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Cloud Computing Trends. Challenges for the Evaluation of the Quality of Services.

Vladimir Campos Kindelan, Yaimí Trujillo Casañola and Ailyn Febles Estrada

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Tendencias de la Computación en la Nube. Desafios para la evaluación de la calidad de los servicios.

Cloud Computing Trends. Challenges for the evaluation of the quality of services.

Nombre y apellidos: Vladimir Campos Kindelan [1*], Yaimí Trujillo Casañola [2], Ailyn Febles Estrada [3]

[1] Universidad de las Ciencias Informáticas. Km 2 ½ carretera a San Antonio de los Baños, reparto Torrens, La Lisa, La Habana. vladimirc@uci.cu
[2] Universidad de las Ciencias Informáticas. Km 2 ½ carretera a San Antonio de los Baños, reparto Torrens, La Lisa, La Habana. yaimi@uci.cu
[3] Universidad de las Ciencias Informáticas. Km 2 ½ carretera a San Antonio de los Baños, reparto Torrens, La Lisa, La Habana. ailyn.febles@uic.cu

[*] Autor para correspondencia: vladimirc@uci.cu

Resumen

Actualmente es imposible concebir una forma de digitalización que no tenga buena parte de su base asentada sobre infraestructuras cloud. Los beneficios y capacidades como la oferta de servicios bajo demanda, su elasticidad, flexibilidad y suministro de recursos de cómputo, constituyen actualmente el paradigma de transformación digital. El presente trabajo aborda como objetivo fundamental, una evaluación de las principales tendencias de la computación en la Nube, así como los retos más relevantes para enfrentar su implementación. Se destacan estadísticas, que demuestran la acelerada evolución de esta tecnología a nivel internacional, así como los desafíos que representa adoptarla en Cuba. A partir de un exhaustivo análisis bibliográfico, respaldado en fuentes de gran impacto se recopila información de alto valor estadístico y su análisis, se propone el objeto de estudio de la evaluación de calidad en la Nube, teniendo en cuenta los resultados expresados.

Palabras clave: *Computación en la Nube; Transformación digital; Elasticidad; Flexibilidad; Evaluación de la Calidad de los servicios en la Nube.*

Abstract
It is currently impossible to conceive of a form of digitization that does not have a large part of its base based on cloud infrastructures. The benefits and capabilities such as the supply of services on demand, their elasticity, flexibility and supply of computing resources, currently constitute the paradigm of digital transformation. The present work addresses as a fundamental objective, an evaluation of the main trends in Cloud computing, as well as the most relevant challenges to face its implementation. Statistics are highlighted, which demonstrate the accelerated evolution of this technology at the international level, as well as the challenges that adopting it represents in Cuba. From an exhaustive bibliographical analysis, supported by sources of great impact, information of high statistical value is collected and its analysis, the object of study of the evaluation of quality in the Cloud is proposed, taking into account the results expressed.

Keywords: *Cloud Computing; digital transformation; Elasticity; Flexibility; Evaluation of the Quality of services in the Cloud.*

Introduction

The exponential growth and use of digital technologies have become a global result. Ubiquitous and continuous connectivity reaches a large part of humanity thanks to the widespread use of smartphones and the consequent access to information, social networks and audiovisual entertainment. The acceleration of technical progress in the digital universe has made the use of devices and applications that use cloud computing (CC), big data analytics, block chains or artificial intelligence every day. Data is a motivating factor for company acquisitions and justifies a significant part of monopolistic positions. Thus, they are a risky strategic asset for the competition. Data-driven and predatory acquisitions are a relevant part of strategy for tech companies, as shown in Figure 1. (CEPAL, 2022; Rovira et al., 2021; United Nations Conference on Trade and Development, 2021).

Figure 1. Leadership in acquisition worldwide (Source: Digital technologies for a new future. CEPAL 2021)

The Cloud is one of the main current disruptive trends, as evidenced by the analysis of various sources that monitor its behavior worldwide. The market study based on the Cloud Computing 2022 survey published by (Cruz, 2022). Some data provided by the consultancy Gartner Inc, ECLAC and (Voas et al., 2022) affirm that end-user spending on public cloud services oscillated around 350,000 million dollars in 2021 and grew by 21.7 % until reaching 482,000 million dollars in 2022. Consulting firm Grand View Research, Inc. states that the size of the global cloud computing market reached values of 368.97 billion dollars in 2021, forecasting a compound annual growth rate (CAGR) of 15.7% between 2022 and 2030 (see figure 2).

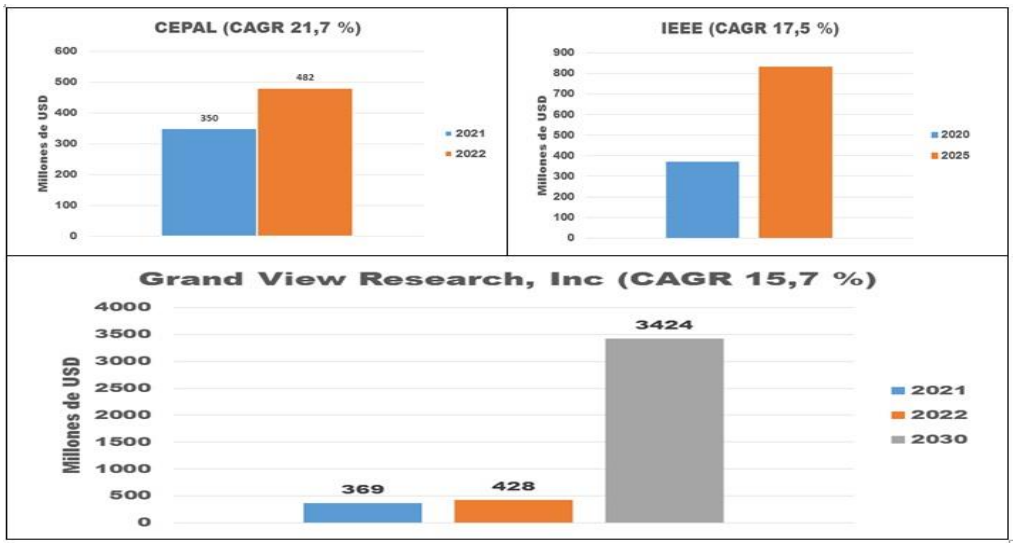

Figure 2. Compound annual growth rate (Source: Own elaboration)

This paper notes some accompanying technologies, including artificial intelligence (AI), machine learning (ML), mobile supercomputing, and the Internet of Things (IoT), among others , placing CC as the engine behind Industry 4.0 or the Fourth Industrial Revolution. Regarding the prospects of services, solutions such as 8x8 Video Meetings, registered users increased by more than 300% in 150 countries, in the last week of February 2020, which reveals the high demand for Video transmission platforms-on-Demand (VoD), such as Amazon Prime, Disney+, Twitch, Netflix, Hulu, YouTube and Apple TV, growing Infrastructure as a Service (IaaS) capabilities to satisfy consumers. On the other hand, Software as a Service (SaaS) represented a contribution to revenues of more than 51% in 2021, as a result of its flexible cost attributions, easy maintenance and implementation, representing the cloud model, where 73% of companies migrate most of their applications (Moore, 2022).

In the same direction, IEEE affirms that the most significant advances in CC are in line with the growth of data, standing out data extraction, storage, and predictive and prescriptive analysis tools, including artificial intelligence (AI). and machine learning (ML). The growth forecasts for the global CC market will increase between values of 371.4 billion dollars in 2020 to 832.1 billion dollars by 2025, with a (CAGR) of 17.5%, which will tend to grow due to the accelerated adoption process (Voas et al., 2022).

Related to the United Nations report on the Digital Economy, regionally the most advanced countries belong mostly to the capitalist bloc, led by the United States. On the other hand, powers such as China are interposed in the competition for the domain of Information and Communication Technologies (ICT), as can be seen in figures 3 and 4.

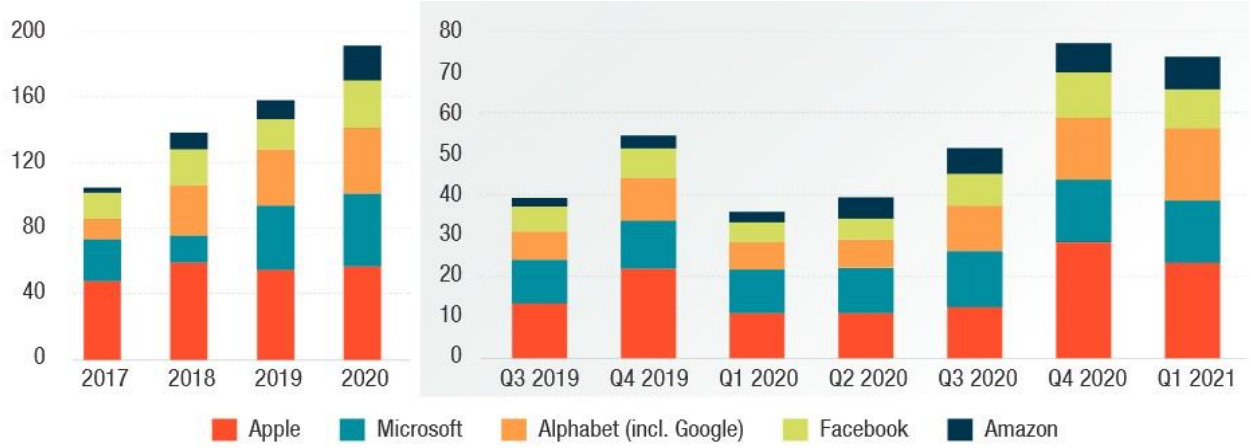

Figure 3. Income calculations based on the Wall Street Journal, USA.

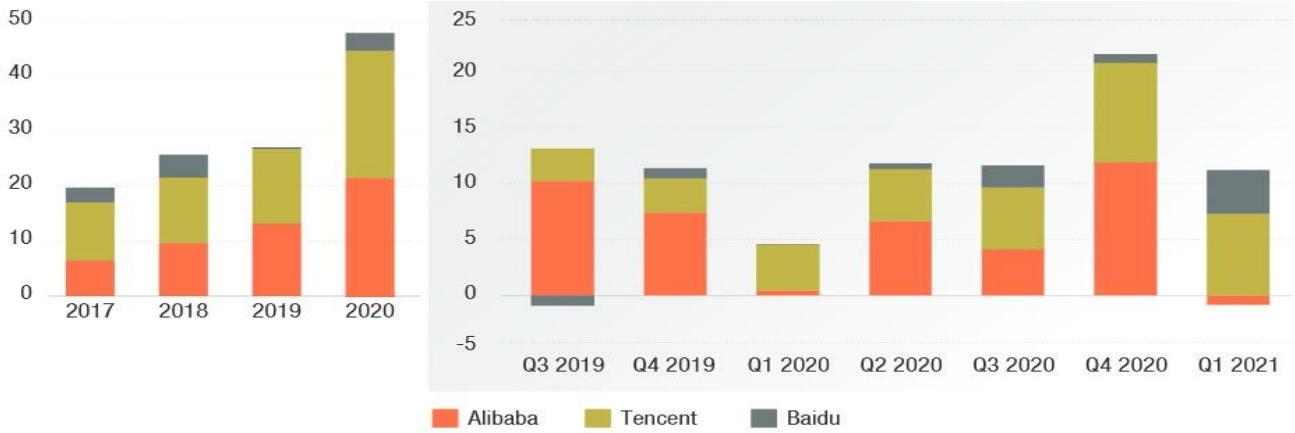

Figure 4. Income calculations based on the Wall Street Journal, China.

Among the most prominent leaders in Cloud services are Amazon Web Services, Microsoft Azure, Google, Alibaba, IBM, Salesforce, Tencent and Oracle (see figure 5). (United Nations Conference on Trade and Development, 2021).

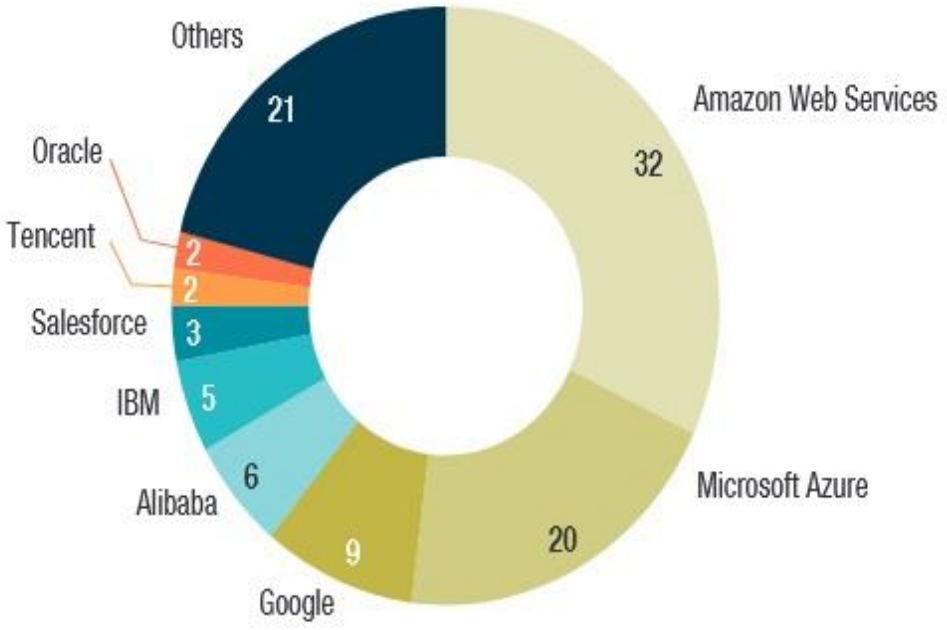

Figure 5. Cloud infrastructure services revenue, by provider, fourth quarter 2020.

In Latin America and the Caribbean, the statistics regarding CC, published by the Economic Commission for Latin America and the Caribbean (ECLAC), Digital technologies for a new future, affirm that, in 2019, software as a service constituted 50% of the cloud market, followed by infrastructure as a service, with 46%, and platform as a service, with 4.3%. Global traffic in the cloud represented 8%, with a growth trend of 22% as an annual average until 2023. The main digital commerce platforms in the region were Mercado Libre, Amazon, AliExpress, Wish, eBay, Shopify and Tiendanube. According to the Datacenter Technologies Cooling Market Map, there are 151 data centers in the region, located in 24 countries, 118 in South America and 33 in Central America and the Caribbean, although it is recognized that the region has low levels of investment in data centers. data about its population. Among the countries leading this advance are Brazil, Mexico, Chile, Argentina, Peru and Colombia (Rovira et al., 2021).

Methods or Computational Methodology

The present work was guided by an evaluation of the state of the art, regarding the most recent trends in Cloud Computing, as well as the most influential problems in the quality of its services. For this, the following questions were formulated:

What are the current trends in Cloud Computing?

What challenges does quality assessment face in the Cloud?

What norm and standards describe the quality for Software as a Service?

From the application of a set of theoretical methods, among which the analytical-synthetic method stands out, an exhaustive bibliographical study is carried out, managing to identify information of high statistical value, regarding trends and problems associated with quality. on the cloud. Through the dialectical method, a critical analysis of background research is established, oriented to the subject of the evolution of standards and models.

Another set of empirical methods, among which the interview and the survey stand out, allowed the collection of information, with the objective of arguing the problem and obtaining a measure of cognitive potential, referring to standards and models related to the quality of services. in the cloud, respectively.

Results and discussion

The new CC paradigm not only transforms the ways of making software, but also modifies the quality levels, which generate new norms, standards, attributes, characteristics and metrics, which make cloud services something very particular (Blas et al., 2016; Deissenboeck et al., 2009).

Cloud Computing, and specifically software as a service (SaaS), brings new challenges, due to the characteristics of cloud software services: elasticity, scalability, concurrency, response time, pay-per-use, among others, which makes that it is necessary to have new quality strategies, specific for this type of software (Cedillo et al., 2017; Fatema et al., 2014).

The report "Risks and threats in Cloud Computing" carried out by INTECO, published by ENISA (European Security Agency) summarizes some documents providing an overview of threats, risks and key aspects of CC security. This report describes CC infrastructures and services, analyzing the different elements that must be taken into account for their security, according to international criteria and standards. The most notable aspects were: Loss of governance, data management, security in terms of unauthorized access and handling of large volumes of data, information leakage, lack of transparency between its actors, data migration, as well as in service agreement contracts (Aguilar, 2012).

In other investigations such as (Ardagna et al., 2012; Cedillo et al., 2017) it raises several new challenges in the area of quality of service (QoS) management denoting the levels of performance, reliability and availability offered by an application and the platform. or infrastructure that hosts it. Something that turns out to be a very noticeable problem is the efficiency of quality assurance.

Some of the findings raised by (Merizalde, 2016) from a bibliographic evaluation, states that most of the evaluations are carried out in a single phase of the life cycle (operation) (see figure 5), after deploying the services, Most of the metrics are of a quantitative type, they are designed for SaaS and IaaS, focusing on performance efficiency and reliability, the evaluation perspectives mainly respond to CSP and CSC, there is a shortage of tools that facilitate the calculation of metrics and the attribute evaluation, most of these metrics are applied to the service in the test phase or during QoS monitoring by CSPs, there is a shortage of metrics in the early stages (Arias-Orezano et al., 2021), there are new characteristics and new attributes of cloud services, which are not reflected in the standards and which, in turn, have not determined metrics to measure them, most of the metrics are not validated based on their usefulness and concludes by indicating that the evaluation of the quality of cloud applications and services imply great relevance and interest, highlighting disciplines such as Cloud Computing and Software engineering (Campos Kindelan et al., 2022).

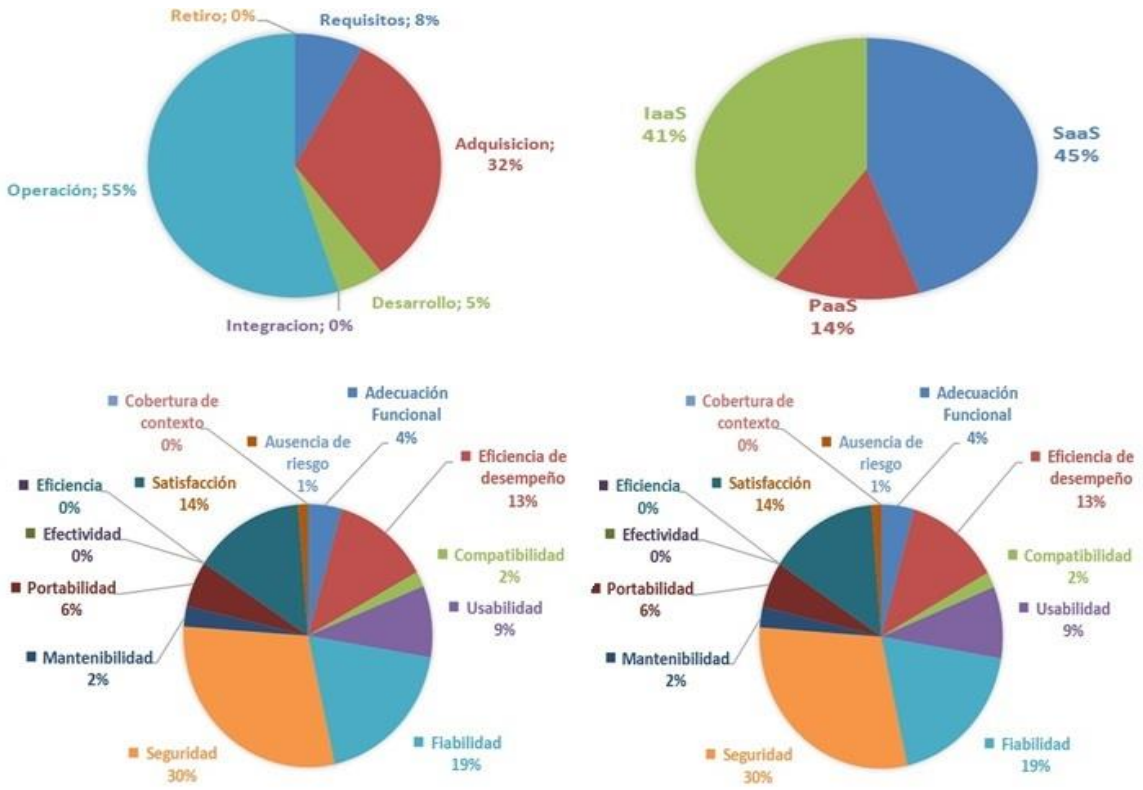

Figure 6. Statistics of the state of the evaluation of the quality of Cloud Computing (Merizalde, 2016)

CC test environments are not exempt, such is the case of tests as a service (TaaS). Several works in this modality have presented their own architectures based on the Cloud, under the protection of cost reduction and scalability improvement. Some address the application of efficient load tests and the automation of unit tests, while others focus on the self-assessment process, based on the monitoring and evaluation of dynamic adaptations, and there are those who have faced the risks of interference between tests and processes. business at runtime. Therefore, there is a need to provide open platform independent monitoring tools as well as uniform monitoring interfaces for different cloud providers (Alroobaea et al., 2019).

The quality of CC services can be supported by monitoring tools that facilitate, through the evaluation of the quality of services, generate reports of non-compliance with service level agreements (SLA). This is how it is stated (Cedillo et al., 2021; Mubeen et al., 2017), referring to the lack of transparency between providers and customers, by not

monitoring the behavior of services in real time. Among other issues, they add that the supported SLAs lack expressiveness for modeling real-world scenarios, the monitoring setup is highly coupled with a given SLA specification, and the SLA violation reports provided are difficult to understand. On the other hand, most commercial monitoring tools are tightly integrated with cloud providers. For example, CloudWatch, offered by Amazon, is a monitoring tool that allows consumers to monitor their applications residing on the Amazon Web-Service (AWS) EC2 service (CPU), but this tool does not have the ability to monitor a component application that can reside on another cloud provider's infrastructure such as GoGrid and Microsoft Azure. In relation to change management, it happens that if a non-functional requirement (NRF) needs to be modified in accordance with an SLA negotiation, this leads to modifying the surveillance structure. Another difficulty is the use of low-level metrics such as latency, uptime, to define high-level indicators such as throughput or availability.

Another current problem is that SLAs are difficult to automate, since they are often specified even in natural language, which has made their automatic treatment and verification very complicated. For this purpose, some specification languages have been created. SLA as in the case of the Web Service Level Agreement (WSLA), however monitoring systems are statically programmed and cover a certain number of non-functional requirements that cannot be easily modified, since they do not describe SLA clauses but rather offer the monitoring of certain low-level properties of running services (Cedillo et al., 2017).

Last but not least, although it should be recognized that not all the investigations seen in this investigation address it, are the legal problems that CC implies. According to (Zalazar et al., 2014), many cloud solutions evaluate service indicators, shifting the responsibility to SLAs, but ignore the legal terms that can solve conflicts not only between CSP and CSC, but also all CC actors. . In this sense, some authors had already indicated relevant issues, for the contracting and migration processes of CC services, in line with this, Kaisler and Money identify the three most important challenges, such as: acquisition: analysis of suppliers, analysis of agreement of level of services, guarantees of access to information, and best cost/benefit; implementation: adapt data to service formats, deploy client services, scale resources, and manage policies for critical applications; and security and privacy: data movement, access control, data deletion, audits, legal and legal aspects. As a conclusion to this section, see Figure 6, which summarizes the root causes of quality assessment problems for Cloud Computing environments.

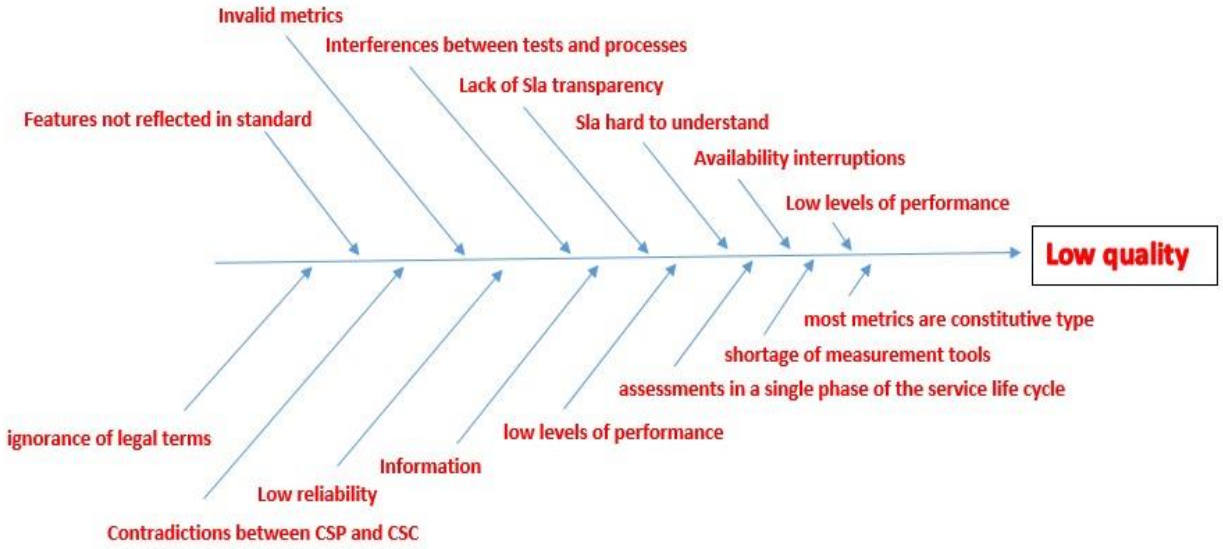

Figure 6. Behavior of the evaluation of quality in the Cloud at an international level (Source: Own elaboration)

In Cuba, the effects of COVID-19 increased the use of technology, showing a growth in Internet access of up to 7 million people, of which approximately 4 million do so through the mobile data network, with 1.3 million connected through fourth generation technology (4G/LTE). This service is deployed regionally in 72 municipalities of the country, representing 50% of its demand. On the other hand, the 3G infrastructure continues to expand in order to increase the quality of connection through mobile data with both services. For 2021, the expansion of capacities in the infrastructure and security of telecommunications systems was forecast, mainly in online payment platforms, such as Transfermovil and EnZona, high-demand applications, for their bonus services (Marine, 2020).

The 2021 investment forecast also included computerization coverage, prioritizing public services for the population. One of the significant measures, in the face of the pandemic, was the implementation of remote work, where the official count in all forms of work was from 627 to 855 thousand people. Among the five pillars, which govern the computerization process of society on the island, are: Cybersecurity, infrastructure, content creation, legal framework and responsible culture; all necessary to achieve greater economic and social development (Marine, 2020).

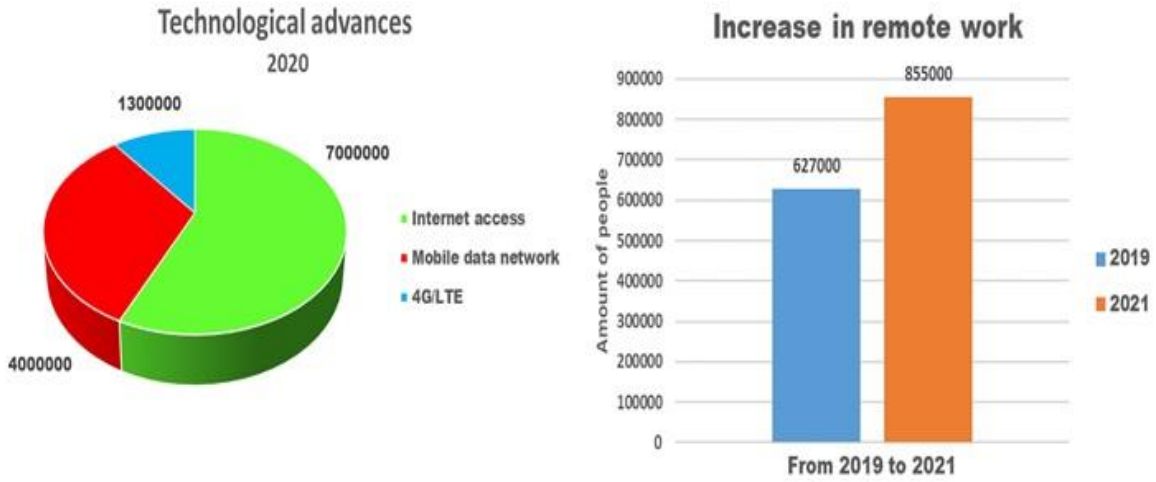

Figure 7. ICT statistics in Cuba (Source Own elaboration)

Despite all the effort, Cuba has also been a victim of the effect of the genocidal embargo currently imposed by the United States, restricting infrastructure technology, and limiting access to advanced knowledge and development platforms, instead alternatives have been found in Free Software (FSF), as a resilient variant that also reinforces its protected sovereign principle, applied to ICTs. In the majority of Cuban institutions CC implementations and deployments use open source OwnCloud tools, mainly in public cloud deployments. The most outstanding services are email and public access applications, such as digital newspapers, portals or other services.

In our country, based on notable advances in its digital transformation program, great efforts are devoted to the development of software platforms with better features (Figueredo, 2021). Some of these applications, for the most part, are based on the public deployment of services and microservices through the mobile Internet data network or on the virtualization of servers, among other aspects that are very familiar with Cloud Computing (Perdigón Llanes et al., 2020).

The development of applications for digital banking, electronic commerce, management of citizen services, as well as some forms of digital multimedia content management, among which Transfermovil, EnZona, TuEnvío, Apklis, Picta, Todus, among others, stand out, is a sample of the undeniable talent that Cuba has achieved in less than a decade (Estrada & Reyes, 2020; Milanés, 2018). Despite these advances, the development and quality of the Cloud

in Cuba continues to be a pending task, which needs to be addressed in the shortest possible time, for what it could represent in all areas for the country (Suárez Batista et al., 2016).

Some advances in this area of knowledge propose a change towards the business model that imposes the use of Software as a Service (SaaS), as a strategic and challenging incentive for entities that are committed to it in Cuba (Suárez Batista et al., 2016). In this work, the authors present the diagnosis made to 85 IT service entities and identify some problems, such as the lack of knowledge of service quality models and the provision of services and a high tendency to improvise, regardless of whether they affirm that none of the entities experiences the application of CC service quality standards and models.

In a recent preliminary diagnostic study, which was carried out on 16 national entities, it has been seen that many developers in Cuba misinterpret features of application virtualization, with the SaaS model, mainly due to the way in which these applications are deployed using Internet protocols. However, it has been verified through a diagnosis carried out within the framework of this research, that the standard that regulates the conceptualization of technology (CC) is unknown. Likewise, the standards, norms and models that establish the analysis, measurement and evaluation of service quality are unknown, leaving several gaps in terms of the identification of quality attributes, characteristics, sub-characteristics and metrics that correspond to the non-functional requirements identified (Campos Kindelan et al., 2022).

Additionally, the monitoring of the services is insufficient, nor is the quality measured in them, it can even be affirmed that there is a high influence of the traditional software development approach, preventing clients and development entities from finding the differences between traditional applications and the Cloud (Campos Kindelan et al., 2022).

Regarding the relationships established between clients, developer entities, as well as infrastructure service provider entities, within the framework of this investigation various contractual anomalies were detected, due to inconsistencies in the SLAs. Mostly these SLAs are oriented to the maintenance and support of applications at three levels, without taking into account the modifications that must be faced in contractual relationships, for virtualization or CC scenarios. At the same time, the lack of transparency between providers (CSP) and consumers (CSC) persists, since it is not established under which criteria the services will be provided, nor are security

requirements evaluated, mainly in terms of data management and accessibility. On the other hand, efforts are concentrated on satisfying business needs based on functional quality, but ignoring that SaaS implies much more complex quality requirements. In this sense, the development entities do not take into account that each RNF can be influenced by one or many attributes at the same time. Nor is a detailed analysis of the RNF carried out, causing inconsistencies with the quality standard, errors in the selection of characteristics, sub-characteristics and metrics, which ends up yielding a poor quality result (Campos Kindelan et al., 2022). As a result of this analysis, the causes have been identified, which appear in Figure 7.

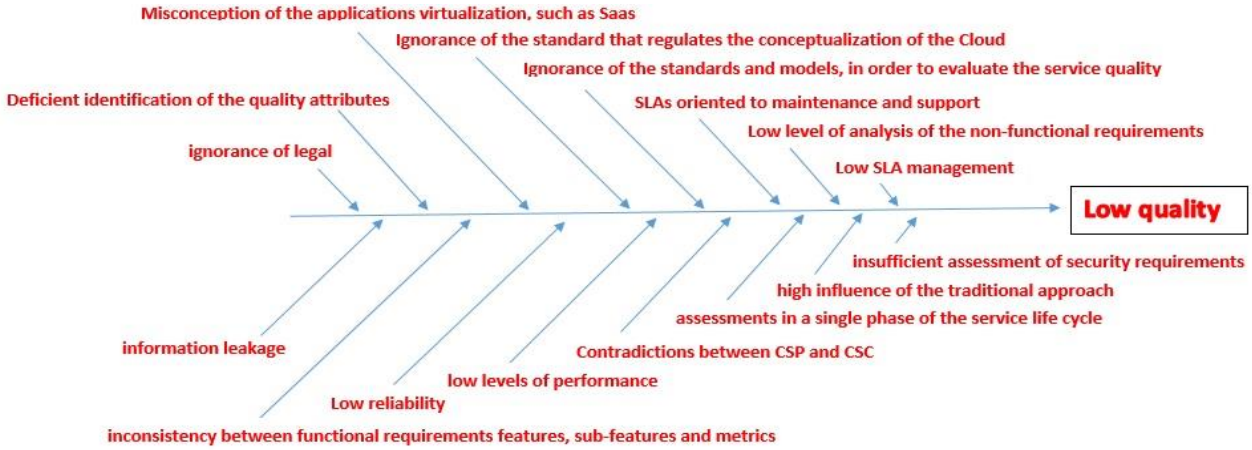

Fig 7. Challenges for the evaluation of the quality of the Cloud at the national level (Source: Own elaboration).

Conclusiones

The above statistics show without a doubt that the 21st century represents the opening of ambitious goals for software engineering and development. Despite the benefits provided by the use of Cloud Computing, great challenges persist today, mainly associated with cost control, lack of skills and experience in Cloud management, security, privacy, relationship between (CSP) and (CSC) depending on the quality against the costs of the services, aspects that can only be mitigated by efficient quality management. Taking into account the above, the proposal of an investigation is added, which addresses the evaluation of the quality for the Cloud environment, based on KPIs indicators and taking into account the life cycle of the services. Future work should be oriented towards methods

and procedures for measuring the quality of cloud services, in order to make transparent the contractual relationships of the key players in this complex technological environment.

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