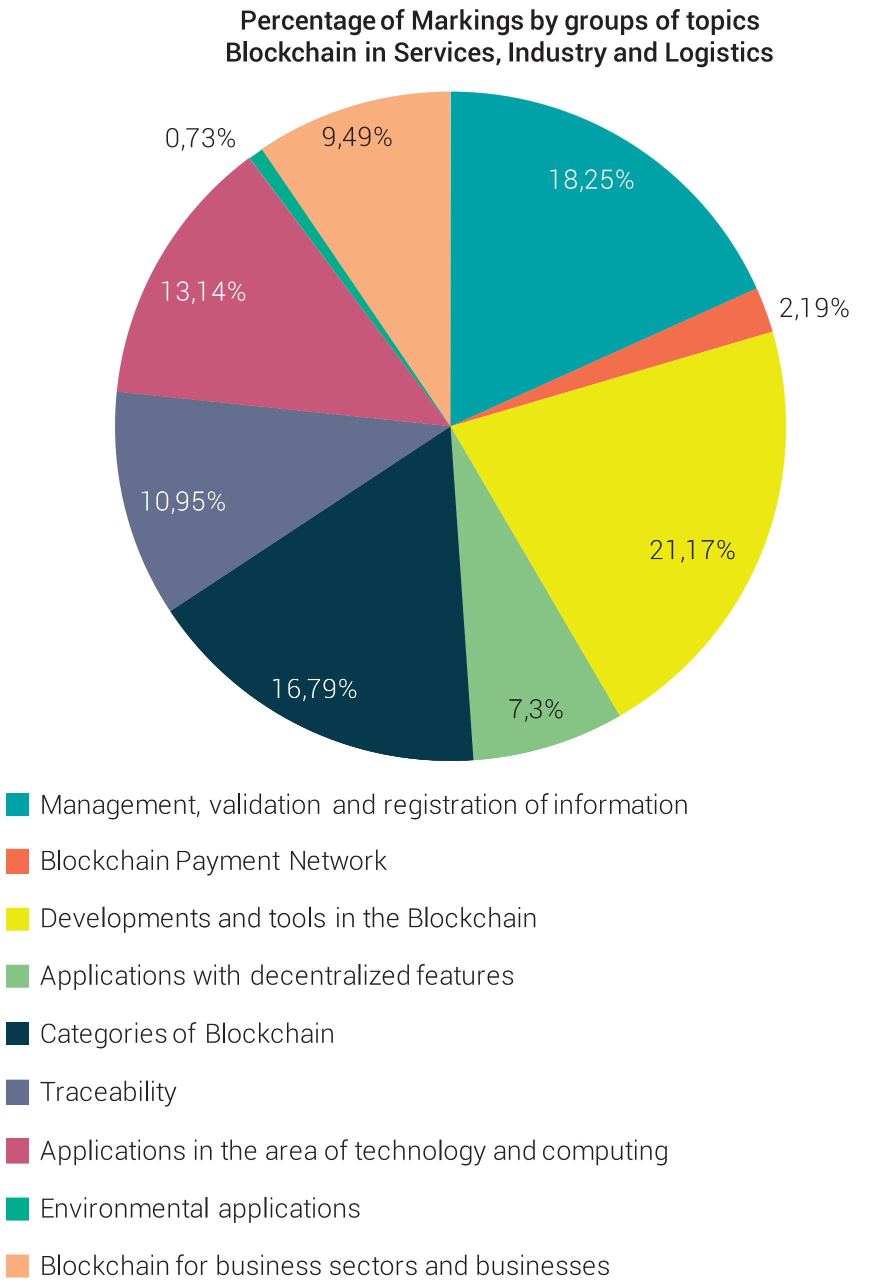

Fig. 1. Percentage distribution of markings by topic groups for Blockchain in services, industry and logistics.

Source: own work

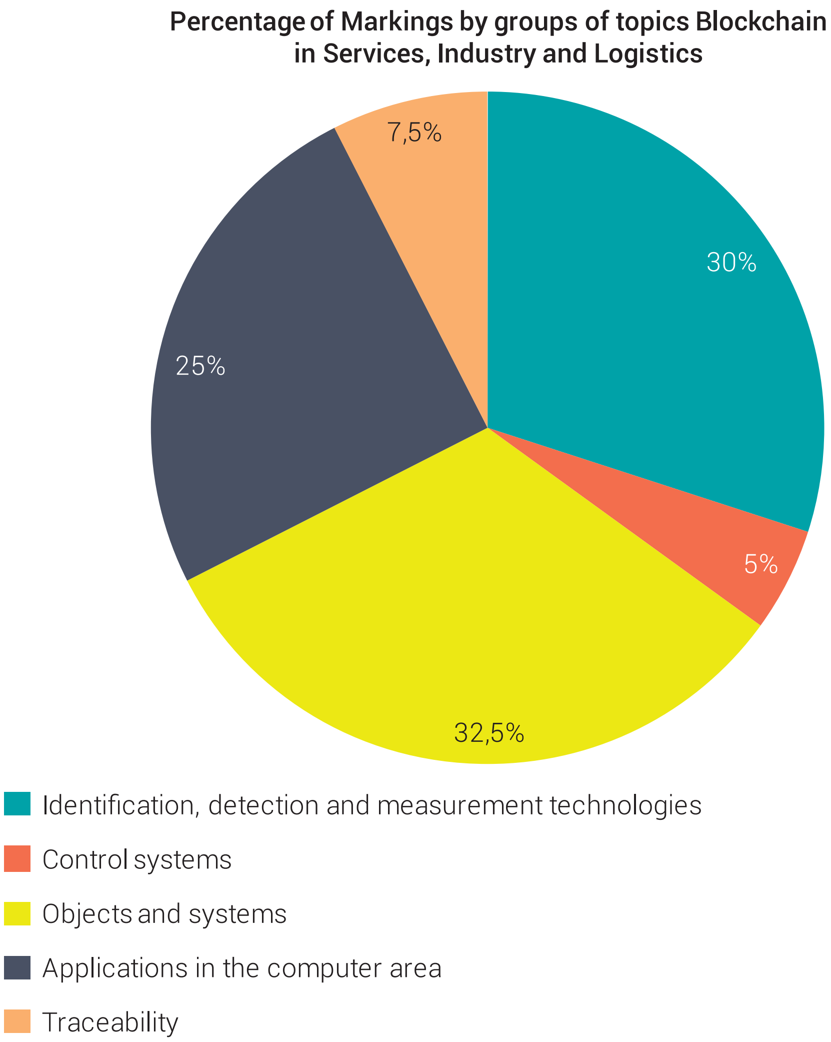

Fig. 2. Percentage distribution of markings by topic groups for IoT (IoT).
Source: own work

3. Integration architecture of blockchains and IoT

The integration architecture of blockchains and IoT, for its cluster application as mentioned above, is developed in two levels; the first with a structural character and the second is made up by the components that allow the functionalities of the area of application. This structure, presented in the following sections with greater detail being provided for each one of its constituent elements, was formed in such a way that an adequate cohesion and operability between its components will be achieved to contribute and generate an appropriate scenario for the operations and activities typical of a cluster. For this purpose, the state-of-the-art was referenced, identifying the characteristics, technologies and considerations to take into account in the approach of the architecture.

3.1. Structural level of architecture

Initially, the structuring level of the architecture will be addressed. This is made up of three basic components: the blockchain data structure in a computer application, the IoT and an intermediate element between these two that is based on computing in Cloud; they seek to leverage their properties, capabilities and applications both individually and jointly, in order to offer the cluster structure a versatile, reliable work scenario with some functionalities. The following three sections present and make specifications on the three components indicated.

3.1.1. Computer applications based on blockchain technology

Blockchain technology, with its protocols of decentralization, encryption, validation and registration, confers a series of attributes such as security, transparency and traceability [9] [2]. Beyond its use in crypto-currencies, with Bitcoin being the most representative and widespread, it can be implemented in various sectors after transferring its properties to non-financial scenarios. For the architecture that is presented, blockchains are the support that strengthens trust and facilitates cooperation between companies and institutions belonging to the Cluster. For this purpose, it is incorporated into a software whose purpose is to be the foundation and center for all the exchanges, interactions and alliances that can be given to the interior of the group.

The principle of blockchains is to be a public book stored around the world [9], although this type of access without restriction has no affinity with a cluster structure, since it does not provide confidentiality when the transparency parameter prevails [5]; handling the data in such a way would expose them openly to the public. Therefore, and in view of the relevance and privacy of the contents in this type of implementation, blockchains in their original form would have no place; it is thus proposed to make use of a particular type of data structure known as private blockchains. This allows participation to be restricted and open only to an authorized group, so that the new participant necessarily requires a permit to be incorporated [5] [14] [24], thus providing a confidentiality mechanism where only cluster members have access to the data handled there, ensuring that they do not leave the established domains. The way of operating a private blockchain retains the attributes of security, transparency and traceability. However, this weakens decentralization compared to its public counterpart [14], reducing the support provided by a global network to a limited local network. On the other hand, to advance beyond cryptocurrencies, the implementation of the functionalities of smart contracts is required; programs that through their codification allow for the automatic execution of business agreements with the fulfillment of certain conditions [5] [2] [8]. These are characterized by autonomy (it starts and runs without surveillance), self-sufficiency (manages resources) and decentralization (distributed in the network) [9], contributing from its logic of operation and coding flexibility to blockchain structures; not only in the generation of contracts as its definition proposes but in programs under distributed structures.

The blockchain network will not directly handle the large volumes of data originated through the IoT (a contrary decision would lead to saturation of the system [22]). The blockchain structure will take over transactions, agreements, property registers and innovations, developments and other goods; in the same way as it is designed to support intelligent contracts, response units with greater development and specification and the structure of the application.

For the proposed computer application, the structure of a private blockchain is conceived in a decentralized application scheme or Dapp, which works by distributing it in a network where each node provides support [9]; so for this case, the network is conformed only by the servers and computers of the cluster participants. The adoption of this type of development seeks to exploit its characteristics of fault tolerance, computational capacity and shared control, avoiding alterations by the sole administrator to the detriment of the users [2]. In this case, the Dapp is built through multiple intelligent contracts interacting with each other [2], where, taking advantage of their structure, different modules are generated that inherit their properties; in the same way, intelligent contracts will be implemented to avoid unauthorized changes, operating as a security system where only modifications to the application can be made under the fulfillment of a series of conditions previously established by the cluster members. The verification of users is another aspect to consider. For this reason, the inclusion of digital identities as a mechanism that provides a unique identification for each company or institution, and being an entry to the records in the chain of blocks, improves the parameters of traceability and restricts access [22] [28]. The aforementioned elements and their configuration make up the computer application based on blockchain technology. In Fig. 3, a general scheme of the same is presented. For this case, a cryptocurrency is not incorporated in the first instance, because the architecture is mainly oriented to data traffic, generation of agreements and cooperation, and a disadvantage that is mitigated in the medium term with this decision is the change in the valuation of the currency; however, it is considered important to allow flexibility for future incorporation and adaptation to this component.

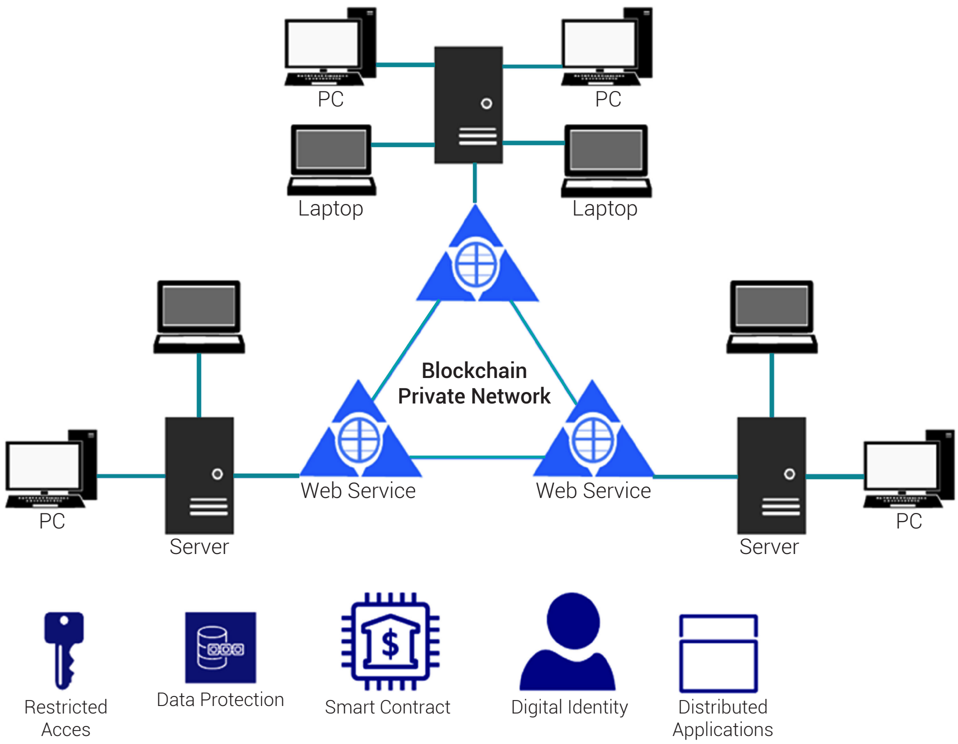

Fig. 3. Computer application based on blockchain technology
Source: own work

Now, for the creation of the application, a development platform is required that allows for the incorporation of the blockchain data structure with the component based on the IoT; it is possible to identify several available tools originated for this type of development. In an article from the University of Malaga entitled "On blockchain and its integration with IoT. Challenges and opportunities" [22], is a comparison chart on a survey that evaluates this type of platform under four criteria: type of blockchain, consensus, cryptocurrency and smart contracts. This comparison is presented in Table 3.

Table 3. Blockchain platforms for creating blockchain applications

Platform	Blockchain	Consensus	Crypto currency	Smart contracts
Ethereum	Public and permission-based	PoS	Ether (ETH)	yes
Hyperledger Fabric	Permission-based	PBTF/SIEVE	None	yes
Multichain	Permission-based	PBTF	Multi-currency	yes
Litecoin	Public	Scrypt	Litecoins (LTC)	no
Lisk	Public and permission-based	DPoS	LSK	yes
Quorum	Permission-based	Multiple	ETH	yes
HDAC	Permission-based	ePoW, Trust-based	Multiasset	yes

Source: Taken from [22]

Table 3 is used as a complement to evaluate which are the most propitious platforms for the development of the application proposed here, considering mainly that they should allow a private blockchain, smart contracts, flexibility to incorporate some cryptocurrency and its approach of operation; therefore, according to these characteristics, Hyperledger Fabric, Multichain, Litecoin and Quorum are discarded since they do not have the capacity to integrate a virtual currency, be a manager of financial resources, operate with public blockchains and their specific orientation to the financial sector respectively [22]. Of the remaining three, and since they meet the established basic requirements, their level of development and flexibility is verified as the last filter. Thus, HDAC will not be considered as a platform in development [22], leaving Ethereum, a pioneer in intelligent contracts and implementation in various areas, and Lisk, that enables the creation and implementation of decentralized applications, as ideal candidates for this development [22].

The elements that make up this application are built from the blockchain data structure. The intelligent contracts that are derived from it provide the tool with versatility without leaving security aside, setting up a suitable space to be an axis of business, interaction, cooperation and development for companies and institutions within the cluster, where everyone can use and participate in the network, thus efficiently connecting to the various sectors present in the group by reducing paperwork, streamlining processes, having better access and control of data. Being connected and participating in the network does not imply exposing all the data of the participants and the implementation of them to full access within the cluster, that is, it is intended that the companies and other institutions determine in common agreement that they will publically handle who has access and at what time. In the same way, for specific cases such as agreements or projects between two or more institutions, where they associate and decide to share the data, it is intended to allow them to establish a muted and restricted exchange for the other members of the network. It is worth mentioning that this application and its data structure act as the receiver and the measurement system for protection, activity logs, processing and other input and output flows generated by objects and intelligent systems in their operation from the configuration of IoT.

3.1.2. Sensory and response network with IoT technology

Porter [1], in his book "Being Competitive", mentions that a cluster provides greater access to specialized resources such as components, machinery, business services, and personnel that results from the spatial concentration of the same. This scenario allows the institutions that make up a reduction of costs, better times and conditions of negotiation [1]; therefore, the resource factor is an axis in this grouping structure where the complementarity of them establishes supporting relationships, shared capacities, improvements in the supply processes and a satisfaction of their propitious needs. An adequate management of resources determines, to a large extent, the increase of productivity and therefore of competitiveness. For this purpose, in this architecture, a new paradigm called the IoT is incorporated that integrates and connects different objects with each other [10], in turn, turning them into intelligent objects determined by a series of criteria such as: identity, detection and storage of measurements, communication with other devices, transmission of information and rationing to act on themselves and their environment [3] [33]. The IoT is configured for a cluster in a sensory and response network in which the generation of data, connectivity and autonomy provide more detailed knowledge, monitoring and efficient access to resources; similarly, the large volumes of data generated by this technology are a valuable asset, helping identify the needs, opportunities, studies, records and the calculation of indicators, to mention some potential applications [31] [1].

The IoT requires integrating electronic components, sensors, actuators, transmitters, control systems, among other elements in a network of connected objects [11]. The infrastructure that this entails is based on the functionality and benefits it can offer, so both the components must be implemented in strategic points, processes, areas and equipment that provide valuable information, improve the operation and generate added value to the companies and institution as well as to the cluster; therefore, the use of this type of technology must be studied and analyzed to exploit its properties to the maximum.

As previously mentioned, the ability of the IoT to capture and interact with the physical environment, making reference to a sensory and response network that perceives and transmits signals of a different nature, in turn generating actions to certain states or properties, makes it comparable to the nervous system of a living organism; for a cluster, this network becomes a sensory and response unit that can be extended to machines, equipment, processes, products, installations and all kinds of objects. Under the premises indicated, some considerations are made about this system at the machine, process, product and instrumentation level, understanding that its implementation and the characteristics that can be taken both structurally and functionally depend to a great extent on the application in question; in this case, the type of cluster. Therefore, some mentions are made seeking to make a general approach for an implementation of the IoT in a cluster type structure.

Machines: Machine state measurements facilitate the monitoring of their conditions and operation records; this allows self-diagnostic actions establishing a source of information and control for maintenance programs [35]. In this way, the companies that are part of the cluster and carry out activities of this type can develop more accurate diagnostics and provide an ideal service in repairs, parts and oil changes, among other interventions that favor an adequate condition of the machine and the conservation of it. With the appropriate sensors, it is possible to evaluate parameters and operation variables such as tolerances, temperature, speed, humidity and identify emergency signals; on the other hand, the implementation of devices that allow for the creation of records in relation to the level of use of the equipment is formed as a tool to know more precisely the work cycles of the machine, thus determining the peaks of activity and times of inactivity, simplifying the programming of joint production between companies in a machine. The actuators perform automatic interventions or are made by a remote operator, thus providing fast, versatile action against any eventuality, reconfiguration of the equipment, commissioning or halting of the same. Machine to machine or M2M integration is emerging as a promising concept in the field of IoT, giving rise to communications between teams that in this case may be inter-institutional, with little or no human intervention [10] [13].

Processes: The set of operations or steps that constitute a process and its holistic vision make up an application area for the IoT in both the services and manufacturing sectors. In each process, specifications must be met and properties are established that arise from the dynamics of the same. Monitor and control is provided by sensors and actuators, covering execution times, quantity of products or services rendered, levels of waste, consumption of materials to produce each unit or production batch, levels of product inventory in processes and bottlenecks. From another perspective, the identification of causes of alterations detected by the collected measurements helps to establish timely responses and continuous improvement. In a complementary way, this instrumentation in the processes can be useful to evaluate the programming of the collected production of the input information for the calculation of performance measurements like the makespan (moment in which the last work leaves the system), costs of enlistment, inventory costs in processes, transport costs, among other indicators [37]. With the considerations made in relation to processes for a cluster, a complete management of activities would be developed with this technology, where it is possible to not only evaluate its performance through statistics and indicators, but also the levels of agreement between processes of different organizations, to inform with greater speed the material requirements to suppliers, the advances in the projects to clients and the eventualities required of joint support or response [12].

Products: The IoT, through sensors and devices, presents an added value in terms of product. The traceability with this technology is evidenced in the state-of-the-art as an outstanding application with extensive research and development, in both the literature and in practice. It is found that it facilitates monitoring the life cycle of the products and, at the end of this, to the recovery of the same [3]. It helps guarantee authenticity [33] and in food products to ensure quality and sanitary controls [34]. Traceability through the IoT is not only applied between links in the supply chain; that is, its vertical integration in a cluster of suppliers, producers and consumers. It also has a place among companies that are in a similar activity or integrated horizontally and internally in the production plants, with real time tracking and records of stock levels and their positioning, quality, specifications and adjustments to be made; information that will be read in the subsequent elaboration stage, thus benefiting the good development of the process, the realization of changes in the configuration and greater solvency in the resolution of problems presented by the part [35].

Instrumentation: Up to now, sensors, devices and actuators have been mentioned without greater detail with regards to the subject. In this section, we will provide more information in this regard. Initially, wireless sensors and RFID tags or radio frequency identification are addressed as tools for perception and virtualization in applications for the industries present in a cluster [20].The wireless sensors (WSN) constitute a network made up of multiple devices that collect data from the physical world and connect to each other and to the Internet [10]. In a cluster, the WSN are integrated into machines, processes and other areas, becoming the sensory component of the network of the grouping; registering the conditions and operation of equipment, generating the input data for the maintenance programs, checking the specifications and evaluating the properties of the processes. The type of records taken will depend considerably on the sensor and the capabilities it possesses, that is to say, the level of precision and accuracy, storage, range of action and the magnitude it is empowered to measure. In the same way, the transmission of information to the centers or devices of control, interested parties and applicants within the cluster as service providers, suppliers, customers, executive directors, will be determined by the scope and quality of the signal issued and where it is addressed. For its part, RFID tags are implemented in people, products and objects for the reading or traffic of information at a distance [14], in the considerations made about the products; traceability was discussed. At this point, it should be noted that RFID tags are an instrument related to this application both internally and outside the factory, offering two classes of passive and active RFID devices; the first identifies and tracks, and the second, in addition to these features, is capable of providing information [33] [38]. The actuators, for their part, are implemented to influence the physical world, that is, they partially configure the response element of the cluster network that is built with the IoT, among them cylinders, motors and valves with energy sources are identified (pneumatic, hydraulic and electric) [39]; the variety in these devices is wide, but the selection of them depends to a great extent on the application and the operating conditions.

Part of the aforementioned cluster's nervous system is the response capacity. Until now, some considerations on actuators have been specified, however, it is necessary to incorporate other components for a complete configuration. Through the IoT, devices take on intelligence and autonomy characteristics [22], therefore, the mechanism or the processing unit that allows objects and systems to act with such characteristics is needed. A structure of two layers is established. The first one is directly integrated to the operation, that is to say to machines, equipment and processes, where each object, as a result of a programming or specification, generates a response in front of a certain signal. For this, programmable logical controllers are incorporated (PLC) that according to inputs captured by sensors, sends responses to the actuators and, along with them, the supervision, control and data acquisition or SCADA systems allow an intervention and interaction with the processes [4]. The second layer is situated at a higher level, both for its development and for its functionality, in which an artificial intelligence unit is housed which is configured and supported through intelligent contracts [9]; a specific design of the unit for each type of cluster with the aim of providing a specialized and comprehensive service for organizations participating in the grouping in topics such as joint programming, optimization, planning and generation of responses that require a higher level of processing and complexity. It is intended that the artificial intelligence unit be a support in the framework of cooperation for the resolution of the most complex problems and a knowledge manager; not that it has absolute control and is a central unit over all operations.

3.1.3. Cloud computing as an intermediate component

The computer application and the sensory and response network presented in the previous two sections, which have part of the structuring level, must work together on several fronts, such as data flow and processing operations. However, due to their own blockchain and IoT architectures, they are identified as certain critical points, that for reasons of incompatibility or poor efficiency are outlined as obstacles to the implementation of these technologies in a cluster, affecting the interactions between the participants of the cluster and the functions and services that are they intend to lend. Below are the problematic fronts:

Information Format: Sensors, RFID tags and other intelligent objects generate data in different formats, where their heterogeneity causes a reduction in application performance [35]. The difference in the type of data caused both by the nature of the measurement and the technology implemented, leads to not being compatible when they are processed together, making it difficult to represent, interpret and analyze them.

Storage of large volumes of data: The large volumes of data produced through the IoT make it difficult to integrate their technology with blockchains [22] since they saturate the network if the storage capacity of the nodes is not sufficient to save a copy of the entire chain of blocks that, for this case, would include all kinds of data on objects, companies, interactions and agreements, which are covered from the creation of the chain and its continuous growth [7].

Blockchain processing speed: The response component was divided into two layers. The second operates through an artificial intelligence unit. If the signal processing that the unit must execute is developed through a blockchain data structure with encryption protocols, validation and registration, the response times would be very slow. Therefore, for specific cases that require an immediate action, this type of operation would be inefficient and inadequate.

In order to properly integrate the components of blockchains and IoT, a support and bridge element is required that allows for a joint and efficient operation, acting as a mediator for some interactions and procedures that occur between the two main axes; to this end, an intermediate component is built on the basis of cloud computing. As mentioned in the initial part of this article, it shares computer resources from memory units, servers and equipment, providing the necessary computational capacity for both processing and storage [11] [32]. The intermediate unit is established as a response to the three aspects identified as a problem, seeking to make up for the shortcomings presented by means of the following functions:

Integration of information: To solve the problem in the cluster that causes the difference in the formats of the data generated by the objects that are part of the IoT, a mechanism is implemented to unify the data, taking them to the same format [35]. Establishing a single point of confluence to unify all the data would saturate the mechanism, so the approach is taken to take a big problem and divide it into many small problems. Such logic and taking advantage of the characteristics of the computation in the cloud are intended in the intermediate component; a certain number of points that will jointly transform the data. In addition to the unification procedure and in order to guarantee the authenticity, transparency and traceability of the contents, a registration is made through blockchains of the operation carried out.

Storage outside the chain: Since the Blockchain network is not capable of supporting large volumes of data, storage outside the chain in the databases within the cloud-based infrastructure would be more appropriate. This methodology is known as an out-of-the-chain solution where access, review, implementation and elimination of the data to an intelligent contract in Blockchain programmed for that purpose is linked so as not to lose security, transparency and traceability [22] [40] [41] [42] [43].

Processing in the cloud: The artificial intelligence unit is configured and supported through intelligent contracts, however, as mentioned, executing processes through blockchains would become very slow in some cases, so this processing is placed in cloud computing [4], taking the computational requirements for the tasks to be performed by different units and equipment in the network conformed in the cluster. Similarly, this type of operation guarantees greater support for equipment failures and shorter response times that are beneficial in a business and institutional environment with high standards of demand and a high number of requirements [44] [45] [46].

3.2. Functional level of architecture

The three aforementioned components conform the structural axes of the architecture. On them, four modules are supported and developed; said configuration is presented in Fig. 4. The part closest to the user, and in which direct interaction with the user is performed, is located in the blockchain technology based application, thus allowing all the associates in the cluster to have access to the information published there and at the same time giving them power to perform some specific tasks that these modules allow according to their specialty. In this way, with the four modules that will be further explained in the following sub-sections, the second level of the architecture or functional level is formed.

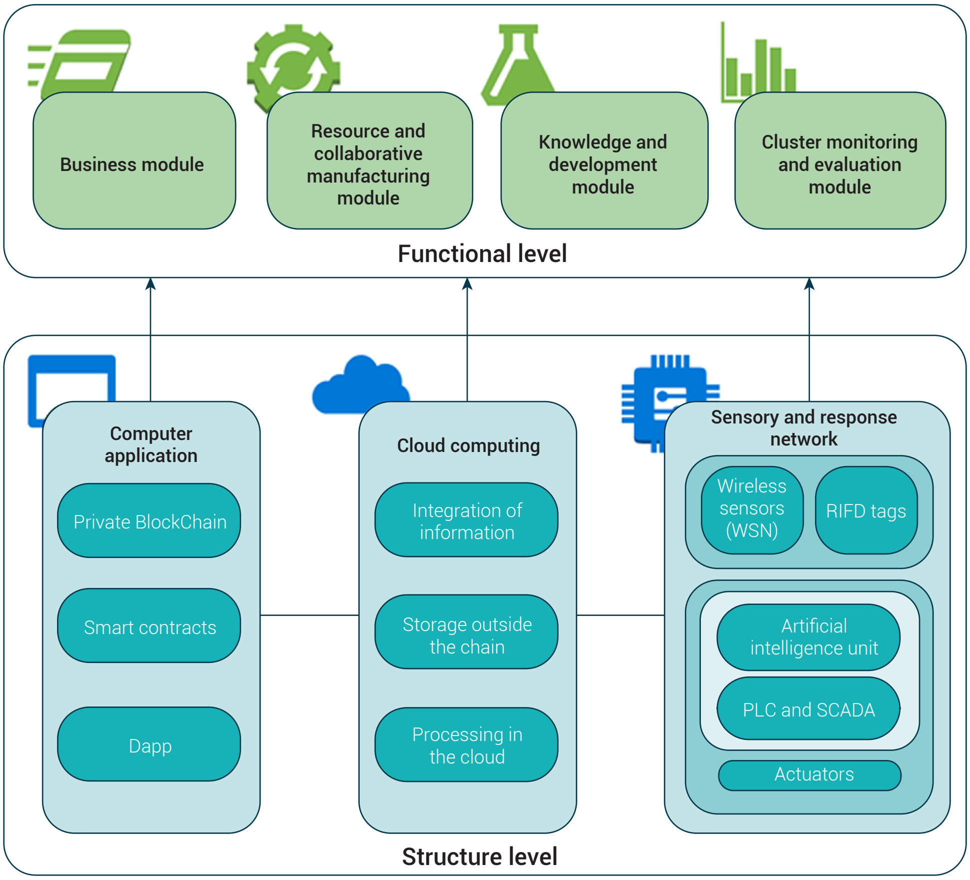

Fig. 4. Architecture of structural and functional levels
Source: own work

3.2.1. Business Module

This module aims to be a platform that offers companies and different institutions within the cluster a specialized nucleus with which to establish processes of approach, negotiation and agreements; for which several elements and characteristics of blockchain and the IoT are used to shape a dynamic and reliable environment for activities specific to these processes [47] [48] [49]. The module is a tool that offers a new way of doing business; a way that is faster, more versatile and reliable, supported by technology, with digitalization and data incorporation.

Smart contracts will be the means to translate the agreements reached between two or more organizations, as the module will have the option to load and link said instruments with the different components, areas or entities involved; in this way they become a mechanism that allows for the registration of the agreements in the chain of blocks, guaranteeing transparency, trust and security and, at the same time, through their codification, the automatic execution according to the fulfillment of established conditions. The module makes a link between intelligent contracts and the IoT. The connectivity of the latter with the physical world creates data inputs through its sensory network and, in collaboration with the artificial intelligence component, supports decision making in the negotiations. In this way, the sensor and actuator networks make it possible to carry out the sections of the contracts that interact with the physical world and that are within reach of the devices, establishing a follow-up on the execution of the same and intervening to make pertinent adjustments in processes or machines. The module includes another function that arises thanks to the combination of blockchains and IoT, derived mainly from the ability to follow up on contracts, where the different data collected and in the continuous comparison with specifications established in clauses and related regulations, generate support for verification processes that investigate irregularities, failures or omissions in order to establish sanctions, compliance with policies and clarification of facts.

As participants in the grouping, the companies and institutions that make up the cluster have access to the business module, allowing for the gathering of bidders, applicants and all types of interested parties, thus promoting the identification of common interests, business opportunities, contracting, generation of projects and initiatives. The structure of private blockchains is built by decentralizing the data between the nodes that make up the network, however, many of the agreements that are generated involve only a small group with the purpose of allowing a higher level of reservation and privacy for such cases; an encryption of the data is established, thus restricting access to the contents without leaving aside the support offered by the network. On the other hand, the digital identity of the organizations within the cluster that was incorporated into the proposed architecture contributes as a measure of commitment, security and validation. Another advantage offered when conducting business through this means is the ease of obtaining an audit on them, initially thanks to a blockchain's operating structure; the activities that go through their protocols are audited [28]. In addition, the participants in the contracts are authorized to select or incorporate companies or specialized entities, such as certified specialists or governmental organizations, to monitor and act as veedores, external auditors or guarantors.

3.2.2. Resource and collaborative manufacturing module

In the context of the resources available in the cluster, the module presented here helps in their management, achieving greater use of them and relating companies and institutions by linking nodes with the availability and capacity to respond to nodes with demand for a good or service in particular. This relationship is closely linked to the business module, where contracts formalize exchanges, the provision of services and the supply of goods once the agreements have been established, such as the supply of raw materials or the provision of maintenance, contracting of personnel or consultancy. The resources and collaborative manufacturing module is implemented as a means to make the direct request of the required resources, achieving greater speed, less paperwork and fewer procedures, thanks to IoT companies and the trust and transparency that blockchains provide. In the provision of services, the instrumentation of wireless sensors provides a more dynamic environment; for the specific case of maintenance and challenges mentioned in the machine section, continuous measurements of the state of the machine are seen by specialists in real time. By means of this module, they perform a remote monitoring of the conditions of the teams, determining more precisely what type of intervention is required and at what moment. In a similar way to the provision of services, the data generated by the sensors can be taken as support, giving rise to various expansions in the field of raw materials and products such as quality measurements, availability, location and product conditions and machines, that through transmission or reading, arrive at the artificial intelligence unit where they are processed with the purpose of being used later by interested parties, either in the productive or academic area.

An important role of this module is to support and encourage collaborative manufacturing. Cooperation in the area of production aims to make better use of resources and reach levels and standards that an enterprise unit would not achieve. Although an industrial facility is conformed by equipment and processes that allow for an elaborate range of goods, it may not have the requirements and flexibility to respond to the variety in the type of demand that the market demands. In the same way, the fluctuations in the quantities may lead to idle capacity or deficit of the same in the installation. Taking advantage of the complementarity and availability of resources in a cluster structure through collaborative manufacturing helps mitigate these difficulties. The first step to achieve collaboration is to implement the sensory network of the IoT, evaluating the level of concordance of production and quality parameters among the participants of the cluster that enter into joint production processes in order to determine if this association is possible. With the approval, formalized agreements are generated through the business module, with devices that elaborate records of the level of use of the equipment and the unit of artificial intelligence. The programming of the joint production and the execution of this program is in charge of the intelligent objects constituted by machines and equipment, that by means of instrumentation such as sensors, actuators, controllers and the RFID tags that are installed in products, allow for the integration of machine to machine (M2M) and the traceability of the products. In this way, it is possible to give continuity to the processes where, when a product passes from one workstation in an industrial facility to another in another production center, the pertinent information is transferred to continue manufacturing.

3.2.3. Knowledge and development module

A cluster, in addition to centralizing resources and generating a space for cooperation in the manufacture of products and services, is a source of information that dramatically increases with the implementation of IoT devices. The relevance and value that information currently has is recognized as an indispensable intangible asset for organizations to endure and grow, which is why this module focuses on its classification, analysis and implementation. Initially, it seeks to manage the knowledge generated in the interior of grouping, both in companies and institutions in isolation, and in the cooperation between them. This helps not to lose elements over time such as know-how, experience gained in certain tasks or projects and developments along with the process to reach them. The data generated through the IoT are stored in the database outside the chain and processed with the help of the artificial intelligence unit to obtain relevant and organized information that can be analyzed and implemented. The availability of these contents supports decision making and the identification of new customer needs and development opportunities [1]. The ability to innovate is presented as a competitive advantage for companies, constituting a determining factor for success. This is presented in scenarios such as the development of new products, projects, techniques and processes where, for its achievement, the alliances between companies, institutes and academics, present in the cluster, become very important. In addition, the importance of data, information and knowledge make blockchains a key mechanism to protect these contents, allowing also to register with the help of this module the ownership of tangible and intangible assets and generate exchange or transfer of knowledge either in agreement or with some type of economic interest [9] [21] [50] [51].

3.2.4. Cluster monitoring and evaluation module

For this last point, a vision of the cluster as a whole is established. The purpose is to make a global evaluation that provides insight into if the grouping is efficient, is generating a collaborative environment, increasing competitiveness and productivity, benefiting its members in the supply of specialized resources, in their growth and innovation, and in the same way, following up on the incorporation of new participants and the creation of companies. To carry out this task and following the procedure of previous cases in this document, intelligent objects are taken as support from connectivity and data generation. Firstly, at the machine, process and product level, the measurements taken are collected and related in a larger system that is at the cluster level, forming input data so that, with the help of the artificial intelligence unit, the calculation of indicators, statistics, reports, concepts and the determination of internal dynamics and flows can be performed. These results are periodically published in the computer application through the section dedicated to this module for internal knowledge and those with authorized access. Its purpose is to be used to evaluate and identify what is done well and what is wrong, to establish early warnings and undertake processes and strategies for continuous improvement that increase the capacity and positioning of the cluster.

4. Conclusions

The implementation of the blockchain and IoT, separately or in joint applications, is becoming more relevant and accepted in various sectors such as finance, industry, services and in the segment of homes. These trends are constantly identifying new advances that gradually mature the technologies and boost their reach.

This document initially presented an approach to the blockchain and IoT, identifying key developments and features such as intelligent contracts, information management and registration, traceability, intelligent objects and identification, detection and measurement technologies, to mention some of the findings.

From the state-of-the-art, a two-level architecture was designed and structured for cluster implementation (grouping structures that includes companies and institutions in sectors such as production, services, academia, research, regulations and state organizations). The first level has a structural role and its approach deepens the integration of base technologies, blockchains and IoT, identifying in turn the critical points that occur in this composition and solving them with the help of computerization in the cloud. Meanwhile, the second part of the architecture is made up of the functional level, this provides a glimpse of the potential and versatility of the technologies implemented thanks to the development of modules with different approaches, from which the users of the cluster can access and support their activities.

The computer application based on blockchains and the decentralization scheme allow for the recognition of the importance of smart contracts for the development of applications in areas that do not directly involve the financial sector and, in particular, virtual currencies. Finally, sensors, actuators and control and response systems are positioned as a source of data and a way to access resources from a digital environment.

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