ESTABLISHMENT OF A HUB-IoT APPLIED IN BUILDING ACADEMIC COMMUNITIES

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Abstract
The use and appropriation of the Internet of Things-IoT grows exponentially, as do its applications in areas such as education and health. In Colombia, despite the efforts and public/private investments in IoT infrastructure, new strategies are required to share resources and build communities around this new technology and thus minimize costs. On the other hand, the Universities have innovated in the educational models towards the application of knowledge in the solution of problems supported in real environments. In this context, IoT teaching requires technological and operational infrastructure that guarantees its application and transfer to the academic and non-academic society. So that, the Telemedicine Research Group of the Universidad Militar Nueva Granada de Colombia, developed a IoT Hub-IoT based on a Service Oriented Software architecture, whose objective is to offer services to create academic and research communities, to the use and appropriation of IoT applications in the area of health. For the implementation of this Hub, the network infrastructure of the Universidad Militar Nueva Granada was used, consisting of a web server (Connection and Access) and an Oracle Linux repository (Processing and Storage) belonging to the domain and address of Universidad Militar. There were used protocols and techniques of modeling and implementation of large Cloud service operators where the state of the Hub-IoT was analyzed comparing its demand and the current market competition. As a result, the use and appropriation of Hub-IoT has been achieved in the construction of a community focused on health solutions, which has allowed the development of research projects, innovative technological developments, research instances, academic agreements and student exchanges with universities such as Universidad de Santiago de Chile, Instituto Federal De Sao Paulo, Institut National des Sciences Appliquées de Lyon, the GISSIC group and data analysis companies such as EyS solutions. It is concluded that the services offered on the Hub-IoT meet the technical and competitive requirements of a commercial provider, with international quality that integrates services and plans to offer a reconfigurable architecture according to the needs of users, applications, heterogeneous sensor networks and with low cost for the population in general, especially academic and research.

Keywords: Internet of Things, Building Academic, Communities, Hub, Healthcare.

1 INTRODUCTION
The educational system of Colombia in search of implementation and use of shared resources requires modern platforms which allow connecting a large number of trained users in different areas of knowledge. To connect and communicate to the users, diverse knowledge networks are required that allow the generation of academic communities, which involve different technological tools that support and lean on the development of recreational and pedagogical activities in the nation.

1.1 Industry 4.0
According to Forbes magazine specialized in finance and business; "We are in the midst of a significant transformation in the way we produce thanks to digitalization. This transition is so convincing that it is called Industry 4.0, a key component is the Internet of Things that is characterized by connected devices and in the cloud where data is stored, although Industry 4.0 continues to evolve, within 30 years companies take advantage of the potential of Industry 4.0 and deal with how to improve their current work capacity to take on new job responsibilities possible thanks to Internet 4.0 and to recruit new employees with the right skills "[1]. With the arrival of a new industrial revolution the most significant change is evident in the education whose technological development incursions into new areas of knowledge with the aim of meeting the labor demand that this revolution generates.

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1.2 Educational platforms

We currently evince platforms oriented to computer-assisted education which allow the creation of academic communities, thus allowing the sharing of academic resources to all users of the field of education, these platforms are limited and are generally affected by economic reasons, preventing sharing their resources to the number of users that would be desired, an example of these platforms was Microsoft Encarta, an offline virtual encyclopedia launched in 1993 which was available with a variety of languages such as German, Spanish, Dutch, French, Italian, Portuguese and Japanese, with a content of 65,000 academic articles and 25,000 informative images until its discontinuation in 2009 [2]; Microsoft Encarta was one of the first to adapt the classic model of encyclopedias to virtual platforms with multimedia, inspiring the arrival of the internet to one of the largest encyclopedias on the planet known as Wikipedia, although this platform is currently discredited by its controversies of access to articles and its information veracity, Wikipedia currently contains 48 million articles with around 300 different languages, currently managed by the non-profit foundation Wikipedia, where a year requires 50 million dollars of donations as funding to be able to continue carrying out its work [3].

1.3 Cloud computing and the Internet of Things -IoT

With the arrival and innovation of various technologies, the training of students, teachers and workers, are increasingly more complex and necessary, for this reason many acquire this knowledge based on assisted self-learning and the solution of specific problems. One of the most widely used technologies today is cloud computing which allows access to consultation services, messaging, storage, security, among other services that large companies such as Google, Microsoft and Amazon Web Services - AWS provide to users for a cost, allowing connecting and communicating continuously to millions of people worldwide[4]. Finally, like cloud computing, many technologies designed decades ago have been implemented so far, as up to now the current tools allow it, one of these technologies is the IoT used as the base infrastructure of cloud computing and as the origin of the 4.0 industry approach.

1.4 Service providers and their costs

Providers such as AWS (Amazon Web Services) and IBM (International Business Machines Corporation) allow to implement IoT systems using their cloud computing services, where their business idea is to provide the connection of all the devices in the network [5]; Although the idea of interconnecting all "things" is ambiguous, its poor implementation is due to the fact that not many quality institutions teach the implementation of these systems, all because their practice needs an infrastructure that generates costs that not any educational entity can afford, currently Microsoft Azure and AWS within their platforms and services, encourage the free development and use of cloud computing to solve current problems through "whitepapers", documents that teach and train their clients in the use of cloud computing and the implementation of IoT systems free of charge, although these documents are accessible to any user, the practices of the same can have a cost ranging from 1 to 100 dollars, depending on the requirements of my equipment and its usage time [6].

1.5 TIGUM Research Group in construction of academic communities

Research Group in Telemedicine from Universidad Militar Nueva Granada -TIGUM, has focused its work in the generation of new knowledge in the area of Medical Engineering and Technology, through its 4 research lines: vital signs telemetry, cardiac monitoring systems, signal processing and hospital management; implemented a WEB server and a Repository server to develop academic and research projects oriented to applications with technologies that use IoT in health. This project analyzed the HUB-IoT of TIGUM based on the offer of commercial services to offer academic services starting from the need to practice new technological systems to students who do not have access to the tools or necessary elements for their training, providing quality services just as a current IoT service provider would do in the market.

2 PRELIMS CONCEPTS

HUB: network element used to connect several electronic devices to each other [7].
IoT: according to Recommendation ITU-T Y.2060 (06/2012) as a global infrastructure for the information society which enables advanced services by interconnecting (physical and virtual) elements based on existing interoperable information and evolution of communication technologies" [8]

HUB-IoT: IoT Hub is a cloud platform as an open and flexible service that supports open source SDK and multiple protocols, used to connect, monitor and securely manage billions of Internet of Things (IoT) applications [9].

Communities construction: are practices and strategies aimed to the creation and development of groups of individuals with a common interest (cultural, religious, political or economic) [10].

SOA: (Service oriented architecture) according to Microsoft; "The SOA Architecture establishes a design framework for the integration of independent applications so that the network can access its functionalities, which are offered as services. The most common way to implement it is through Web Services, a technology based on standards and independent of the platform, with which SOA can decompose monolithic applications into a set of services and implement this functionality in modular form" [11].

CRISP-DM: (Cross Industry Standard Process for Data Mining). It is a model of data mining processes used for the application of technologies in specific projects, where its structure is divided into 6 phases [12].

3 METHODOLOGY

3.1 Materials

Website: web page which provides different homogeneous or heterogeneous services as they are; navigation, storage, processing, etc. and where it also allows interaction between them, this can be programmed in PHP or in HTML5 [13].

Web server: a web service that provides secure and modifiable cloud computing capabilities. It is designed to simplify the use of web-based cloud computing for developers, allows access to files stored on a physical server and allows them to be used and downloaded as needed [14].

Repository: computer with 4 cores, 8 GB of RAM, 1 TB of storage with Oracle Linux operating system, responsible for the storage and processing of all HUB-IoT information [15].

MariaDB database: license database manager system open to the public-GLP, capable of storing structured and unstructured information used in the WEB server [16].

Panel: is a Linux web hosting used to administer web servers locally or remotely by means of automation tools with a graphical interface based on a control panel for web pages [17].

3.2 Project Methodology

The development of the project is divided into three phases:

- Phase 1. Project research and general diagnosis
- Phase 2. Design and implementation of methodologies, standards and infrastructures
- Phase 3. Analysis and comparison of pre and post project results

In Fig. 1, the architecture of the CRISP-DM model used in this project is shown, where the set of process feedback allowed developing, evaluating and implementing the solution consecutively and emphasizing the handling of the data for each process.
3.2.1 Phase 1. Investigation and general diagnosis of the Project

In the research phase the environmental factors were analyzed, associating the Universidad Militar Nueva Granada as a business and as a project the implementation of the HUB-IoT for the creation of academic communities, at the same time the infrastructure, the elements and the tools available to the TIGUM research group, refer to the value of the data within the CRISP-DM model.

3.2.1.1 Understanding the business

In business terms, this first phase is the most important from a business perspective, it is necessary to fully understand the problem that you want to solve, collect the correct data and interpret the results correctly. In this phase it is very important to be able to turn knowledge into a problem whose goal is to solve it and thus achieve business objectives.

From the aforementioned, the following factors were raised:

**Problem:** The need for an infrastructure that allows several users to connect with each other, that supports quality services oriented to the IoT academy and self-teaching, as a conventional service provider can do considering the time costs, money and labor that are generated by providing these services to a client.

**Hypothesis:** Is the telemedicine research group of Universidad Militar Nueva Granada, capable of implementing a HUB-IoT that provides quality services aimed at the creation of academic communities as a conventional service provider would do?

**General objective:** To understand the general objective of the project, the environment in which the HUB-IoT operated was analyzed, for which a market study was carried out where the best cloud computing providers were compared with infrastructure as a service that tend to Leading the market, for the extraction of this information was advised with the consulting and research company of information technologies GARTNER, which analyzes the (annual) trends of the market and its development, where the mode of representation of this information it performs thanks to the so-called magic quadrants, where it groups different providers according to its complete vision and its execution capacity [18]. Figure 2 identifies three suppliers (Google, AWS, Microsoft) cataloged as visionaries and leaders in the market of infrastructure as a service, these suppliers will be the reference as a competence and makers of good practices, allowing us to raise the general objective: "Analyze the requirements of the HUB-IoT TIGUM based on the current commercial services offer".
3.2.1.2 Understanding the data

This second phase aims to establish a first contact with the problem, identify the quality of the data and establish relationships with the hypothesis. In this phase the data is collected, explored and verified, in this case it corresponds to the elements and tools that we have in the infrastructure, for this the Fig. 3 summarizes the architecture and the elements available in the HUB-IoT TIGUM.

3.2.1.3 Data preparation

Once the initial data collection has been carried out, it is prepared and adapted to be used afterwards; these can be data visualization techniques, search of relationships between variables or other measures for their exploitation. In the preparation, the current elements and tools are used to establish an approach of what is missing or required to fulfill the project, for which a comparative analysis was made between the HUB-IoT TIGUM with respect to the current conventional service providers (AWS, Microsoft, Google) a system of metrics was used to evaluate the performance of each operator. For the creation of the metrics, unique factors were taken into account that directly affect the services that the HUB will provide, assigning to each metric a weight according to the impact and the importance that it has at the moment of providing such a service, as shows in Table 1.
Table 1. Evaluation metrics.

<table>
<thead>
<tr>
<th>Assessment factor</th>
<th>Value Factor</th>
<th>Metrics To Evaluate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security</td>
<td>30%</td>
<td><strong>Integrity</strong>: ability to detect if the data are true [6].</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Privacy</strong>: ability to limit data access privately [6].</td>
</tr>
<tr>
<td>Accessibility</td>
<td>20%</td>
<td><strong>Multiplicity</strong>: ability to visualize the server from multiple devices [19]</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Speed</strong>: ability to reduce access time to medium [19].</td>
</tr>
<tr>
<td>Architecture</td>
<td>15%</td>
<td><strong>Processing</strong>: server operations processing capacity [20]</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Storage</strong>: server data storage capacity [20].</td>
</tr>
<tr>
<td>Order and control</td>
<td>15%</td>
<td><strong>Programming</strong>: ability to support various programming languages and unify them into one [21].</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Fault tolerance</strong>: ability to detect faults by the system or by the users themselves [22].</td>
</tr>
<tr>
<td>Availability</td>
<td>20%</td>
<td><strong>Availability</strong>: server capacity available anytime and anywhere [21].</td>
</tr>
</tbody>
</table>

It is analyzed that each evaluation factor gives rise to different evaluation metrics, this because a factor cannot be defined by itself, in turn only the most important metrics to be taken into account when providing an IoT service or a health care service where its value represents the importance that must be given to it, being the sum of all the metrics a value of 100% equivalent to the perfect provision of services. Thus, the Table 2 shows the evaluation of the three leading providers in the market (Google, AWS, Microsoft) with respect to the Hub-IoT. There is a great difference between the best evaluated provider (AWS) with respect to the HUB-IoT TIGUM with a difference of 63% where the factors of greatest impact which are the most deficient on the part of the HUB-IoT TIGUM are; security, accessibility, order and control. From the previous analysis we identified advantages and disadvantages that the project currently has, where a solution that responds to the proposed hypothesis is modeled.

Table 2 evaluation of service providers.

<table>
<thead>
<tr>
<th>Metrics To Evaluate</th>
<th>Value Metrics</th>
<th>AWS</th>
<th>Microsoft</th>
<th>Google</th>
<th>HUB IoT tigum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrity</td>
<td>15,0%</td>
<td>12,0%</td>
<td>10,5%</td>
<td>9,8%</td>
<td>0,0%</td>
</tr>
<tr>
<td>Privacy</td>
<td>15,0%</td>
<td>14,3%</td>
<td>12,0%</td>
<td>11,3%</td>
<td>4,5%</td>
</tr>
<tr>
<td>Multiplicity</td>
<td>12,0%</td>
<td>8,4%</td>
<td>7,2%</td>
<td>8,4%</td>
<td>1,2%</td>
</tr>
<tr>
<td>Speed</td>
<td>8,0%</td>
<td>8,0%</td>
<td>7,2%</td>
<td>6,4%</td>
<td>4,0%</td>
</tr>
<tr>
<td>Processing</td>
<td>9,0%</td>
<td>9,0%</td>
<td>8,6%</td>
<td>7,7%</td>
<td>7,2%</td>
</tr>
<tr>
<td>Storage</td>
<td>6,0%</td>
<td>6,0%</td>
<td>6,0%</td>
<td>6,0%</td>
<td>2,4%</td>
</tr>
<tr>
<td>Programming</td>
<td>7,5%</td>
<td>6,0%</td>
<td>5,3%</td>
<td>5,3%</td>
<td>2,3%</td>
</tr>
<tr>
<td>Fault tolerance</td>
<td>7,5%</td>
<td>6,0%</td>
<td>6,0%</td>
<td>5,6%</td>
<td>1,5%</td>
</tr>
<tr>
<td>Availability</td>
<td>20,0%</td>
<td>20,0%</td>
<td>18,0%</td>
<td>17,0%</td>
<td>4,0%</td>
</tr>
</tbody>
</table>

100% 90% 81% 77% 27%

3.2.2 Phase 2. Design and implementation of methodologies, standards and infrastructures:

After carrying out market analyzes and identifying the data (elements) that exist and what is needed to complete the project, we proceed to design and implement solutions that will solve the problem in a practical way.

3.2.2.1 Modeling

In the modeling phase, the implementation of techniques and parameters that will provide a solution and response to the hypothesis are carried out. A design was made through the exploratory method that starts from the concept of a specific topic (SOA infrastructures), where a development structure is not defined and the focus goes directly to simple solutions that provide the necessary support of complying with the standards of necessary quality, where by means of the exploratory method we lay the foundations of the design according to 3 fundamental axes; the TIGUM research group, Universidad
Militar Nueva Granada and the current market of services. To improve the performance of the HUB-IoT TIGUM, technical changes were made in the following 3 factors:

**Security:** to improve the security factor of the HUB-IoT an SSL certificate is installed, which authenticates and encrypts all the information on the web portal giving a security credential to the services. Apart from SSL, the HTTPS security protocol is applied, which encrypts the data to prevent theft of information, ensures integrity of the data so that it cannot be modified and authenticates the web page giving security and confidence to the users who provide information.

**Accessibility:** Taking into account that the HUB-IoT did not comply with the "Responsive web Design" the "WPTouch" plugin was implemented which adapts the graphic interface of the web portal originally designed for computers to a format according to the mobile device, either cellular or digital tablet ensuring access from different platforms.

**Order and control:** To optimize the functioning of the Hub-IoT a C panel was installed responsible for the distribution of attributes and properties of the web server, since it allows the visualization and management of files, licenses, databases, with a graphical interface based on web pages that allows to order and control better the tools available in the Hub.

### 3.2.3 Phase 3. Analysis and comparison of pre and post project results

It is the procedure that allows analyzing different factors of study in order to reach a conclusion, a necessary method to evaluate the pre and post implementation

#### 3.2.3.1 Evaluation

A comparison matrix was made between the HUB-IoT TIGUM and the largest web service providers in the market, where the state of the HUB-IoT was stored after implementing the new web portal and having applied new management tools with its respective security policies. The Table 3 shows the analysis of the Hub-IoT TIGUM pre and post modeling where an improvement in all the factors is evidenced due to the modeling of new applications as they were: the new C panel, the WPmobile plugin and the HTTPS protocol with its respective SSL. These changes allowed a 30% increase in the reference level of the IoT Hub in the market and reduced the gap that existed with respect to the best service provider (AWS) by 33%.

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Factor</th>
<th>Evaluate</th>
<th>%</th>
<th>Hub IoT Pre</th>
<th>Hub IoT Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security</td>
<td>30%</td>
<td>Integrity</td>
<td>15</td>
<td>0.0%</td>
<td>9.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Privacy</td>
<td>15</td>
<td>4.5%</td>
<td>9.0%</td>
</tr>
<tr>
<td>Accessibility</td>
<td>20%</td>
<td>Multiplicity</td>
<td>12</td>
<td>1.2%</td>
<td>9.6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Speed</td>
<td>8</td>
<td>4.0%</td>
<td>4.0%</td>
</tr>
<tr>
<td>Architecture</td>
<td>15%</td>
<td>Processing</td>
<td>9</td>
<td>7.2%</td>
<td>7.2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Storage</td>
<td>6</td>
<td>2.4%</td>
<td>4.8%</td>
</tr>
<tr>
<td>Order and control</td>
<td>15%</td>
<td>Programming</td>
<td>7.5</td>
<td>2.3%</td>
<td>4.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fault tolerance</td>
<td>7.5</td>
<td>1.5%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Availability</td>
<td>20%</td>
<td>Availability</td>
<td>20</td>
<td>4.0%</td>
<td>6.0%</td>
</tr>
</tbody>
</table>

After the analysis, the development of the project was evaluated and it was questioned if the project met the business expectations (Providing quality IoT academic services) while responding to the hypothesis and solution to the problem. Therefore, it was decided that the project is capable of providing academic IoT services, but in the same way it requires several improvements in the course of its execution where it is expected in the future to further reduce the gap with respect to service providers in the market and provide a better quality service to all users.
3.2.3.2 Implementation

In this final phase, the model was implemented and its future development was analyzed. The address server of the New Granada Military University is implemented, which provides the connection between user and server, giving access to the new web portal, currently available at http://tigum.umng.edu.co.

4 RESULTS

4.1 Service offer

With the implementation of the current Hub-IoT TIGUM, different service offerings arrived, which use the Hub infrastructure to implement their projects and thus provide IoT services oriented to health care.

**Monitoring and fall system for older adults:** The project is based on a mobile app which monitors and reports if a patient (person prone to injuries) suffered a fall and is in danger, thanks to a monitoring and notification system incorporated in the App that constantly informs the patient's condition, and in case of an emergency, notify relatives and family doctors for prompt attention. The app uses the Hub-IoT repository where all the clinical information is stored in the Hub's database along with its processing and management of notification resources.

**Internet of things for health monitoring applied to the thermal sensation for inpatients:** The project presents a thermal sensing monitoring system using IoT technology in closed spaces, as in those that remain older adults. This information is shared through an IoT-Cloud development using the Hub-IoT TIGUM for health professionals in real time, increasing the possibilities of timely intervention in case of activating the alarms of the thermal system that the body of the person is perceiving in real time [23].

**Application of the internet of things for cardiac and respiratory monitoring of patients:** The project focuses on designing a monitoring system that makes use of the IoT technology for cardiovascular and respiratory diseases aimed at the population over 60 years of age, using the Hub-IoT TIGUM that will have the necessary storage and the subsequent processing of the information stored there; making use of sensors, a dialogue will be generated between them that allows an exchange of information for its later visualization of the data in the server. Alerts and graphs for the specialized treating users [24].

4.2 Communities created

The provision of IoT services has allowed the creation of communities and academic agreements with different entities of higher education at an international level, agreements that translate into student exchanges, the use of virtual laboratories and the sharing of academic resources.

**Universidad de Santiago de Chile –USACH:** On November 2, 2016, the Laboratory of Modeling and Simulation in Photonic Networks (LabSim) of the USACH University (Santiago de Chile University) was inaugurated and receives its first international intern, Engineer Jeisson Sánchez Mahecha from Universidad Militar Nueva Granada UMNG Bogotá-Colombia, who did the internship in the Telecommunications Technology Career of the Department of Industrial Technologies. At the same time that department started the research activities of the Modeling and Simulation Laboratory in Photonic Networks (LabSim), it is directed by Dr. Arturo Rodríguez G. In Dr. Rodríguez's opinion the department has taken an important step on its way to internationalization, generating the milestone of initiation that will bring knowledge and research practice to levels that will allow a sustainable development in the future *, this internship is the result of the joint international effort between the Research Group TIGUM of the UMNG, led by Dr. Leonardo Ramirez L. and the Research Group on New Technologies GINT of the USACH [25].

**Instituto Federal De Sao Paulo IFSP:** The GITES (Information and Technology Group in Education and Society) belonging to the IFSP (Instituto Federal De Sao Paulo) promotes the realization of studies and research, focused on research and technological innovation with the improvement of computer knowledge and information technologies in the context of education and society, a group that has made international agreements with the TIGUM Telemedicine Research Group of the UMNG, led by Dr. Leonardo Ramirez L. which has allowed the creation of an academic community oriented to provide educational and IoT services to researchers belonging to both groups [26].
5 CONCLUSIONS

A Hub-IoT was implemented using the resources and infrastructure of the TIGUM research group, whose modeling and development was based on analysis in the market for cloud service providers, of which 3 suppliers stood out: Amazon Web Services, Google Cloud, Microsoft Azure, these were reference for the development of the project, allowing to evaluate the requirements necessary to provide IoT services to users as these providers would do, from the above it is concluded:

- The implementation of the Hub-IoT TIGUM allowed the creation of academic communities oriented to the use and learning of non-profit web services, based on the concept of sharing resources and knowledge to users who require it
- The competitive gap between the Hub-IoT TIGUM and the best evaluated cloud services provider (Amazon Web Services) was reduced, where the Hub was optimized by 30% thanks to the good management of resources and the respective analysis of requirements made in the draft
- Although good practices and market references allowed the optimization of the Hub, it is also planned to continue working on the development of IoT services aimed at academia and health care applications.

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