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EDITOR'S LETTER

Dear readers,

We are pleased to present this new issue of Tono Journal, which showcases the vitality and ingenuity of the scientific and technical community like no other. The papers in this issue once again reveal that in Cuba, innovation is fueled by a powerful combination of an understanding of global trends and the creative ability to apply them to our context with practical, high-impact solutions.

Undoubtedly, the common thread running through this issue is the digital transformation that has been taking place since the beginning of the century. The article "Networks for Artificial Intelligence and Artificial Intelligence for Networks" addresses this phenomenon from its foundations. This paper establishes a dialogue with one of the most recurrent themes in the scientific field in recent years: Artificial Intelligence (AI). The theoretical approach of this paper is complemented by the others research in this issue. One excellent example is "Python tool for behavioral studies of IP Pools in the BRAS," which uses open-source software to optimize and diagnose our existing network. This is another example of practical intelligence that solves specific problems with readily available resources.

The paper "Dynamic Assessment of Business KPIs: Optimizing Territorial Management Through DashBoard" reflects the same commitment to efficiency. In a country where the rationalization of resources is crucial for development, this proposal utilizes data to the service of strategic decision-making, enabling visual, agile, and evidence-based management to enhance collective performance.

In terms of physical infrastructure, the "Implementation of a Smart Beam-Switching Antenna System" promises to improve the efficient use of the radio spectrum and enhance service quality for users. Similarly, the "Wireless Control of Heavy Rotating Platforms Based on Arduino and XBee Module" proves the feasibility of automating complex industrial processes with open, accessible, and locally developed hardware solutions.

We conclude this journey with a celebration: "Transfermóvill: 10 Years with Us." It is more than just an app; it is a symbol of what can be achieved with the knowledge of Cuban specialists. Its history reminds that technology conceived for public service can be integrated into the lives of Cubans and transforms a nation's deeply rooted habits.

In short, this issue is a testament to technological sovereignty. The journal's editorial team would like to thank all the authors and contributors who shared their work, thereby enriching the fields of national science and technology.

Editorial Team
Tono Scientific-Technical Journal

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COLLABORATION

Networks for Artificial Intelligence and Artificial Intelligence for Networks: Implications for Telecommunications

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Abstract

The development and widespread growth of AI tools and solutions creates opportunities with significant positive effects for nearly all economic, social, and governmental sectors. For the telecommunications industry, the transition to AI is a challenge but also an opportunity. On the one hand, telecommunications enable AI; however, the increased use of online services based on AI will put additional pressure on connectivity networks, their costs, management, and the sustainability of investments required to maintain and expand them. On the other hand, successfully integrating AI into the optimization and management of the telecommunications value chain creates opportunities to increase business profitability and design value propositions for end users and industrial customers.

Keywords: AI, Telecommunications, Networks, Connectivity, Digital Ecosystem

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Introduction

The development of AI tools and solutions is generating a positive impact in all sectors, although it is important to address the risks associated with their use. The transformation is relevant for sectors related to connectivity, infrastructure and digital systems. Specifically for the telecommunications industry, the transition to AI is a challenge but also an opportunity.

On the one hand, telecommunications enable AI, but the increased use of online services based on it will put additional pressure on connectivity networks, their costs, their management and the sustainability of investments riquered to maintain and expand them. On the other hand, successfully integrating AI into the optimization and management of the telecommunications value chain creates opportunities to generate efficiencies that impact business profitability, as well as design value proposals for end-users and industrial customers. In addition, AI can be an enabler and catalyst for the transition of telecommunications companies into companies providing technological solutions leveraged on capabilities and resources related to connectivity network infrastructure and management.

The AI Revolution Begins

Advances in AI in recent years position it as one of the technologies with the greatest potential to transform the economy and society by automating tasks at the decision-making scale and (Basso *et al.*, 2025). The expected potential of AI use is based on its ability to process information and automate complex processes, and generate efficiencies and innovation in modern digital economies and societies. Eventhough there are obstacles to its deployment, widespread growth and escalation in the short term, its adoption is imminent. Technology is rapidly becoming a fundamental layer in the processes of public and economic value creation, as well as in the experiences of service users and productive sectors in the digital ecosystem that employ it.

It is not easy to define clearly what AI is. In general, the diversity of definitions focuses on its intention or ability to fulfill objectives and perform functions related to, or at least imitating human skills and intelligence: perceiving, reasoning, decision-making, reacting and relating to the environment, as well as internalizing processes of understanding, learning and feedback (Sheikh *et al.*, 2023). The European Commission's High Level Expert Group on AI defines it as systems that prove intelligent behaviour by analyzing their environment and taking actions, with a certain degree of autonomy, so as to achieve specific objectives (European Commission, 2018). It also categorizes technology into two basic types, those systems based purely on software, acting in the virtual world (voice assistants, image analysis software, search engines, speech and face recognition systems), and those that can be integrated into physical devices (such as advanced robots, autonomous vehicles, drones or Internet of Things applications).

Another useful typology to classify AI is according to its practical applications (Sheikh *et al.*, 2023). There are at least five general types for everyday use: Machine Learning, Computer vision, Natural language processing, Speech recognition and Robotics. There are also applications that combine various functionalities of these types such as generative AI (Gen AI) for content creation or the Edge AI or IA at the edge, which performs AI processing locally on devices and not in the cloud (Annex 1). All of them with different characteristics and potential uses that together are begining to revolutionize the digital economy and society, and the operation of networks.

AI requires three layers of key enablers to its deployment and escalation: (1) access to large volumes of data to train and operate models, (2) data infrastructure such as data centers and cloud platforms for data storage and computer processing and (3) electronic communication networks for data exchange and distributed AI operations (Stryker, 2024).

Intelligent systems are embedded in infrastructure and processes related to the digital transformation of public and private services, as well as industrial uses in a wide range of sectors. In addition, generative AI is becoming a digital tool available to more people and workers. Its acceptance and mass use will redefine the way people and businesses relate to digital and physical environments, which has significant implications for the digital ecosystem in general and telecommunications in particular.

Networks for AI - AI for networks: implications for the digital ecosystem and telecommunications

Telecommunications is positioned at a key intersection in the advancing AI era: networks as a key element for AI development and exploitation, and AI as a strategic resource to enhance network and business models in telecommunications (Jarich, 2025). On the one hand, networks support computing tasks, communications and data exchange required for the development, training and deployment of AI applications. As in previous booms of digitization, networks will primarily enable the development of digital technologies such as AI.

However, AI will also be a disruptive technology and its impact will advance rapidly across productive sectors and social arenas (Ericsson, 2022; Jarich, 2025). AI applications intended to end-user are democratizing and attracting more and more users. Innovation soars in general and industrial use cases and applications, as well as in competitive strategies in economies, markets, businesses, and organizations to leverage AI. All in a high complexity context for digital environments and telecommunications. Telecommunications operations range from voice, text and data to smart networks solutions that need to be delivered simultaneously. The need for greater capacity to sustain the growing data traffic generated by new applications is prioritized and connected devices are multiplying especially in Internet of Things (IoT) environments. Security risks become more difficult to manage. Customers demand quality user experiences that match their expectations of digital environments use, and manufacturing industries are looking for new connectivity services to help them create business opportunities.

On the other hand, AI promises opportunities for economies and businesses, representing a window for its use in telecommunications networks and operations. Like other sectors and industries, telecommunications is advancing the adoption of AI solutions in various value chain segments to improve its value offer, generate efficiencies, increase profitability and productivity, as well as remain competitive in a complex sectoral context.

The future of connectivity and telecommunications networks in the AI era

The massification of AI solutions among productive sectors, end users of the digital ecosystem and public platforms will impact data traffic on networks, the demand for infrastructure and connectivity services, and also in new requirements and capabilities in the management processes of the networks that support the entire digital ecosystem. This involves a challenge for infrastructure maintenance and expansion, as well as the sustainability of network investments. Firstly, it is very likely that in the coming years the networks will experience a significant growth of traffic and data exchange needs related to AI. According to Omdia analysis, in 2024, 8% of the traffic on networks was related to new AI traffic, either in software or native AI solutions (use cases that would not exist without AI) or programs with enhanced functionalities with IA (services that existed before AI but that now some functionalities are being improved with its incorporation) (Korolov, 2025). At the same time, 27% of the traffic was concentrated on software functionalities and applications that are not related to AI (even if the applications have such functionalities). Conventional traffic, that is applications without any AI functionality, accounted for 66% of the total. The 39 exabytes of AI-related traffic recorded in 2024 is expected to reach up to 79 exabytes in 2025. In addition, the growth rate of AI traffic is projected to be higher than that of conventional traffic (Holma, 2024). By 2030, it is possible that more than two-thirds of network traffic will involve AI, especially in video and image content (Shrivastava et al, 2025; Javaid & Zerbib, 2024).

The above is attributed to massive use cases such as generative AI, chatbots, immersive experiences of virtual/augmented reality, video games and streaming generated by IA, but also its use for optimization of solutions and digital platforms, communication links (uplink and downlink), communication between devices, sensors and data processing (machine to machine), industrial platforms and systems in real time. AI-powered cloud services require data exchange: data and information upload for analysis, processing, delivery of results from AI applications and IoT sensors that deliver data to AI engines.

Secondly, there will be new network requirements and infrastructure provision to support AI-centric applications. In other words, not only will there be an increase in traffic on the networks, but the capacity of these networks will have to be higher to transport larger packets, and maintain continuity and quality in the connectivity service. This includes the need to have more spectrum available for mobile broadband, especially in mid-bands for 5G, sooner than expected to meet the demand for connectivity. Without more spectrum supply at affordable prices in the face of local market conditions, there is a risk of experiencing congestion, reduced quality of service, and lack of capabilities for the development of new AI use cases (Accenture, 2025). For carriers, it can also mean the need to implement efficiency measures for spectrum use and allocation, refarming or the reallocation of frequency bands from 2G/3G to 5G spectrum to boost capacity.

There will be an increase in demand for bandwidth and fiber optic backhaul for data packet-intensive applications (video, generative AI, real-time applications, etc.). Another necessary consideration will be linked to AI solutions that require low latency (manageable with 5G) due to their sensitivity to inconsistency and variability in data transmission (Houpis et al, 2024). Some of these AI applications are those used in industrial IoT solutions, virtual/augmented reality (AR/VR) and real-time services such as translations, video games, autonomous vehicles, or even telemedicine with remote robotic medical procedures.

Network segmentation (network slicing) can help meet AI-driven demands (Jarich, 2025), by partitioning networks to adapt each segment to specific and differentiated needs for latency, bandwidth, technical parameters and network prioritization. This would help manage, ensure service and prioritize the complexity of traffic generated in an AI-powered digital ecosystem. However, the investment needs for its implementation, the operational complexity and the immaturity of some business models for its application hinder the scenery for its development. AI functionalities that require low latency could lead to decentralization of data center distribution for information processing, network redesign and component integration with new hardware specifications (for example with processing chips) (Body of European Regulators for Electronic Communications [BEREC], 2023). This will bring difficulties for equipment investment, integration with legacy hardware and software systems and implementation of OpenRAN schemes in the context of technical equipment changes (Uitto, 2024).

Finally, thirdly, there is the need to transform the design and operation of infrastructure (Javaid & Zerbib, 2024; Pearson, 2024). In this sense, Edge Computing in networks to shorten the data exchange distances by bringing processing closer to devices, would be useful to complement efforts to meet the requirements of an AI-influenced network and reduce dependence on network backhaul segments (BEREC, 2023). Similarly, carriers should prioritize investments to increase the capacity of the Radio Access Network (RAN) (Jarich, 2025; Holma, 2024). This part of the network is critical to provide both speed and last mile capacity to users.

It is worth mentioning the relevance of access to energy and data centers in adjacent arenas of the telecommunications value chain for the efficient operation of AI solutions.

The challenges of AI in the telecommunications market

Telecommunications networks are the backbone of digital transformation. They provide the necessary data traffic for the online service provision and have enabled the development of a global digital ecosystem. In previous waves of digitalization, connectivity infrastructure has supported and enabled traffic generated by digital service platforms and used up by end users and industrialists for use. Networks have enabled the transition from telephony and messaging services to the Internet provider and network infrastructure, as well as the emergence of the digital revolution driven by the massification of smart mobile devices and smartphones.

However, telecommunications companies have failed to capture revenue in proportion to the growth in global traffic associated with the emergence of disruptive technologies such as the introduction of smartphones, digital platforms and services, as well as video streaming traffic and mass consumption of social media. Between 2010 and 2023, global mobile data traffic grew by more than 60%, while total telcos revenues remained almost constant with growth of just 1% (Shrivastava et al, 2025). In Latin America, from 2015 to 2023, the average revenue per user (ARPU, for its acronym in Spanish) in real terms has fallen by up to 40% for some carriers in the region, and the profitability of the investments also remains low (cet.la & NERA, 2025).

In addition, the investment requirements needed to meet traffic challenges and pressure on networks pose challenges for infrastructure sustainability. The Center for Telecommunications Studies and NERA estimate that it will be necessary to invest 49,100 million dollars until 2030, in addition to those planned for network operations: 17,000 million dollars to close digital gaps and modernize networks, and another 32,000 million dollars to expand the network capacity to be able to support the increase in traffic (et.al and NERA, 2025). The abovementioned amounts may underestimate the impact and growth of AI functionalities: some estimates indicate that Artificial Intelligence will add between 20% and 80% of traffic to mobile networks, in addition to what was previously projected (Powell & Hatt, 2025).

The deployment and massification of AI in digital environments poses challenges for carries: the increase in demand for connectivity and data traffic, as well as greater complexity in network operation. The exponential growth of traffic in the networks, stagnant revenues, intense regulation and competition in the digital ecosystem, difficulties in increasing profitability and high infrastructure investment requirements represent trends in the telecommunications industry that threaten its development.

The essential question for the telecom business is whether the AI adoption in industry and the broader economy will translate into an opportunity to generate value and increase the income needed to make network investment sustainable, or whether, on the contrary, the disruption of AI will only generate costs for the network infrastructure. The answer may lie in AI itself, which has the potential to be used as a resource and a technological capability that offers opportunities for the telecommunications sector to enable its competitiveness.

Integration of AI into the telecommunications proposal and value chain

AI also represents an opportunity to optimize the internal operations in the telecommunications industry, both for carriers and other sectors related to the connectivity value chain. In other words, not only networks for AI, but AI for networks. In fact, in 2024 globally, the telecom industry is the one in which spending on AI platforms has grown the most and also the sector that invests the most as a percentage of revenues (Basso et al, 2025). Ericsson's research reveals that, already in 2022, 66% of the surveyed carriers had some kind of AI deployment implemented or under development (Ericsson, 2022).

Some market studies indicate that during 2024 about 90% of carriers had integrated AI solutions into their operations, with 48% in pilot phases and 41% with active deployments (Market Growth Reports, 2025). According to a BEREC survey, telecommunications companies consider that its adoption in operational processes will be the criterion by 2030 (2023).

The implementation of AI solutions includes use cases and applications in virtually all segments and organizational processes of the telcos value chain (Wall, 2024). For example, in the area of administrative and corporate management its applications are related to efficiency, cost reduction and automation of processes and systems that support internal corporate operations. These areas include human resources, finance, monitoring systems, marketing and sales processes as well as administrative and legal management. This may also include the development and management of applications for

IT operations, software and technological capabilities related to code writing, system optimization and internal information systems performance (purchase orders and service delivery, collections, billing, etc.). However, AI support for administrative functions is a capacity that will be enabled transversely between economic sectors.

Outside the administrative sphere, the integration objectives of this technology into strategic telecommunications operations are focused on exploiting operator expertise with predictive AI, as well as the use of generative AI to drive efficiencies, improve customer experience and automate complex processes, network management (Market Growth Reports, 2025). This would make it possible to take advantage of technological solutions so as to optimize and generate efficiencies in processes and develop value propositions for its users, customers and service recipients.

Carriers will have to prioritize four strategic objectives to address critical aspects such as operational complexity, revenue weakness and the transformation of telcos in a volatile environment: cost reduction, service differentiation and user experience, safe and reliable operations and revenue growth (World Economic Forum and Accenture, 2025).

Cost reduction

The operating costs of telcos remain globally between 65% and 70% of revenues (Gabriel & Venturelli, 2022 as quoted in World Economic Forum and Accenture, 2025). The annual NVIDIA survey shows that in 37% of carriers, AI may be reducing costs by more than 5%, and 40% of them comment positive reductions but less than 5% (NVIDIA, 2025). In 2022, 63% of surveyed carriers mentioned network operations optimization as one of the main benefits of incorporating AI into their businesses, especially in aspects such as optimization and improvement of network performance and efficiency and anomaly detection (Ericsson, 2022). AI can help in creating cost-effective network designs, automating the components integration from multi-vendor, as well as monitoring performance, and carring out predictive maintenance. In addition, the transition of network infrastructures with monolithic architectures to disaggregated hardware and software layer architectures required for automation of the networks is promoted (World Economic Forum and Accenture, 2025).

Investing in AI solutions for network operations optimization brings multiple benefits to continuity, stability and quality of service, as well as speed, efficiency and scalability of operations. Given the pressures on network operation, AI becomes a tool to keep low management costs and better return on investment. In the area of intelligent network management, which involves planning, designing, evolving, deploying infrastructure, operating and managing networks, the potential is significant. Some relevant use cases are the development of network architectures and infrastructure, antenna and fiber deployment patterns, traffic and demand projections and optimization, solution deployment automation, maintenance, monitoring, optimization and reconfiguration of real-time parameters and resources, network virtualization functionalities, as well as quality of service, power use, cybersecurity and dynamic spectrum access (GSMA, 2019; Pearson, 2024).

In addition, AI allows performance monitoring, fault detection, as well as predictive maintenance, preventive and real-time adjustments of networks, equipment and functionalities. It also includes traffic/demand management, upgrade, integration and automation of equipment operations and *Network Operations Centers*. AI can be essential for managing complex fiber-optic networks, 5G and 6G, while also accelerating the path to greater management autonomy of these. Similarly, this technology increases the value of *Edge Computing* offerings and solutions for industrial robotics, video surveillance, autonomous vehicles, AR/VR services, network maintenance and monitoring (Hatt & Jarich, 2025).

Differentiation in service and customer experience

More than 70% of survey respondents by Ericsson mentioned this as one of the most important benefits of AI for their business, including customer care and management solutions (Ericsson, 2022). This would allow a differentiation in their services compared to competitors and reverse the drop in revenues. Carriers implementing

AI solutions report significant increases in customer satisfaction (Market Growth Reports, 2025).

This group of solutions includes customer relationships, quality and personalization in care, contact channels, and in general, AI-enabled interactions for user attraction and retention. Chatbots, virtual assistants and digital self-service platforms are key applications in AI adoption. The functionalities also extend to the monitoring and analysis of customer experience data, service quality, churn prediction and proactive retention. And for users in the business segment and industrial applications allows to offer better business-to-business (B2B) services as portals for corporate users designed to manage their telecommunications resources dynamically, with self-service capability, for the provision of IoT devices on the network or troubleshooting connectivity issues on site.

Safe and reliable operations

These administrative functions include high-priority specialized areas such as network security and technology systems that could be leveraged in the IA to detect and address threats to critical infrastructure and operating and customer service platforms. The new risk scenario in digital environments requires telcos to adapt to new threats, but also opportunities, which brings the introduction of AI into cybersecurity issues. This technology works to identify and remedy vulnerabilities, and analyze real-time security incidents or prevent fraud.

Revenue growth

Approximately 25% of telecommunications companies report that implementing AI solutions in their operations increases revenues by more than 5% (NVIDIA, 2025). Some specific initiatives for revenue growth relate to marketing, sales, and product development. In these areas, processes such as product lifecycle management, customer acquisition and retention strategy redesign, market segmentation, user-anticipating customer journeys, marketing targeting and advertising, pricing strategies, offers, and loyalty programs can be transformed. For B2B services, improved infrastructure with AI capabilities can be leveraged and data center services can be offered alongside cloud, Edge, and connectivity solutions (World Economic Forum and Accenture, 2025; Shrivastava et al., 2025).

In the future, the use of AI could not only generate efficiencies in telecommunications operators' current processes, but could also accelerate and make more profitable the transition to new business models that will lead companies in the industry to cease being solely telcos and transform themselves into techcos, or connectivity and technological solution providers in verticals adjacent to their core business, but leveraged on the capabilities and resources obtained in the delivery of their services. This transition requires a rethinking of operating and business models, as well as the necessary technological layers. Diversification and transitioning to tech companies have the potential to increase revenue and move to other links in the value chain. These links are leveraged by AI to dynamically respond to user needs (World Economic Forum and Accenture, 2025).

Conclusions

In the AI era, telecommunications are at a strategic intersection. On the one hand, connectivity networks enable the development of AI within the digital economy, industry, and society ecosystems. However, the increased demand for connectivity infrastructure, triggered by the use of AI-based solutions, poses significant challenges to the sustainability of infrastructure investments. On the other hand, integrating AI into telecommunications operations creates opportunities for greater efficiency and new service and business models beyond traditional connectivity schemes. This could usher in a new era of AI-powered telecommunications.

With the emergence of AI and its widespread use by consumers and productive sectors, it is necessary to address the risk that we will follow the same trend as in previous waves. This trend includes the intensification of network usage requirements, an inability to balance the sharing of costs and benefits in the ecosystem, and greater financial fragility to sustain infrastructure expansion and maintenance.

All players in the ecosystem must address the implications of this trend in digital environments. Operators must have a strategic vision to capitalize on the AI revolution. Authorities must modernize the regulatory and public policy environment in the sector. Given the support they provide to the digital ecosystem as a whole, other stakeholders must recognize the importance of the sustainability of connectivity networks and services. In this context, the sector must evolve to provide smart and sustainable connectivity services for people, devices, services, and platforms. Similarly, public and regulatory policies must advance to ensure the adoption, management, and development of AI solutions in the telecommunications value chain.

References

Accenture (2025). The Looming Spectrum Crisis. CTIA U.S. *Wireless communications industry*. Disponible en: https://www.ctia.org/news/the-looming-spectrum-crisis

Basso M., Capaccio F., Hoang J., White K. y O'Regan K. (2025). AI in Action: Beyond Experimentation to Transform Industry. *Foro Económico Mundial (WEF) y Accenture. Flagship White Paper Series*. https://reports.weforum.org/docs/WEF_AI_in_Action_Beyond_Experimentation_to_Transform_Industry_2025.pdf

Body of European Regulators for Electronic Communications, BEREC (2023). BEREC Report on the impact of Artificial Intelligence (AI) solutions in the telecommunications sector on regulation. *BoR* (23) 93. Disponible en: https://www.berec.europa.eu/en/document-categories/berec/reports/berec-report-on-the-impact-of-artificial-intelligence-ai-solutions-in-the-telecommunications-sector-on-regulation

Centro de Estudios de Telecomunicaciones de América Latina, cet.la y NERA (2025). *Contribución del conjunto del ecosistema digital al desarrollo sostenible de infraestructura de telecomunicaciones*. Disponible en: https://cet.la/estudios/cet-la/contribucion-del-conjunto-del-ecosistema-digital-al-desarrollo-sostenible-de-infraestructura-de-telecomunicaciones/

Comisión Europea (2018). *A definition of AI: main capabilities and scientific disciplines*. Directorate-General for Communication, High-Level Expert Group on Artificial Intelligence. Disponible en: https://ec.europa.eu/futurium/en/system/files/ged/ai_hleg_definition_of_ai_18_december_1.pdf

Ericsson (2022). *AI business potential: understanding the value of AI for telecom operations*. Disponible en: https://www.ericsson.com/4ac6ca/assets/local/reports-papers/further-insights/doc/ai-business-potential.pdf

Foro Económico Mundial y Accenture (2025). Artificial Intelligence in Telecommunications. *World Economic Forum (WEF) Whitepaper*. Disponible en: https://reports.weforum.org/docs/WEF_AI_in_Action_Beyond_Experimentation_to_Transform_Industry_2025.pdf

Gabriel, C., & M. Venturelli. (2022). Telecoms opex: worldwide trends and forecast 2020-2027. *Analysys Mason*. Disponible en: https://www.analysysmason.com/research/content/reports/opex-forecast-2022-rdns0/

GSMA (2019). *AI in Network Use Cases in China*. Disponible en: https://www.gsma.com/solutions-and-impact/technologies/networks/wp-content/uploads/2019/10/AI-in-Networks-Use-Case-V.03-231019-Document.pdf

Hatt, T. y Jarich, P. (2025). *Distributed inference: how AI can turbocharge the edge*. *GSMA Intelligence*. Disponible en: https://www.gsmaintelligence.com/research/distributed-inference-how-ai-can-turbocharge-the-edge

Holma, Harri (2024). *The AI revolution: Preparing for a surge in 5G uplink traffic*. *Nokia*. Disponible en: https://www.nokia.com/blog/the-ai-revolution-preparing-for-a-surge-in-5g-uplink-traffic/

Houpis G., Kenny C. y Ovington T. (2024). The impact of artificial intelligence on the telecoms sector. *Frontier Economics*. Disponible en: https://www.frontier-economics.com/uk/en/news-and-insights/articles/article-i20841-the-impact-of-artificial-intelligence-on-the-telecoms-sector/

Jarich, Peter (2025). *The mobile AI era: what it means for mobile networks*. *GSMA Intelligence*. Disponible en: https://www.gsmaintelligence.com/research/the-mobile-ai-era-what-it-means-for-mobile-networks

Javaid, U. y Zerbib, B. (2024). *AI needs a new networking core: Are we ready for it?* Disponible en: https://inform.tmforum.org/features-and-opinion/ai-needs-a-new-networking-core-are-we-ready-for-it

Korolov, Maria (2025). *AI workloads set to transform enterprise networks*. Disponible en: https://www.networkworld.com/article/3963141/ai-workloads-to-transform-enterprise-networks.html

Market Growth Reports (2025). *AI in Telecommunication Market* [...]. Disponible en: https://www.marketgrowthreports.com/market-reports/ai-in-telecommunication-market-100015

NVIDIA (2025). State of AI in Telecommunications: 2025 Trends. *Survey Report*. Disponible en: https://resources.nvidia.com/en-us-ai-in-telco/telco-report-state-o

Pearson, Chris (2024). *How Generative AI Could Impact Network Planning, RAN Configuration, and Spectrum Management*. *5G Americas*. Disponible en: https://www.5gamericas.org/how-generative-ai-could-impact-network-planning-ran-configuration-and-spectrum-management/

Powell L. y Hatt T. (2025). *Distributed inference: AI adds a new dimension at the edge*. *GSMA*. Disponible en: https://www.gsma.com/newsroom/article/distributed-inference-ai-adds-a-new-dimension-at-the-edge/

Sheikh, H., Prins, C., Schrijvers, E. (2023). *Artificial Intelligence: Definition and Background. In: Mission AI. Research for Policy*. Springer, Cham. https://doi.org/10.1007/978-3-031-21448-6_2

Shrivastava A., Gaffey B., Grundin G. Cubela S. y Lajous T. (2025). *AI infrastructure: A new growth avenue for telco operators. McKinsey & Company*. Disponible en: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/ai-infrastructure-a-new-growth-avenue-for-telco-operators

Stryker, Cole (2024). *What is an AI stack? IBM*. Disponible en: https://www.ibm.com/think/topics/ai-stack

Uitto, Tommi (2024). Advanced automation for advanced networks. *Nokia*. Disponible en: https://www.nokia.com/blog/advanced-automation-for-advanced-networks/

Wall, Mathew (2024). *How Mobile Phone Networks are Embracing AI. GSMA*. Disponible en: https://www.gsma.com/get-involved/gsma-foundry/content-type/news/how-mobile-phone-networks-are-embracing-ai/

Annex

Artificial Intelligence: This technology is based on the fundamental principles of algorithms as problem-solving instructions, yet it encompasses a broad spectrum of tasks and functions that surpass traditional complex algorithms and calculation methods. In fact, it could be argued that it is not just a technology, but rather a set of approaches, techniques, and capabilities for developing advanced technological solutions.

Machine learning: (along with other machine learning techniques), whose main objective is to generate predictions based on data analysis, algorithms, and pattern learning. These techniques are used in forecasting and optimization models.

Computer vision: is used for the observation and analysis of visual information and images. Natural language processing is used to understand, interpret, and process human language. It is widely used in chatbots, text analysis, and transcriptions, for example.

Speech recognition: is a form of AI used for processing spoken language in voice-controlled assistants. Robotics combines AI capabilities with physical functionalities in hardware and robots. There are also applications that combine the functionalities of these types. For example, generative AI (Gen AI) is used for content creation, and Edge AI performs artificial intelligence processing locally on devices rather than in the cloud.

RESEARCH

Python tool for behavioral studies of the IP Pools in the BRAS

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Abstract

The deployment of postpaid services at interoperable hotel Wi-Fi sites nationwide—allowing up to three devices per account—alongside expanded coverage and higher occupancy, has increased IP address utilization. Consequently, the Telecommunications Company of Cuba S. A., ETECSA has experienced an increase in terms of requests for IP address ranges at these sites, currently allocated via empirical calculations based on estimated guest numbers and service usage. The absence of tools providing accurate IP address usage statistics hinders behavioral studies to determine optimal pool sizing. This may cause service disruption and dissatisfaction for both customers experience address exhaustion, while ETECSA faces inefficient network resource allocation. To address this, a Python-based utility was developed to collect data for behavioral analysis. This tool was developed so as to solve the this problem. This paper describes the work performed and the results obtained with this tool, contributing to our Company enhancing tourism-sector service delivery and optimizing network resource efficiency.

Keywords: Python, Netmiko, Network Automation, WiFi.

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Introduction

The service known as Wi-Fi Interoperability constitutes one of the possible forms of Internet access provided by ETECSA, as a service provider for hotels, campsites, restaurants, hospitals, universities, public transport hubs, and many other places. This service's network architecture, which uses an IPoE solution with Web authentication (Figure 1), customer traffic is transported by layer from the Wi-Fi network Access Points (AP) deployed at each location, to the ME60 devices, operating as Broadband Remote Access Servers (BRAS) in the IP/MPLS network. To accomplish this, service VLANs are appropriately routed through the access switches and transit equipment of the transport/aggregation networks, which terminate at the corresponding BAS sub-interfaces on such BRAS. User control is guaranteed in these latter devices through interaction with the other system elements, such as: Session Control, Captive Portal, AAA, and DNS. The BRAS also function as the DHCP servers towards the customers, dynamically assigning IP addresses to their Stations (STA) or terminal equipment. For this, it is necessary to configure a private IP address pool, exclusive to each particular site. ETECSA, as the service provider, manages and controls these ranges, and their dimensioning is performed based on information provided by the personnel where the service is installed, which includes the estimated number of concurrent customers, calculated from the number of installed APs and the expected occupancy of the facilities, elements which can vary from time to time.

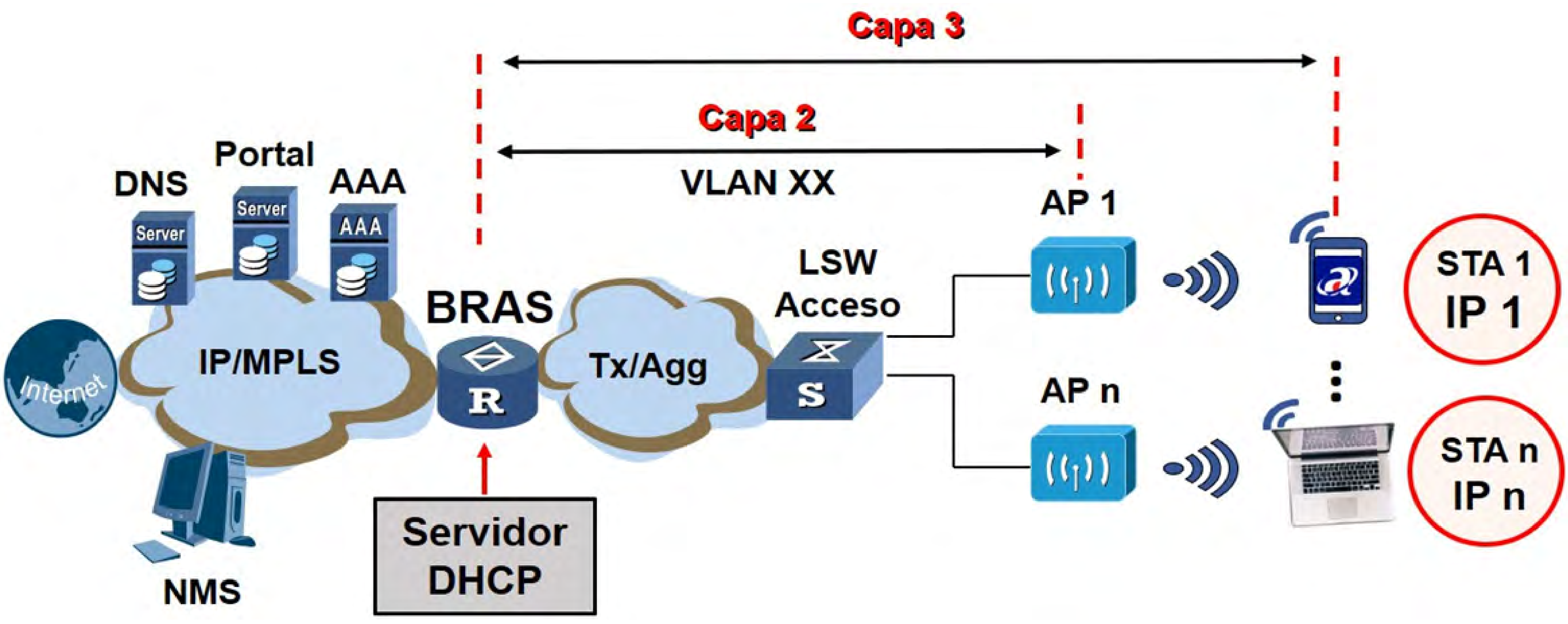


Figure 1. Summarized diagram of the Wi-Fi Interoperability service

In the designation of the above-mentioned Pool IPs may occur the following cases:

1. Under-dimensioned pool: It is below actual needs. It may happen that a number of customer devices request IPs and there are no available addresses left to assign to them (the range configured on the server is exhausted). This causes service impairment in those customers who fail to get IP addresses.

2. Over-dimensioned pool: It exceeds the actual needs. It leads to an inefficient use of network resources (IPs) to the detriment of the provider, which, in an extreme case, may be left without free ranges for its operation.

3. Correctly dimensioned pool: It matches the actual needs. There is no negative impact for either the customers or the provider.

As part of the Company's prioritized attention to the tourism sector, we are continuously working on improving the Wi-Fi service in hotels and solving their demands. As a result, the Wi-Fi Interoperability modality called Postpaid Wallet, which has been applied with good results since 2022; started in Havana and has spread throughout the country. Here are some new features of this service:

1.- Billing based on total traffic processed and not on the credit consumed from active accounts.

2.- Creation of customer accounts from the hotel itself, with access to GESNAUTA platform.

3.- Possibility to connect up to 3 devices per account.

4.- Need for accounts to remain connected

as long as possible once authenticated. In order to achieve this, the disconnection for low traffic and inactivity was disabled in the BRAS. In the particular case of hotels on the Gaviota chain, this last option was set for disconnection at 15 minutes.

In this postpaid modality, customers' accounts can remain active until logout, disconnection that the AAA sends at 12 hours of being authenticated. This, together with the expansion of WiFi service in hotel facilities, with coverage in practically all areas and increased levels of occupation, has brought with it greater use of IP addresses, and thus the need to expand the Pool in those places where it is required. In this context, there has been an increase in demands for the expansion of the IP Pools by the hotels' technical and administrative staff, who make an estimate based on the number of guests according to housing capacities, multiplied by the 3 possible devices to connect per account, resulting in a high number of requested IP addresses (mostly /22 and /21 ranges).

On the other hand, the provider's NCE management system provides indications of IP address exhaustion in the Pools, by generating usage alarms above 80% of IP addresses (a configurable value, it comes with a default value), but it does not provide in a timeline the specific values it reaches, but only when they exceed the configured threshold value. Therefore, in the cases under analysis, the required information was obtained on a case-by-case basis, by manually probing the BRAS where the specific service was set up.

This is an inconvenience for precise monitoring use of IP addresses, which makes it difficult to carry out behavioral studies, that allow to choose the optimal Pool and serve as evidence to show in response to customer demand. This can lead to service impairments and dissatisfaction, both for customers and our Company, a fact which constituted the problem to be solved in our case and which motivated the development of a scheduled utility on Python, with which it was possible to collect the information needed to conduct the relevant studies and analyses related to IP Pools.

Python is a trend in the world of data network automation. (Damien, 2020), given by its simplicity, versatility, modularity, database processing, file management and graphical interfaces for viewing information, as well as by the multiple and powerful libraries available for connection to equipment from various manufacturers, as is the case with Netmiko (Byers, 2024), used in this work. Furthermore, it has a large international community of developers, which is active, participatory and collaborative. These elements, as well as having previous experience of its use, were crucial when choosing the programming language used. This paper describes the work done and the results obtained with the developed computer tool.

Materials and methods

This research was developed under an applied engineering and research approach for development (R+D). The methodology was structured in three sequential phases to address the core problem of the lack of accurate data on the use of IP addresses in the Wi-Fi Interoperability service. Phase I consisted of the analysis of possible commands to be used on the BRAS ME60, which would allow gathering the necessary information. Phase II focused on analyzing the tools available for network automation that would allow remote management of the BRAS via the SSH protocol. Phase III consisted of the development and implementation of a utility for automated data collection, processing and presentation. These phases are described below.

Study of possible commands to obtain the required information

As a first task, a survey of technical information was carried out, to know the available commands and to choose the one suitable for defined purposes. Among them was chosen the command disp ip-pool pool-usage pool-name (pool name), the output of which simply and explicitly provides the required information, which is: Pool address range, IPs in use (including those allocated, conflicting and blocked) and the percentage of use they represent.

Network automation with Netmiko Python library

As a second step, the possible tools for collecting the required information were studied and the Netmiko library of Python was chosen for this purpose. This library was developed by Kirk Byers as an improved version of Paramiko and is designed to facilitate automated interaction with multi-manufacturers' network devices, such as: Cisco, Juniper, Arista, and many others (Byers, 2024). Netmiko uses several communication technologies, the most important being the SSH (Secure Shell) protocol, which encrypts the management information transmitted thus achieving safer communication. SSH is available on most telecommunication devices for their remote access, this being the most used method when applying automation to the field of telecommunications networks (Damien, 2020). This library helps network operators to send commands to equipment such as switches, routers, firewalls, among others, in a scheduled and repeatable way, and offers a simple and consistent way to automate network device management tasks (Figure 2). This minimizes the manual intervention by operators and reduces the margin of human error. This fact, combined with Python's multi-area capabilities, were the reasons for deciding on this tool when choosing an effective network automation method.

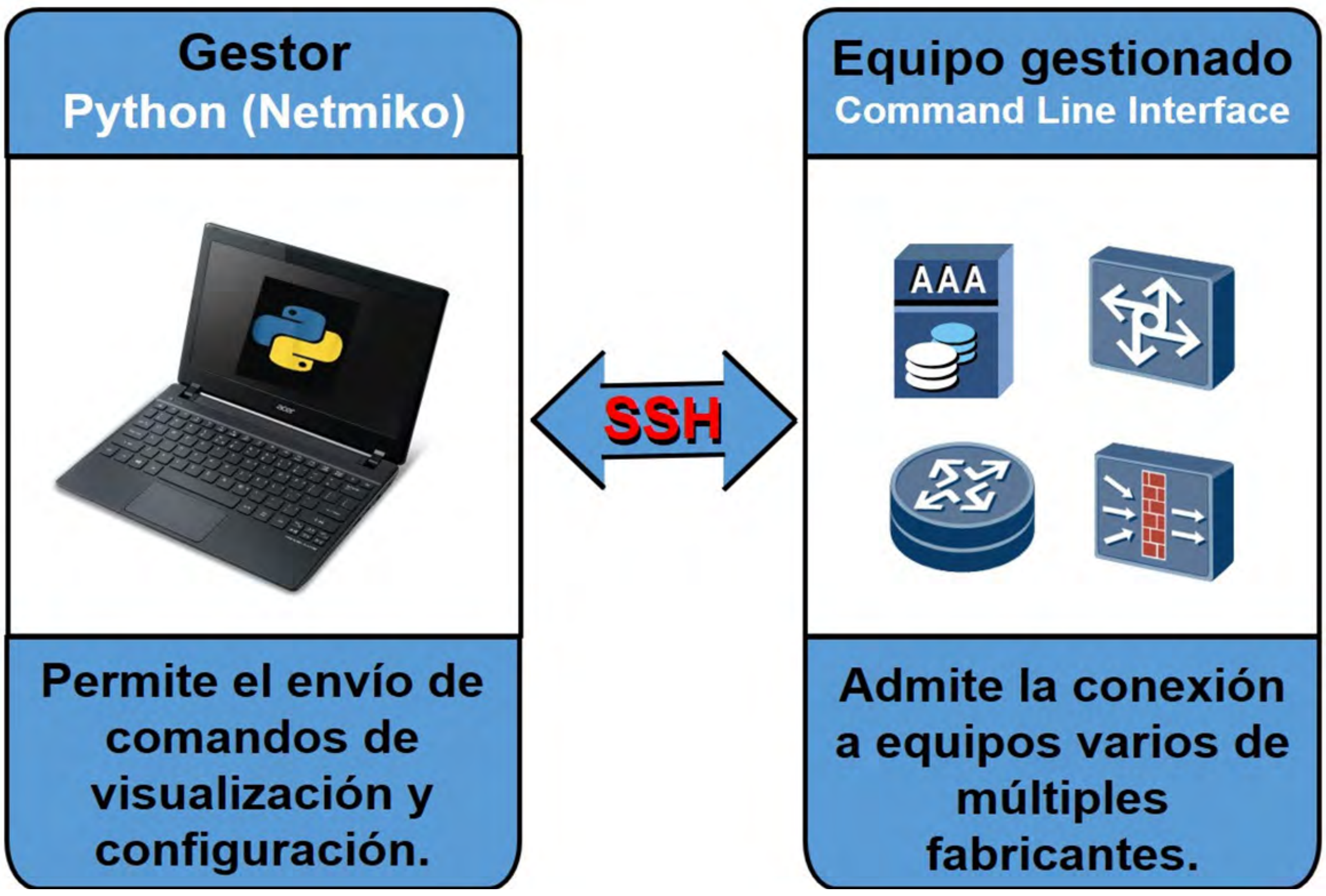


Figure 2. Network automation using Netmiko

Structure of the Python-based program

Subsequently, a program on Python was developed, consisting of two modules (Figure 3); the first one (left) shows a Graphical User Interface (GUI), which allows to enter the necessary parameters for its execution. In its development, it was used primarily in the Tkinter library. The second one (right) has in turn two parts: one for the periodic connection to the equipment via SSH (using the Netmiko and Schedule libraries), where the chosen command, described above, is sent to the BRAS. This allows to query one or several selected IP Pools and properly process the information it returns. The other part, after finishing the

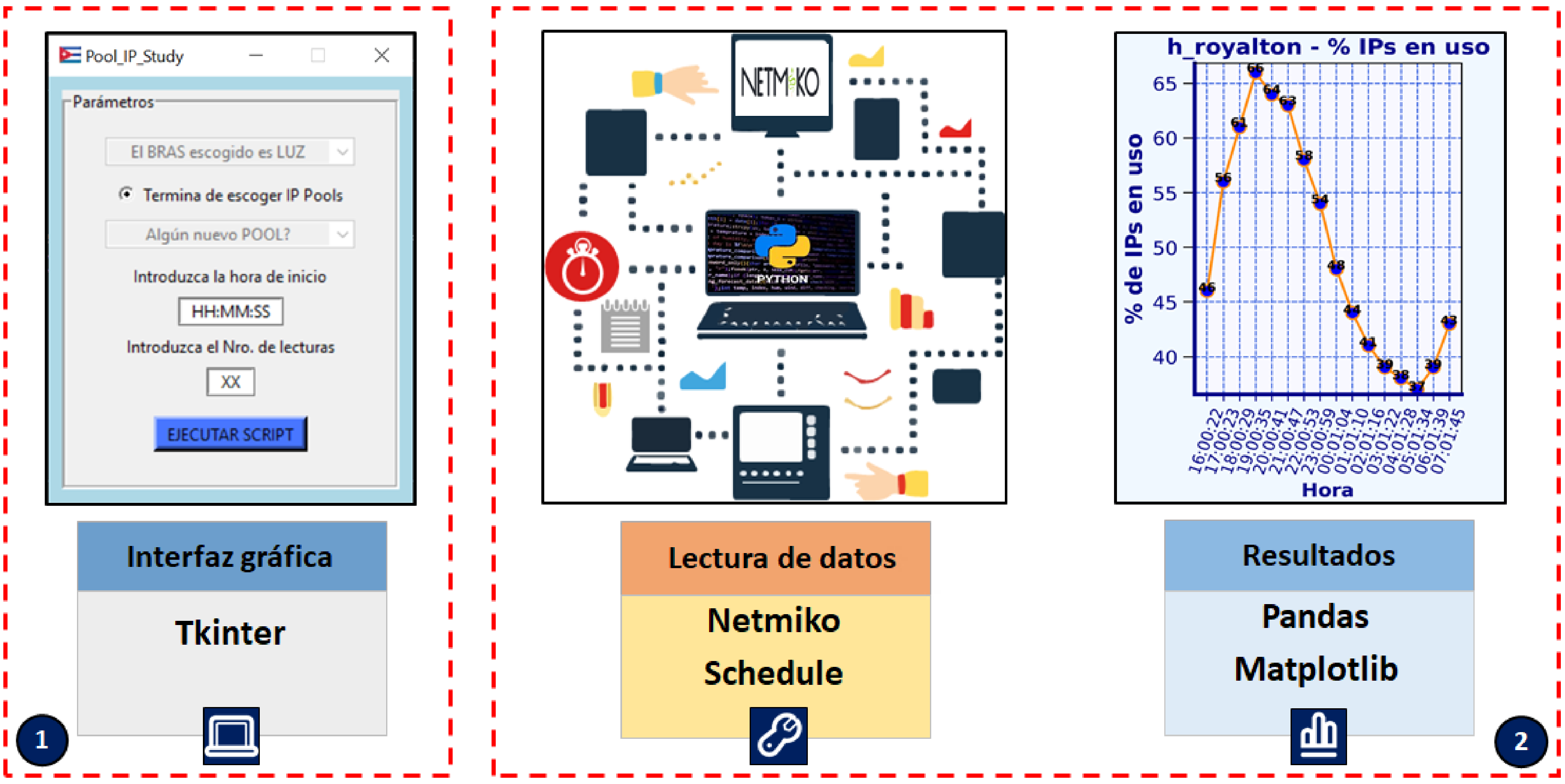


Figure 3. Structure of the Python-based program

number of defined readings, stores the data obtained in files with .csv, .txt and .pdf extensions, in the latter case shows them graphically. The Pandas and Matplotlib libraries were used for this part.

Program execution steps

The program execution consists of four steps (Figure 4):

1. Choosing the desired BRAS from a drop-down list (Figure 4a).
2. Choosing the IP Pool(s) to be analyzed from a drop-down list (it automatically obtains them by connecting to the selected BRAS) (Figure 4b).
3. Entering the start time to take readings and the number of readings to be performed (Figure 4c).
4. Clicking on the 'Execute Script' button (Figure 4c).

Once the above is done, module 2 starts running at the time entered; it takes the number of desired readings and processes the obtained information.

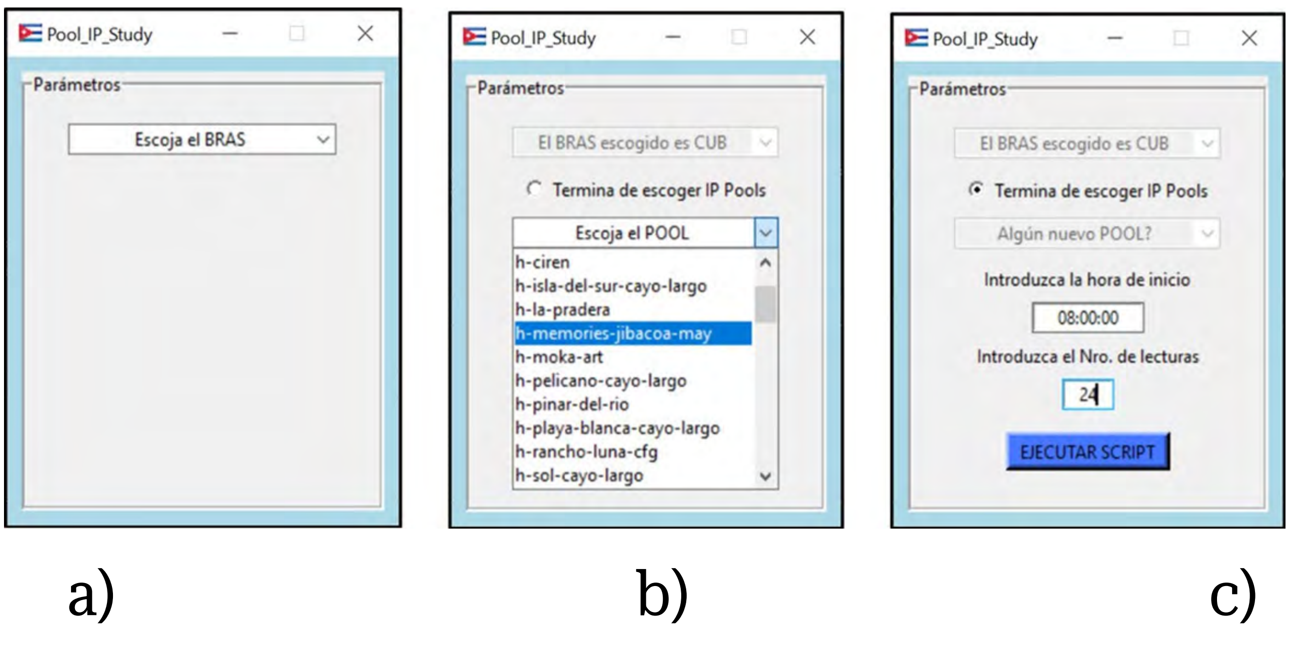
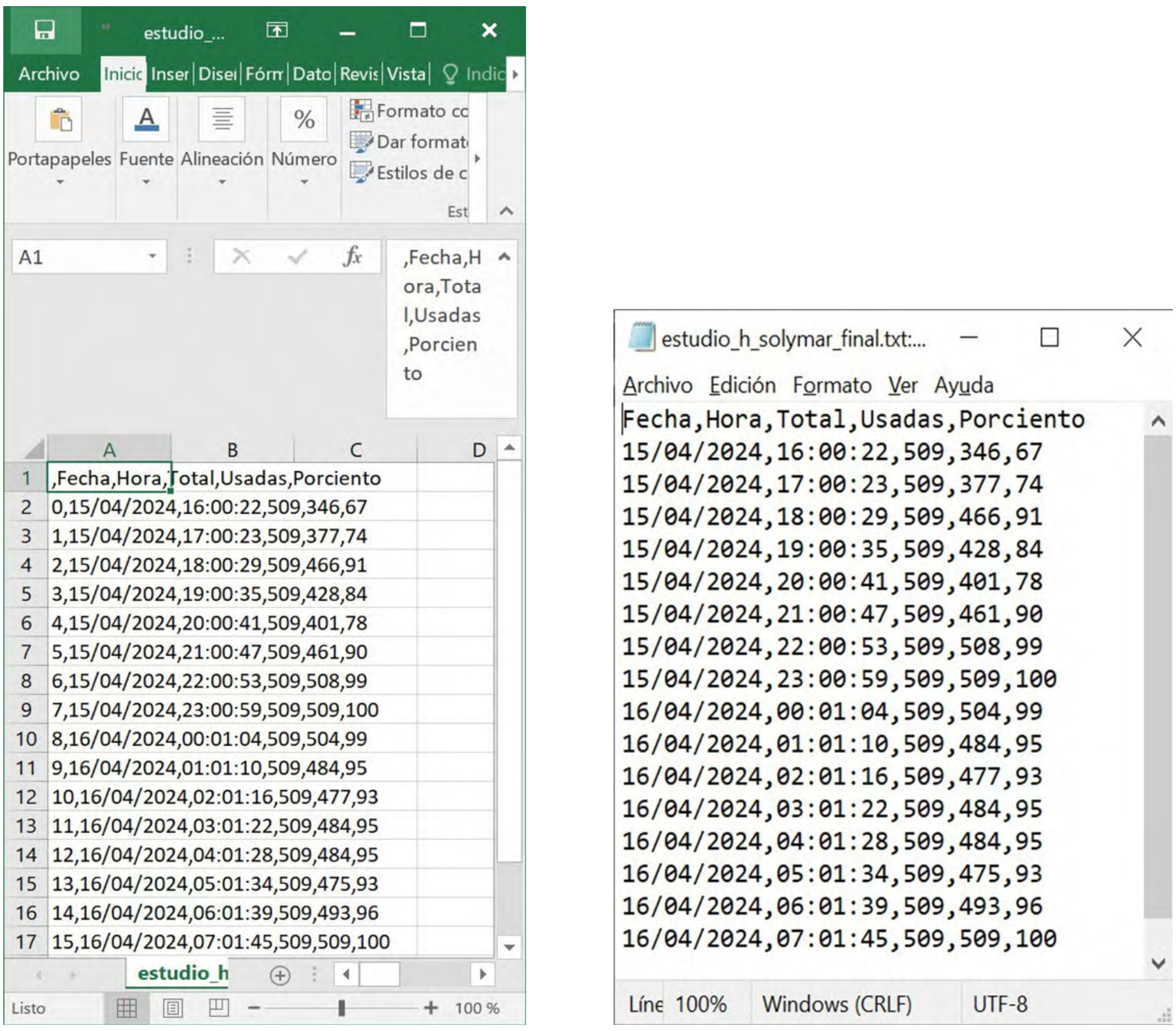


Figure 4. Program execution steps

Results and discussion

Once the execution cycle of the program as shown in the previous section is finished, the information obtained is stored in Excel and text files, with .csv and .txt extensions (an example of this is shown in Figures 5 a and b, respectively), as well as graphs with a .pdf extension.



a) b)

Figure 5. Example of Excel and text information files

The case in Figure 6 is one of those that was monitored based on the alarms generated in the NCE management system. According to the information obtained with the Python utility, it was verified that IP address exhaustion was occurring (in the red circles, moments when it reaches 100% use) and thereby affecting customers.

Figure 6. Under-dimensioned IP Pool Behavior

Figure 7 shows a case where the IP pool was increased to /21, in respond to a hotel demand. It can be seen in the obtained graphs that does not exceed 20% of the use of IP addresses, being an example of over-dimensioning, with implications for our Company.

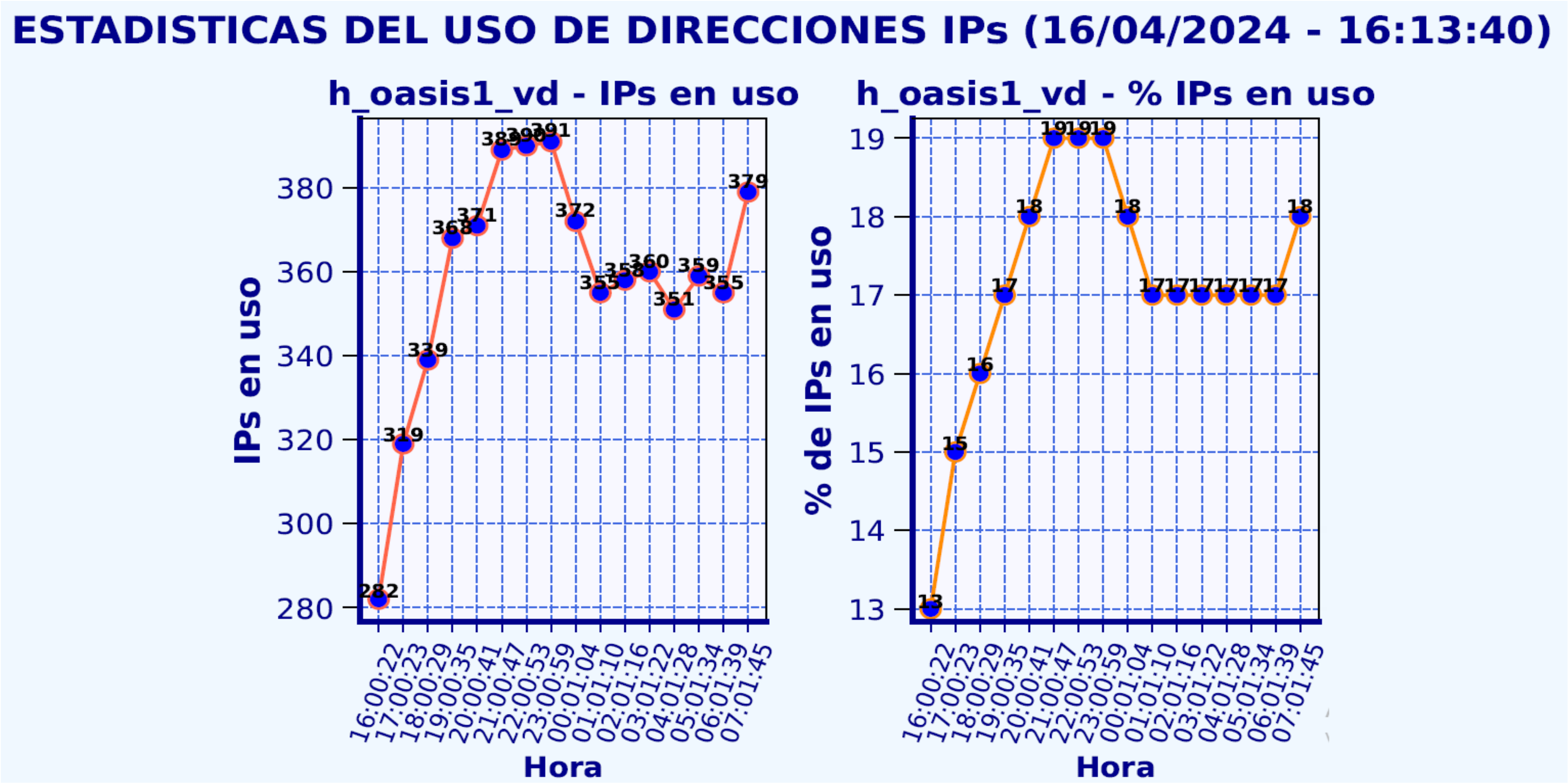


Figure 7. Over-dimensioned IP Pool Behaivor

Figure 8 shows a correctly sized case. This particular one requested to expand its IP address range, which was not necessary to do at that time, based on the statistics obtained and shared with the hotel staff.

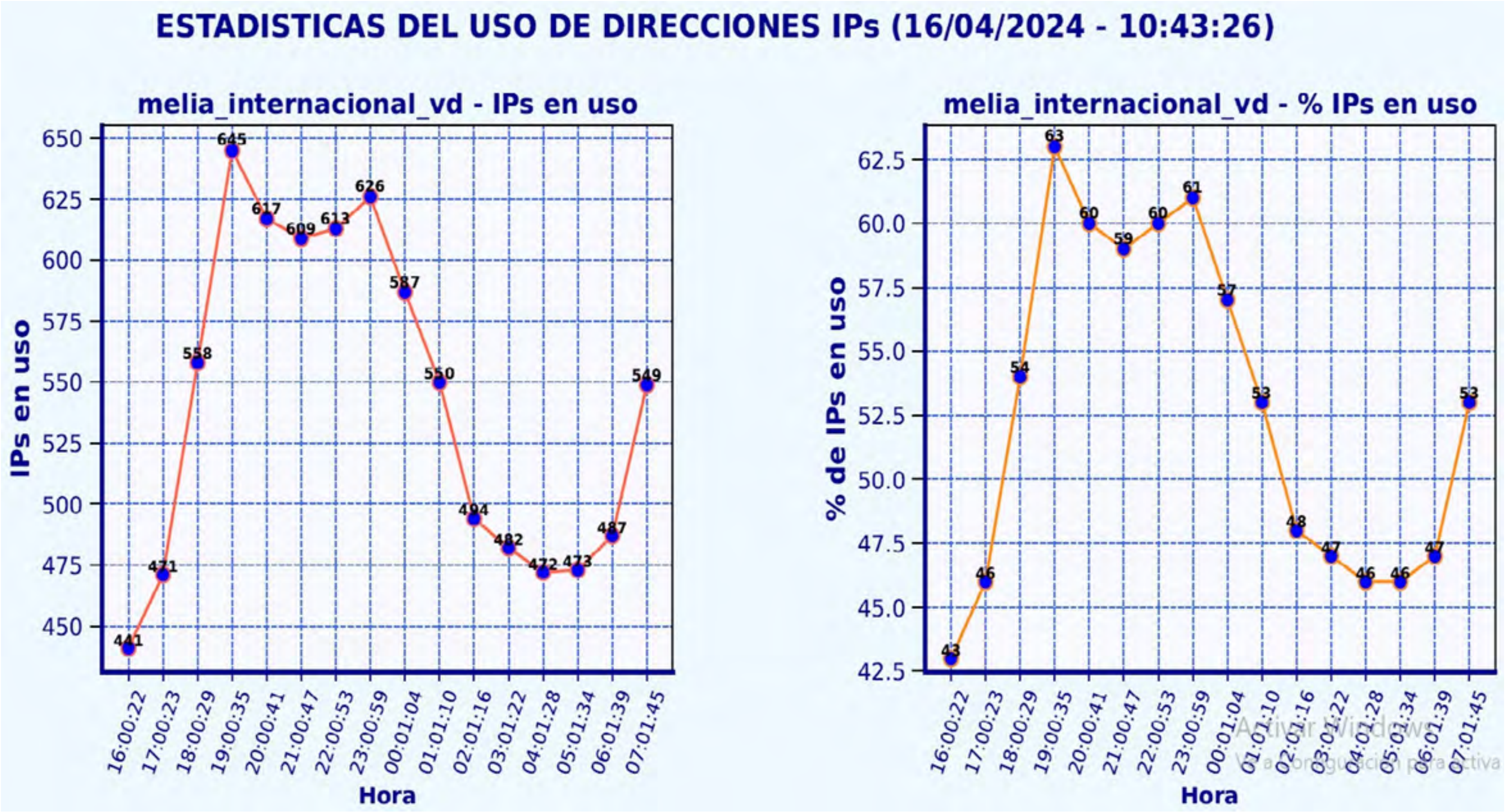


Figure 8. Correctly-dimensioned IP Pool Behaivor

It should be mentioned that in all the examples shown, there was a high level of occupancy in the hotels, which in turn suggests high percentages of IP address use.

Conclusions

The conclusions of this research reflect the positive impact of implementation of a computer tool developed in Python to analyze and manage the IP Pools within ETECSA's network. First of all, it is shown that this tool is an effective solution to overcome the lack of accurate information, allowing for automated collection and processing of behavior of IP Pools, especially in environments where BRAs act as DHCP servers. This facilitated early detection of issues, such as exhaustion of IP addresses in hotels, and allowed timely corrective actions to be taken, such as expanding the address range, avoiding service interruptions. In addition, it was found that a correct dimensioning of the Pools avoids unnecessary costs in the acquisition of new IP addresses, contributing to a more efficient use of resources. The statistics generated not only improve service quality Wi-Fi for users, but also provide valuable evidence for technical and administrative staff, increasing customer satisfaction. Finally, although the tool was initially designed for the hotel sector, its application potential is extended to other network IP Pool services, demonstrating its flexibility and usefulness in different ETECSA's network resource management contexts.

References

Garros, Damien (2020). *NetDevOps Survey*. https://dgarros.github.io/netdevops-survey/reports/2020

Byers, K. (2024). *Biblioteca Netmiko*. https://github.com/ktbyers/netmiko

ME60 V800R023C00SPC500 Configuration Guide. Información técnica del proveedor Huawei (2023). https://support.huawei.com/enterprise/en/doc/EDOC1100335692/d0a3124b/configuration-management-configuration

RESEARCH

Dynamic Assessment of Business KPIs: Optimizing Territorial Management Through a Dashboard

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Abstract

At ETECSA's Sancti Spíritus Territorial Division Center, dispersed statistical data on key indicators —distributed across monthly/yearly databases— hampers comprehensive analysis and decision-making. To address this limitation, an Excel dashboard was developed to centralize and unify this information into a single file, which can be updated monthly. This tool consolidates preliminary, monthly, and cumulative indicator values, enabling dynamic visualization via interactive period-segmented charts. The Dashboard generates accurate, real-time reports, to evaluate performance against annual business objectives; streamlines management decision-making by managerial decisions by unifying ETECSA's KPIs; and supports the Territorial Director in monitoring results through integrated data from Network Operations, Sales, Logistics & Services, Human Resources, and Investments. The solution is implemented using Microsoft Excel in its advanced version, leveraging dynamic links

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between databases, VBA (Visual Basic for Applications) macros to automate update and validation processes, and interactive charts configured to reflect monthly trends and historical comparisons. All the information processed ranges from divisional to national levels, ensuring consistency in reporting. This project not only optimized data management but also deepened the company's mastery of Excel as a Business Intelligence tool, proving its potential to transform operational processes into strategic ones.

Keywords: Dashboard, KPIs, VBA, Business Intelligence

Introduction

In contemporary business management, the real-time monitoring of Key Performance Indicators (KPIs) has become a keystone for strategic decision-making. Nevertheless, various organizational units within the Empresa de Telecomunicaciones de Cuba S.A., ETECSA's territorial divisions, face specific challenges: the presence of multiple non-integrated information systems, disparate data collection formats, and the absence of automated mechanisms for temporal comparative analysis. This significantly hinders performance assessment and the timely detection of deviations. This paper introduces an interactive Dashboard engineered to streamline the assessment of business KPIs within the territorial division which allows executives to monitor the achievement of objectives through dynamic graphical visualizations, monthly as well as accumulated and speed up the evaluation process of institutional performance.

The primary objectives of this research were to develop a tool that centralizes and automates the analysis of KPIs based on their compliance, in addition to facilitating the graphical display of the indicator performance in monthly and cumulative periods; as well as, optimizing the performance evaluation process of the executives and managers in the Territorial Division.

Recent research has highlighted the value of Dashboards in Business Management. Authors such as Few (2006) and Eckerson (2010) laid the foundations for the design of effective control panels, while more recent studies by Terreros (2023) and Pérez (2025) have shown their impact on improving decision-making agility. However, few papers address specific solutions for territorial management, where data heterogeneity and the need for local contextualization represent unique challenges.

This research is justified by three key factors: the need to unify criteria in the analysis of KPIs dispersed in multiple sources, the demand for accessible tools that automate the generation of reports for executives, as well as the lack of purpose-built solutions to the territorial scale, where indicators require historical benchmarking and georeferencing.

This paper has influence on the field of operational Business Intelligence by proposing a scalable solution, developed with widely accessible technologies (advanced Excel + VBA), which combines analytical rigor with utility for managerial environments. The results show how the integration of interactive displays and business logic can effectively transform raw data into data-driven recommendations, bridging the gap between information and strategy.

Materials and Methods

The implemented methodology was based on the use of Microsoft Office Excel, leveraging its advanced data management and analysis capabilities through the use of VBA — Visual Basic for Applications — for process automation, Alexander and Kusleika (2022). This approach allowed to establish dynamic connections with multiple data sources generated by Network Operations, Commercial, Logistics and Services, Human Capital and Investments departments. It also allows standardizing and consolidating the key indicators aligned with ETECSA's annual Business Objectives, as well as developing an automated updating system that guarantees the information integrity and timeliness. The choice of this tool is justified by its widespread use in corporate environments, its scalability to process significant volumes of operational data, and its ability to generate customized outputs through advanced programming, which makes it a cost-effective solution for the strategic management of indicators.

The design of the dashboard is conceived from the needs demanded by the Territorial Division executives, who required a visual way to analyze the performance of their key indicators after months. To achieve this, a system was developed that displays the information in easy-to-understand graphs (Figure 1), which allow to quickly identify trends, compare results and detect possible problems. Each area of the organization has its own customized dashboard, connected directly to its databases in Excel. This enabled to gather all the information that reaches the Territorial Management Center in a consistent and orderly format, facilitating joint analysis without losing the specific perspective of each department.

Figure 1. Business KPIs Management Dashboard Interface – ETECSA

For a better understanding, the main Dashboard is organized in functional sections, starting with a module that has all organizational units reporting information to the Management Center. For each unit, the total figures of analyzed indicators and the percentage of compliance calculated using the formula: %Compliance = (Current Value / Planned Target × 100, applicable for both monthly and cumulative analysis, are shown. Indicator values that fail to meet their targets are highlighted by graphical visualizations detailing the frequency of monthly non-compliance. This functionality was implemented through VBA programming that automates data update, generates the graphs dynamically and ensures consistency of calculations.

In this same section, the functionality of visualizing customized control dashboard for each department was implemented (See Indicators), adapted to the specific characteristics of their indicators. The data can be displayed in both graphical and tabular formatting, depending on analysis needs. All dashboards are interconnected through data segmentation based on Excel's dynamic tables and advanced functions, which include the use of dynamic ranges to optimize information processing. This technical solution was designed to ensure smooth performance, even when handling the high volume of data generated in the year, ensuring an efficient user experience on all workstations.

The main Dashboard includes another section dedicated to the key indicators for the performance evaluation of executives. The values use Excel conditional formatting, which automatically highlights in red and with an alert icon those that do not meet the established objectives. The information is complemented by a pie chart that visually displays the percentage of compliance or non-compliance and a detailed table that quantifies the exact number of indicators met and not met. This design allows for immediate identification of problem areas, combining the clarity of the graphical visualization with precision of tabulated data.

The Dashboard includes a section that automatically displays all the indicators that have not met their targets. The most useful thing is for this information to be updated automatically: by changing the month or year option (cumulative) in the time segmentation, the numbers and list of indicators with problems instantly change. This enables to easily see if there are indicators that are repeated every month or if they are one-off situations, helping to better focus improvement efforts.

In the upper section of the main Dashboard, interactive buttons are used to display the density values of four key services: Fixed Basic Telephone (hereinafter, TBF, for its acronym in Spanish), Public Telephony (hereinafter, TP, for its acronym in Spanish), Nauta Hogar (hereinafter, NH, for its acronym in Spanish), and mobile service. For the first three services, the buttons display, through forms developed with VBA, detailed tables that break down the data by telecommunications centers.

In addition, a specific function is added to display in a customized way all the indicators related to each telecommunications center, extracting data from the control dashboard. This function allows specific analyses to be performed faster, generate automated PDF reports using macros and optimize the working time of executives, specialists and technicians by facilitating access to accurate and segmented data.

Results and discussion

The traditional method used to carry out the monthly closing report of the KPIs in the Territorial Division, relies on the manual update of multiple Excel databases and their consolidation into a single PDF file with tables and graphs, which has significant limitations. Among them are the lack of historical visibility, since the graphs do not display the cumulative annual progress broken down by months; the dispersion of information into different sheets, which makes it difficult and delays data location; and the inability to customize reports for specific telecommunications centers when executives require particular analyses. These restrictions impact on the efficiency of the process and the quality of strategic decision-making.

With the implementation of an interactive Dashboard for the dynamic assessment of corporate KPIs in territorial management, it allows obtaining a comprehensive view of the performance of the different organizational units in the Territorial Division (Figures 2 and 3). This tool facilitates immediate monitoring of key indicators, centralizing information and reducing reporting times compared to the traditional method. In addition, it allows the early identification of deviations, which makes it possible to quickly detect negative trends, allowing to respond to methodological areas with timely and customized interventions. The availability of updated and visually intuitive information increases data-based decision-making, strengthening territorial management and improving key indicators.

Figure 2. Customized Dashboard for KPIs Management in the Commercial Area

Figure 3. Customized Dashboard for KPIs Management in the Network Operation Area

The obtained results show that the dynamic assessment of KPIs through a Dashboard represents an effective tool for territorial management in the business context, particularly in environments where speed and accuracy in decision-making are crucial. The ability to display key indicator performance enables executives to identify problems, assess the impact of implemented initiatives, and adjust strategies in an agile way.

Furthermore, data centralization and accessibility foster more collaborative management, promoting the alignment of objectives and initiatives across the different organizational units. The reduction in reporting and analysis times contributes to greater operational efficiency, optimizing resources and enhancing user satisfaction. The dynamic assessment of KPIs through Dashboards not only improves territorial management, but also boosts the data-driven decision-making culture, a key element for competitiveness in today's business environment.

Conclusions

The implementation of this interactive tool allows the executives from the Territorial Division to conduct an exhaustive analysis of business indicators. This results in a better understanding of the organization's performance throughout the year.

It allows to graphically display the indicator performance on a monthly and cumulative basis, facilitating the identification of trends, anomalies and opportunities for improvement, thus contributing to more informed and timely decision-making.

The tool provides executives with a solid basis on which underpin continuous improvement strategies by providing up-to-date and accurate data on indicator compliance. This helps foster a culture of constant evaluation and process adjustment in the Territorial Division.

Furthermore, the use of this tool allows a better alignment between the strategic objectives and operational actions of the Territorial Division, ensuring that all organization levels work in synergy towards achieving optimal results.

Bibliographic references

Alexander.M & Kusleika.R, (2022). Excel VBA Programming For Dummies, 4th Ed. John Wiley &Sons. https://www.amazon.com/-/es/Excel-Vba-Programming-Dummies-4e/dp/1119077397

Eckerson, W. (2010). Performance Dashboards: Measuring, Monitoring, and Managing Your Business. 2 a Ed. Wiley & Sons https://www.amazon.com/Performance-Dashboards-Measuring-Monitoring-Managing/dp/0470589833

Few, S. (2006). Information Dashboard Design: The Effective Visual Communication of Data. Editorial Academia. https://www.academia.edu/1380138/Information_dashboard_design_The_effective_visual_communication_of_data

Pérez, N. (2025). Implementación de Dashboard de gestión empresarial para mejorar el proceso de la toma de decisiones en la empresa minera, Andahuaylas (Tesis de pregrado, Universidad San Ignacio de Loyola). Perú. https://repositorio.usil.edu.pe/entities/publication/cf67796d-bb30-4e0f-ae55-785ac28b8606

Terreros, D. (2023). Qué es el análisis predictivo, tipos, ejemplos y herramientas. HubSpot, Inc. https://blog.hubspot.es/marketing/que-es-analisis-predictivo

RESEARCH

Implementation of a Smart Beam-Switching Antenna System

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Abstract

Last decades have been marked by an increase in the number of users employing the various developed communication services. This has made it necessary to evolve the technologies used to better satisfy current demands. This paper shows the proposal for the development of a smart antenna array with beam switching for use in a communication system. It uses ARRadio-HSMC radio frequency cards as an implementation platform coupled to the TR4 development board. The proposed design allows dynamic control of the main direction of seven digitally synthesized radiation patterns, ensuring spatial coverage of an angular sector of 100º. Doing this project opens a line of work applicable in different systems, capable of easily adapting to complex antenna geometries and with the possibility of incorporating adaptive algorithms to increase the performance of the digital beamformer for each beam.

Keywords: digital beamformer, smart antennas, switched beam

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Introduction

Controlling an antenna's radiation pattern increases the performance of radio communication systems in which user locations or spectral operating conditions change over time. Smart antennas are key elements to solving this problem. These antennas combine an array of radiation units with digital signal processing blocks to ensure dynamic beam formation based on real-working needs (Ong, 2015).

Initially, smart antennas were only used for radar, sonar, and military communications applications. However, advancements achieved in digital signal processing technology have made it possible to integrate smart antennas into the world of modern telecommunications systems (Zhai, 2017). Smart antennas form the basis of satellite links using Space Division Multiple Access (SDMA) techniques and are incorporated into IEEE 802.11ac and Long Term Evolution (LTE) telecommunications standards (Chen & Haas, 2015).

Switched beam systems are one type of smart antenna implementation. These systems form multiple fixed directional beams. The reception system activates in each direction to identify signals. Once a useful information source is detected, the user's identification and location are stored in order to establish communication through the predefined radiation pattern that points in their direction. As the source moves, the patterns switch to maintain the link with the maximum possible antenna gain (Sharma, Sarkar, Maity, & Bhattacharya, 2014).

Several authors have addressed the development and use of this technology. Rosa presents the implementation of a Local Area Network with electronic switching of eight antennas arranged in a cylindrical geometry (Rosa, Supriyanto, Rahman, Rahim, & Moradikordalivand, 2014). Almorabeti proposes a design based on the Butler matrix to form four orthogonal patterns, implements it on microstrip, and incorporates a switch with PIN diodes (Almorabeti, Rifi, Terchoune, & Tizyi, 2018). Ahmed and Tiang analyze the use of beam switching in Vehicle-to-Vehicle (V2V) communication systems (Ahmed, Tiang, Mahmud, Gwo-Chin, & Do, 2023; Settawit Poochaya, 2016).

This paper presents the implementation of an antenna array with digital formation of multiple radiation patterns for a switched beam system. The design is based on ARRadio-HSMC transceiver cards coupled with the TR4 development board. The main objective is to present a design architecture applicable to this smart system variant, which can adapt to complex antenna geometries and incorporate adaptive algorithms to improve the performance of the digital beamformer for each beam. While the development does not include the signal search and identification algorithm, it provides a platform that ensures the formation and switching of multiple beams during reception. The work's main contribution is presenting a design variant for developing smart antennas in telecommunications systems.

Materials and Methods

To implement the switched beam smart antenna system, we used a hardware architecture consisting of a TR4 development board with a Stratix IV EP4SGX230C2 FPGA as the main processing core and four ARRadio-HSMC daughter cards equipped with Analog Devices AD9361 transceivers, which provided a total of eight independent reception channels. The antenna array consisted of eight half-wave dipoles arranged in a uniform linear configuration, spaced between elements by 0.6 at the operating frequency of 2.412 GHz. The experimental methodology consisted of three sequential phases: hardware configuration, signal processing programming, and metrological validation.

The experimental methodology was structured in three sequential phases: hardware configuration, signal processing programming, and metrological validation. Initially, the operational parameters of the AD9361 RFICs were configured using an NIOS II softcore embedded in the field-programmable gate array (FPGA). This softcore was managed via a serial peripheral interface (SPI) to control the center frequency, bandwidth, gain, and sampling rate. The FPGA-based digital signal processing included in-phase and quadrature (I/Q) data acquisition and demultiplexing, followed by a frequency-domain calibration algorithm based on the discrete Fourier transform (DFT) to compensate for amplitude and phase deviations. Finally, seven directional beams were synthesized by applying precalculated complex weights. Experimental validation was performed in an anechoic chamber using a 2.4121 GHz reference sinusoidal signal to characterize system performance. Radiation patterns were measured via angular sweep with a rotary positioner, and the obtained data was exported to MATLAB for comparative analysis with theoretical simulations. Specifically, the analysis evaluated the sidelobe level and radiation angle accuracy.

Digital Beamforming

In a conventional antenna, the electromagnetic field contribution in different directions in the far-field region is determined by the current distribution law on the radiator's surface. Thus, the antenna's directional characteristics depend on its geometry and the feed point (Stincer, 2001).

An antenna array consists of independently fed radiation units. By modifying the amplitude and phase of the input signals, an equivalent current distribution is established, which allows for the desired directional characteristic to be obtained. This process is known as radiation pattern formation (Rodríguez, García, & Miller, 2017).

The use of digital beamformers is a crucial leap for the development of smart systems. In these systems, signals acquired by the elements are digitized and sent to a signal processor. A complex weight factor is then applied to each channel to ensure pattern synthesis. Operating in the digital domain enables the shaping of multiple beams with different, dynamic characteristics without altering the antenna array's physical structure, a feature exploited by switched beam systems (Bailleul, 2016).

Reception and Processing Platform

The first step in digital beamforming is acquiring and digitizing the signals at the input of each element. Peter Delos (2017) proposes using a Radio Frequency Integrated Circuit (RFIC) for this purpose. In the work (Delos, Frick, & Jones, 2020), a prototype based on the AD9061 four-channel transceiver is shown. Direct operation with the available RFIC requires advanced mounting technology capable of supporting complex designs. For example, the integrated AD9361 requires a connection of 144 pins in a 102 mm² area (HSMC ARRadio Daughter Card).

One solution is to use evaluation boards that include the RFIC and the necessary hardware elements for their operation.

This paper uses the ARRadio-HSMC card. This card can be coupled to an external handling device via the High-Speed Mezzanine Card (HSMC) interface and contains the AD9361 two-channel transceiver RFIC as its base element.

The processing stages in digital beamformers are characterized by their hybrid architecture (Yu, 2017). Digital Signal Processor and Field Programmable Gate Array (DSP and FPGA, respectively) predominate in digital beamforming performance. The selection of one or the other depends on the specific application being developed, although most literature on the subject favors the use of FPGA (Dikmese, Küçük, Şahin, & Tangel, 2010).

The AD9361 RFIC has two 12-bit data buses, through which interleaved transmission and reception (in baseband) signals from two transceivers circulate. It also has a control bus for communication management and a Serial Peripherical Interface (SPI) for configuring the system's operational parameters, such as frequency, bandwidth, sampling rate, etc. The ARRadio guarantees access to all these signals through the HSMC connector. The device used for digital data processing must be able to connect to this interface.

The need to use multiple acquisition cards and the associated control issues led to the selection of the TR4 Development Board. This board has six HSMC connectors for transceiver cards and features the EP4SGX230C2 FPGA from the Stratix IV family as its processing core.

System Architecture

Based on the selected reception and processing platform, the connection scheme shown in Figure 1 is proposed for the switched beam antenna system. This scheme includes four ARRadio-HSMC cards that are connected to the TR4 development board. These cards allow for the processing of signals from eight antennas to form multiple radiation patterns digitally.

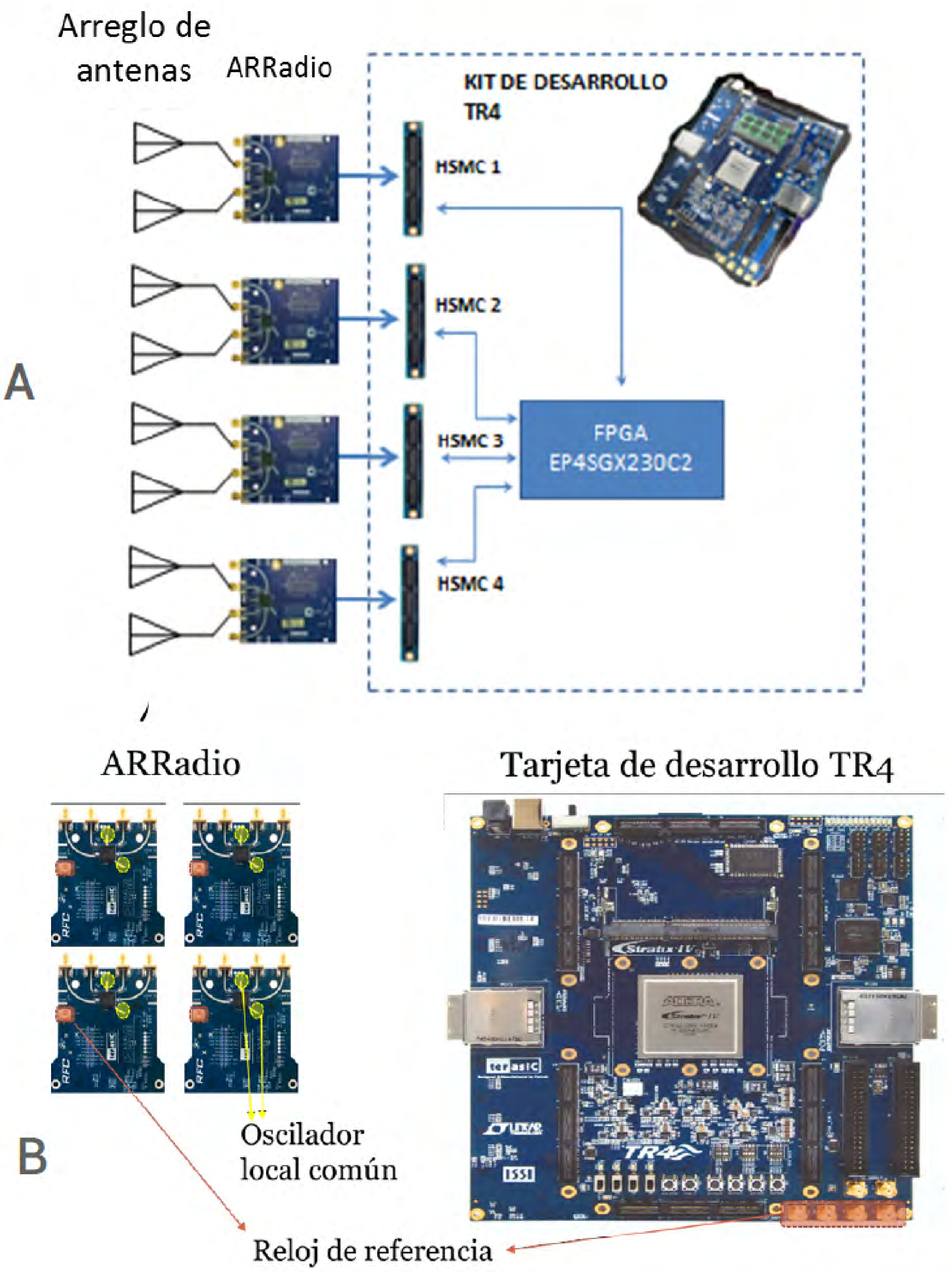


Figure 1. Diagram of the smart antenna array. a) Connection between the transceivers and the processing system. b) Connection of signals for multichannel coherence.

The image on the left shows the communication path between the integrated transceivers and the TR4 development board. The AD9361s are linked with the FPGA through the HSMC lines, where the bulk of processing takes place. The image on the right shows the points for connecting a local oscillator to ensure the radio frequency coherence of signals from each channel, as well as the clock distribution mode to guarantee baseband synchronization.

The FPGA fulfills three essential functions for the system. First, it configures the transceiver cards. Second, it ensures the correct reception and calibration of signals from the AD9361. Third, it performs digital synthesis of the seven digitally formed radiation patterns. Figure 2 shows the functional diagram displaying its key elements.

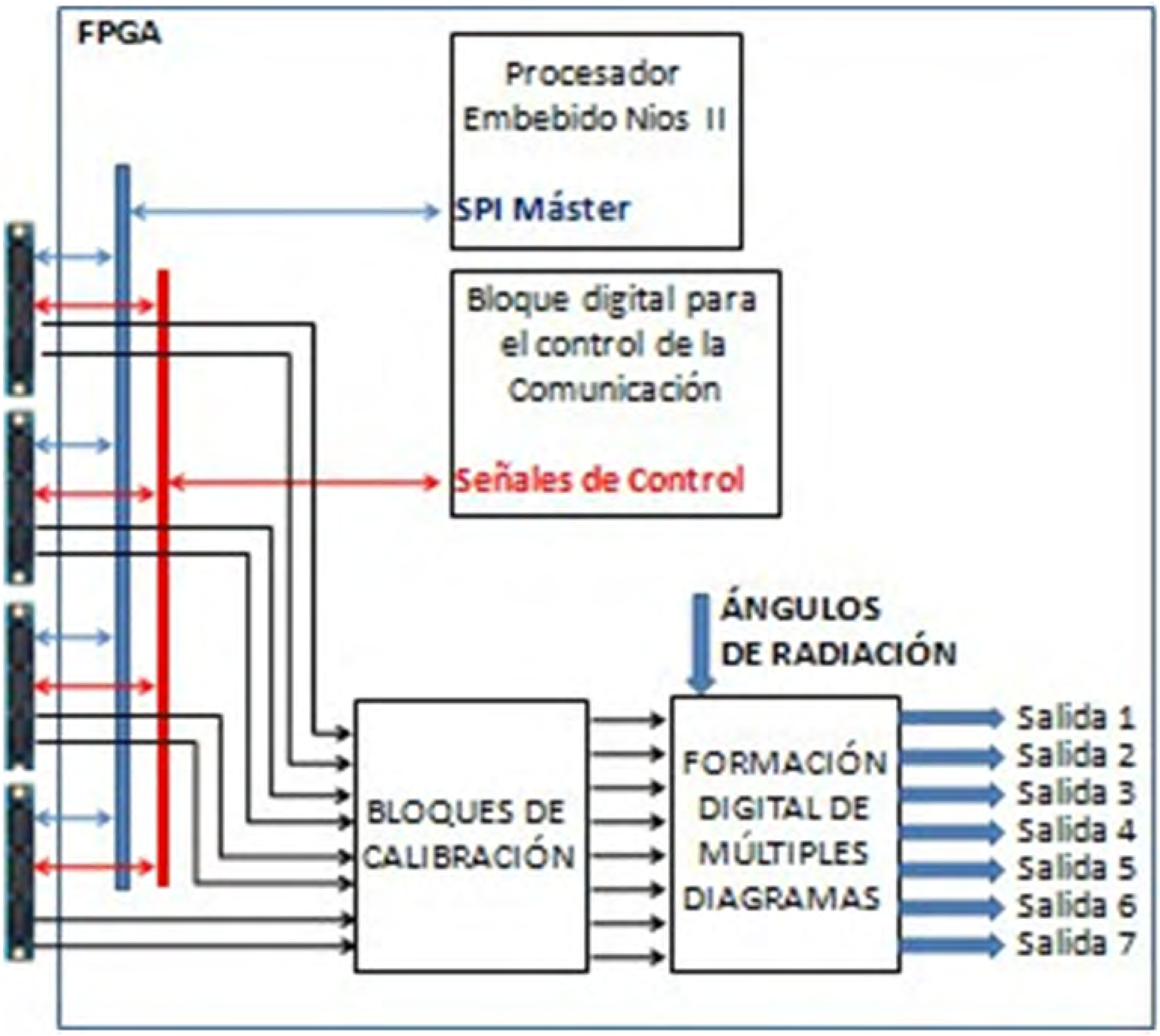


Figure 2. Functional diagram of the FPGA design.

The Softcore, developed by Altera NIOS II and embedded in the FPGA, is used to initialize the operational parameters of the AD9361. Through the SPI communication interface, the Softcore sends a configuration sequence that includes:

- Enablement of two receiver channels.
- Radio frequency receiver bandwidth configuration.
- Operating center frequency configuration.
- Signal sampling rate configuration.
- Internal digital filter programming.
- Manual gain configuration.
- Internal calibration of reception offset and I/Q channel balance.

The communication control logic is developed based on the communication protocol established by the AD9361 manufacturer. Based on the data sampling clock defined during initialization, the logic recovers the data from each channel, which are interleaved with the sequence I1, Q1, I2, Q2, where I and Q represent the in-phase and quadrature components of the signals, and the numbering indicates the transceiver channel.

The first processing block that the acquired signals pass through is the calibration block. This begins operating during system initialization, where it uses a reference signal generated by one of the transmitters and distributed to all receiving channels to determine the amplitude and phase differences between channels. To do this, it uses an algorithm based on the Fourier transform. Once the differences have been determined, the correction coefficients are calculated and applied continuously throughout system operation.

The calibrated signals are sent to the block where directional patterns are digitally formed. The block consists of seven similar subsystems, each of which is responsible for synthesizing a beam. The desired radiation directions are applied to each subsystem as appropriate. Weights for forming each beam are calculated using a conventional algorithm based solely on the input radiation direction (S. Venkata Rama Rao, 2019).

As a switching circuit, the simple scheme shown in figure 3 is proposed. In this configuration, a fixed directional pattern is established in the synthesized channels for sequential reading of each output. This configuration is useful when the data processing units following the antenna array cannot handle large amounts of information. The developed platform enables the implementation of complex processing architectures, such as adaptive systems or others, in which each beam operates independently and switches sequentially.

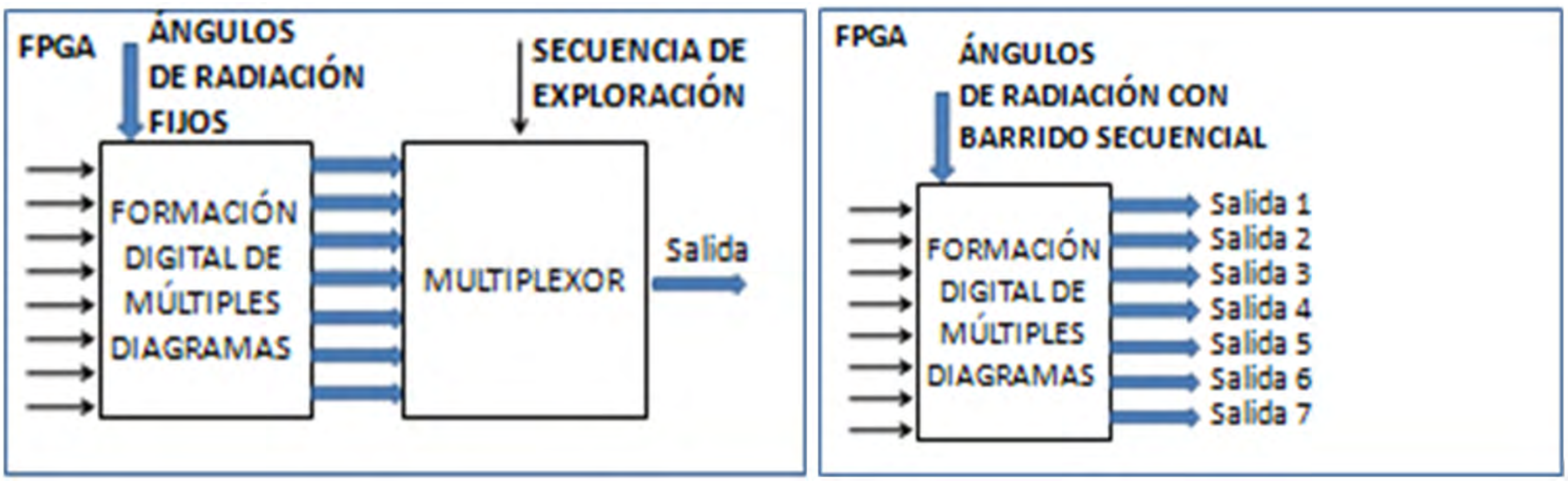
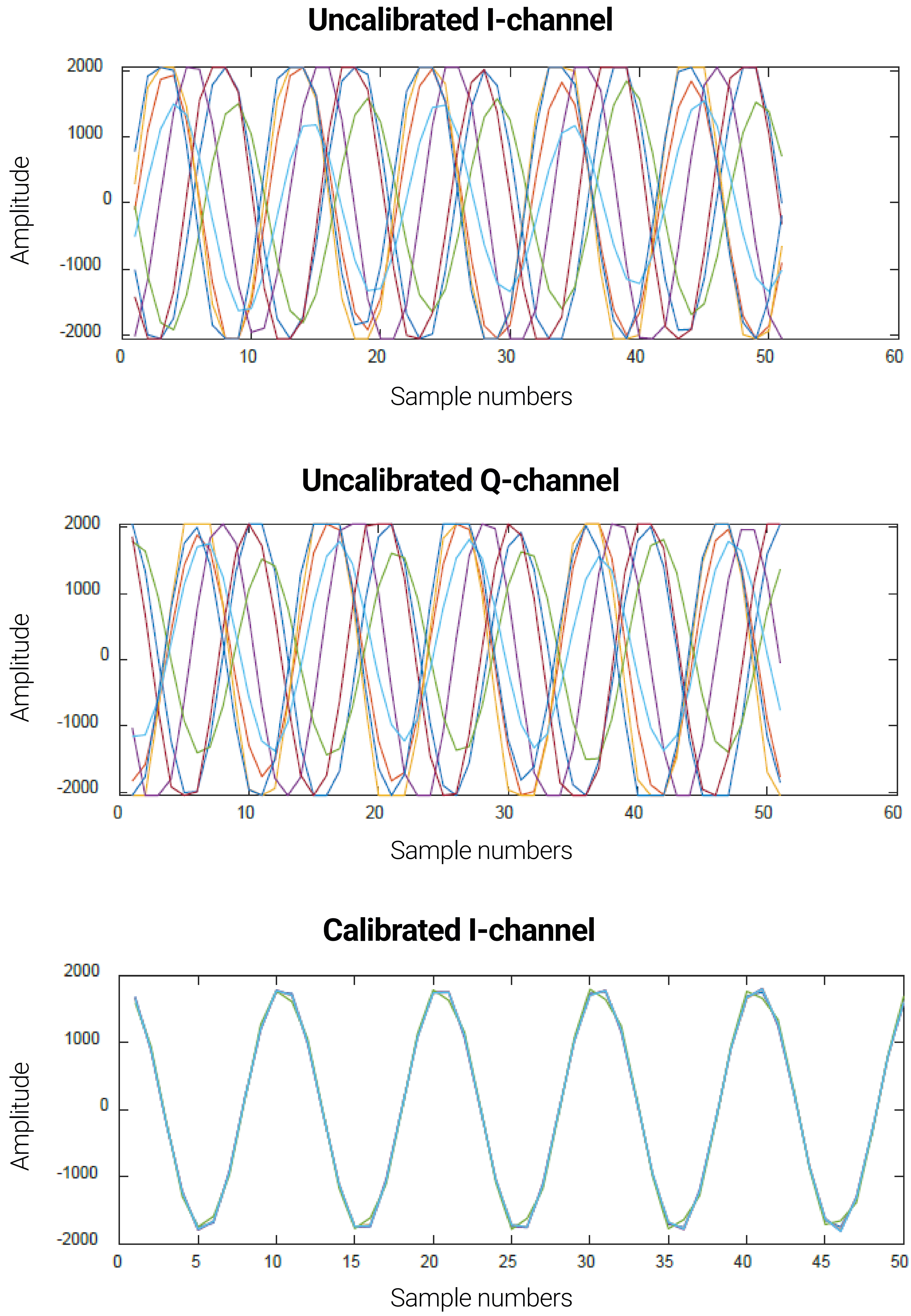


Figure 3. Beam switching system.

Discussion and Outcomes

The technology proposed in this paper for developing smart antennas with beam switching was validated to confirm its real capabilities for implementation. To do so, a verification system consisting of eight reception lines, each with an antenna separated by 0.6 times the operating wavelength, was used. Tests were performed at the frequency of 2.412 GHz, which corresponds to the first Wi-Fi access channel.

Calibration is a key to forming the correct directional pattern, so it was the first element checked. Figure 4 shows the in-phase and quadrature components of the signals received by the receivers before and after this process was performed.



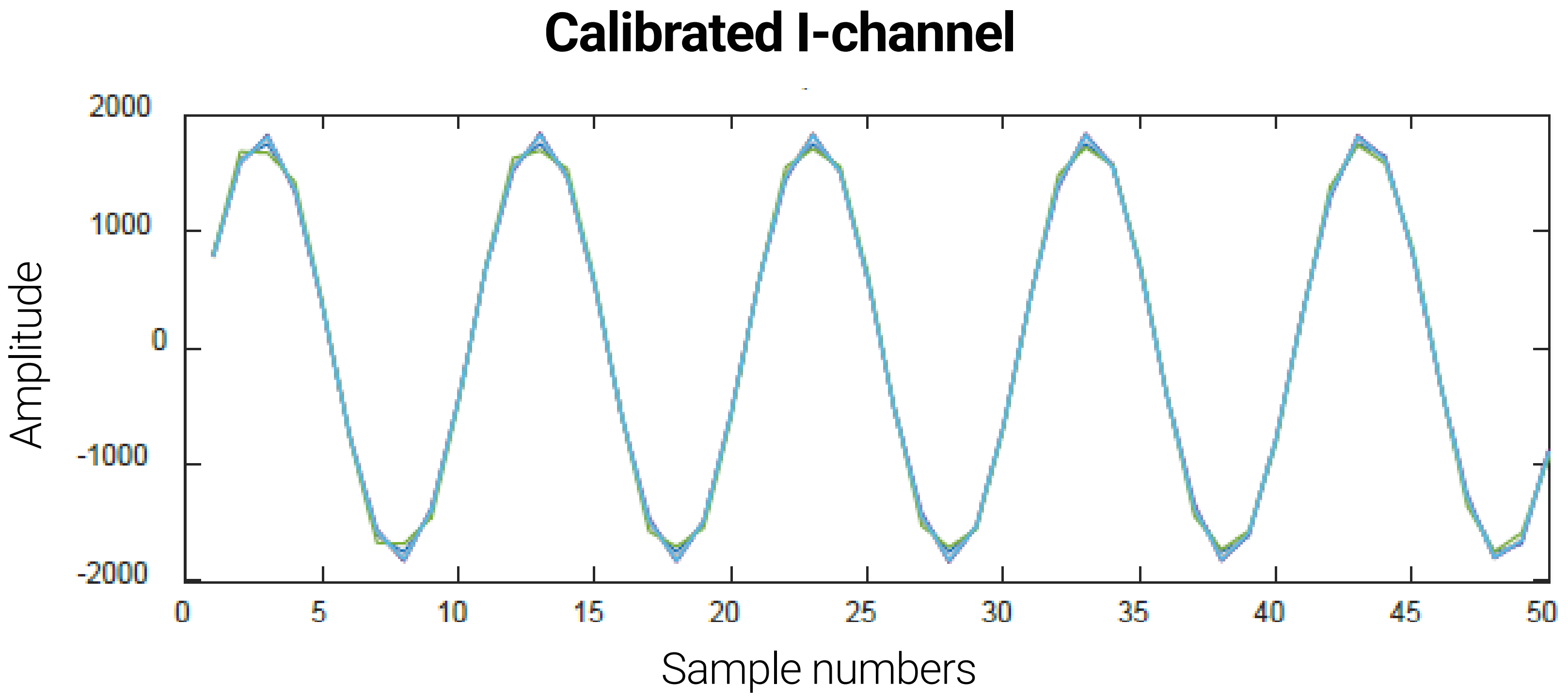


Figure 4. Signals received before and after calibration.

The alignment of the signal phase and the compensation of the amplitude differences between the channels can be seen. As a reference, a sinusoidal signal shifted 0.1 MHz from the center of the operating frequency was used.

To assess the calibration behavior between channels over time, 40 captures of the output signals were made, distributed in groups of 10 captures, separated from each other by one hour. This provided information during the first three hours of system operation after calibration (the first group of data corresponds to the moment when the weights were applied). The data were processed using the MALTAB computer tool, and the results are presented in Table 1.

Time (in minutes)	Standard deviation of absolute phase error (°)	Standard deviation of relative amplitude error (%)
0	0.0351 0.0621	0.0351 0.0621
60	0.1473	0.2828
120	0.6828 0.3594	0.6828 0.3594
180	0.7538	0.3971

Table 1. Behavior of amplitude and phase errors between channels after calibration.

The values in the table indicate an increased tendency for deviations after calibration. This is due to temperature variations in the transceiver system elements. Nevertheless, amplitude and phase errors remain small, even in the worst case. Therefore, radiation pattern formation can be guaranteed without introducing significant errors in the synthesized patterns (Mailloux, 2018).

Subsequently, the formation of the directional characteristic was verified using the measurement scheme shown in Figure 5. This check was performed in an anechoic chamber to emulate free-space conditions. The resulting signals from each beam were sent to a PC via a serial communication interface. A program developed for system verification is responsible for graphing the shape of the digitally synthesized directional pattern.

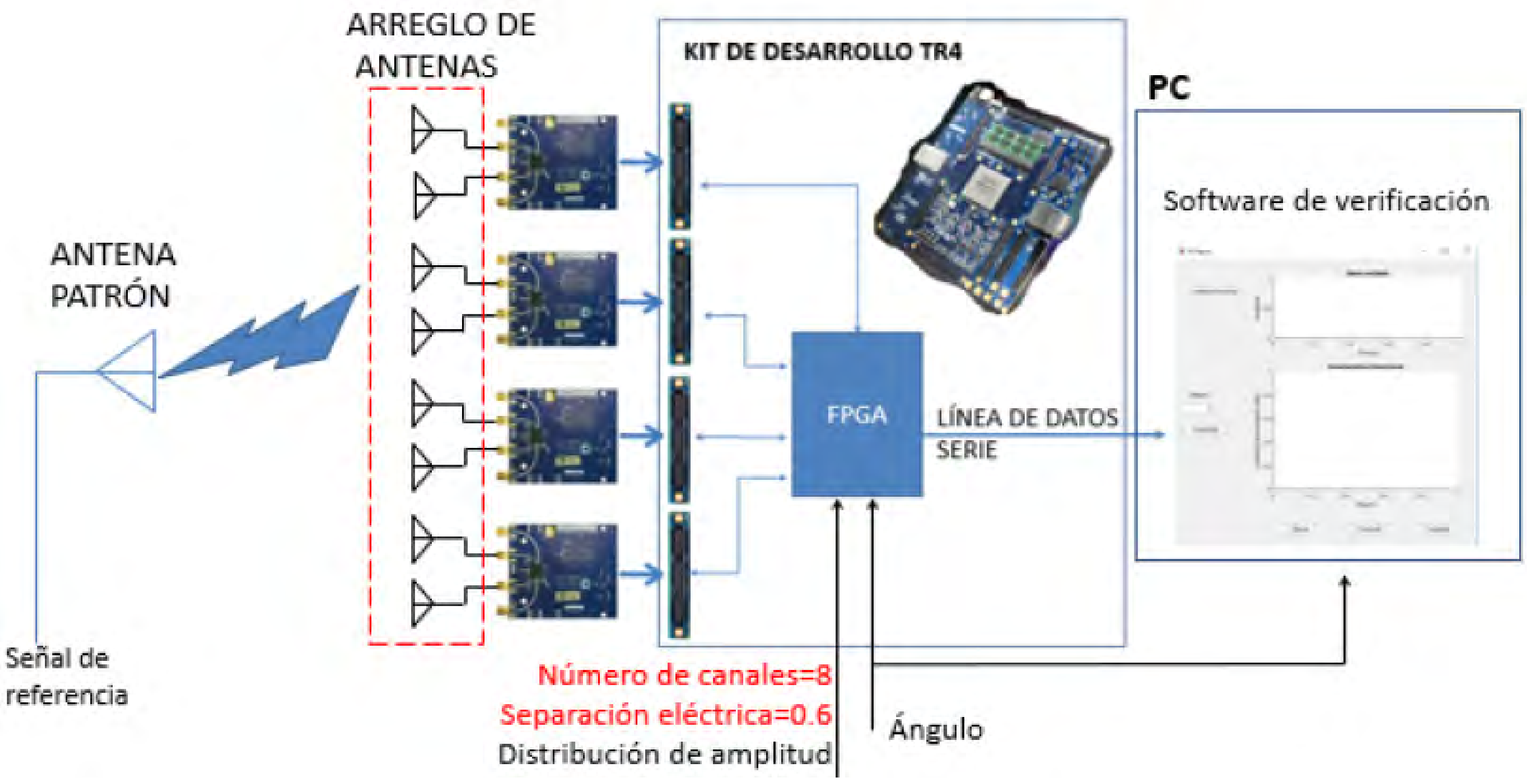


Figure 5. Diagram for measuring the directional characteristic.
As a result, the radiation patterns shown in figure 6 were obtained.

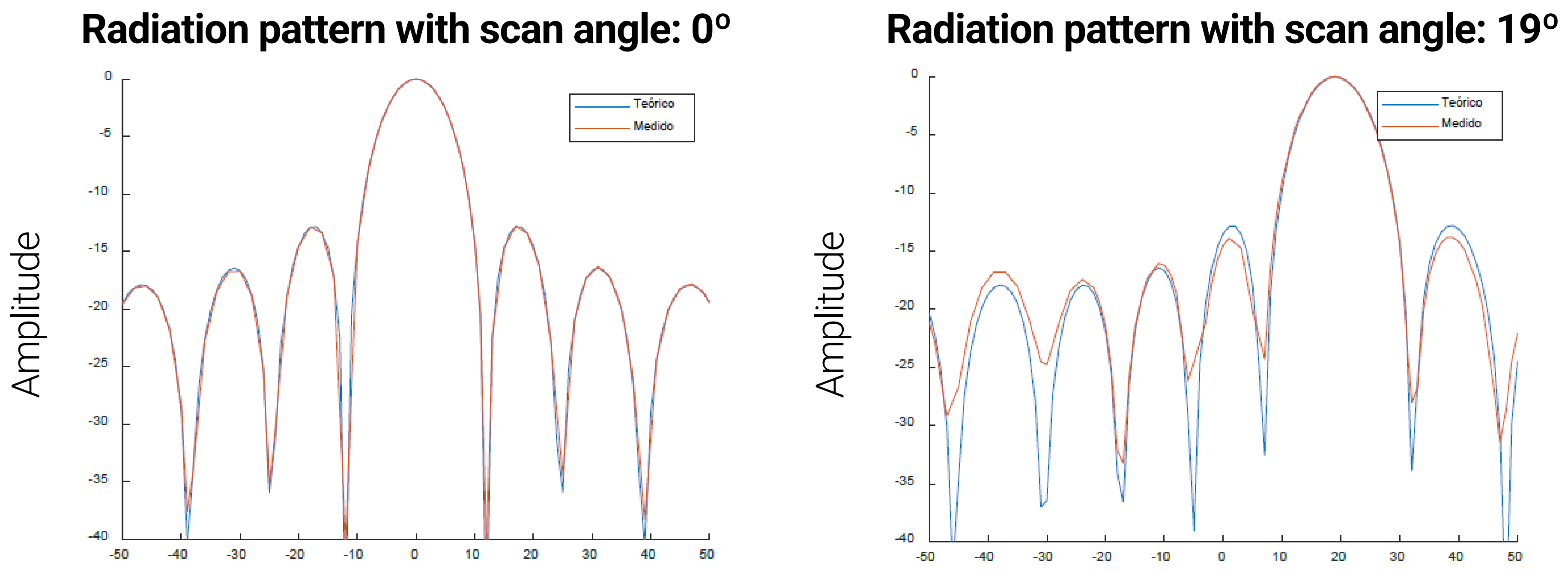


Figure 6. Radiation diagrams generated digitally Top: 0°, Bottom 19°

Figure 6 shows the measured and simulated diagrams for two channels of the switched beam antenna system. The two are correspondingly similar, with an absolute error of less than 1.5 dB in the level of the side lobes and 0.39° in the radiation angle. The key differences between the two are evident in the depth of the radiation nulls and are a direct consequence of the amplitude and phase errors present in the system. With the geometry used, employing seven directional patterns, it is possible to cover a scanning system of 100° for the switched beam antenna system, as shown in Figure 7.

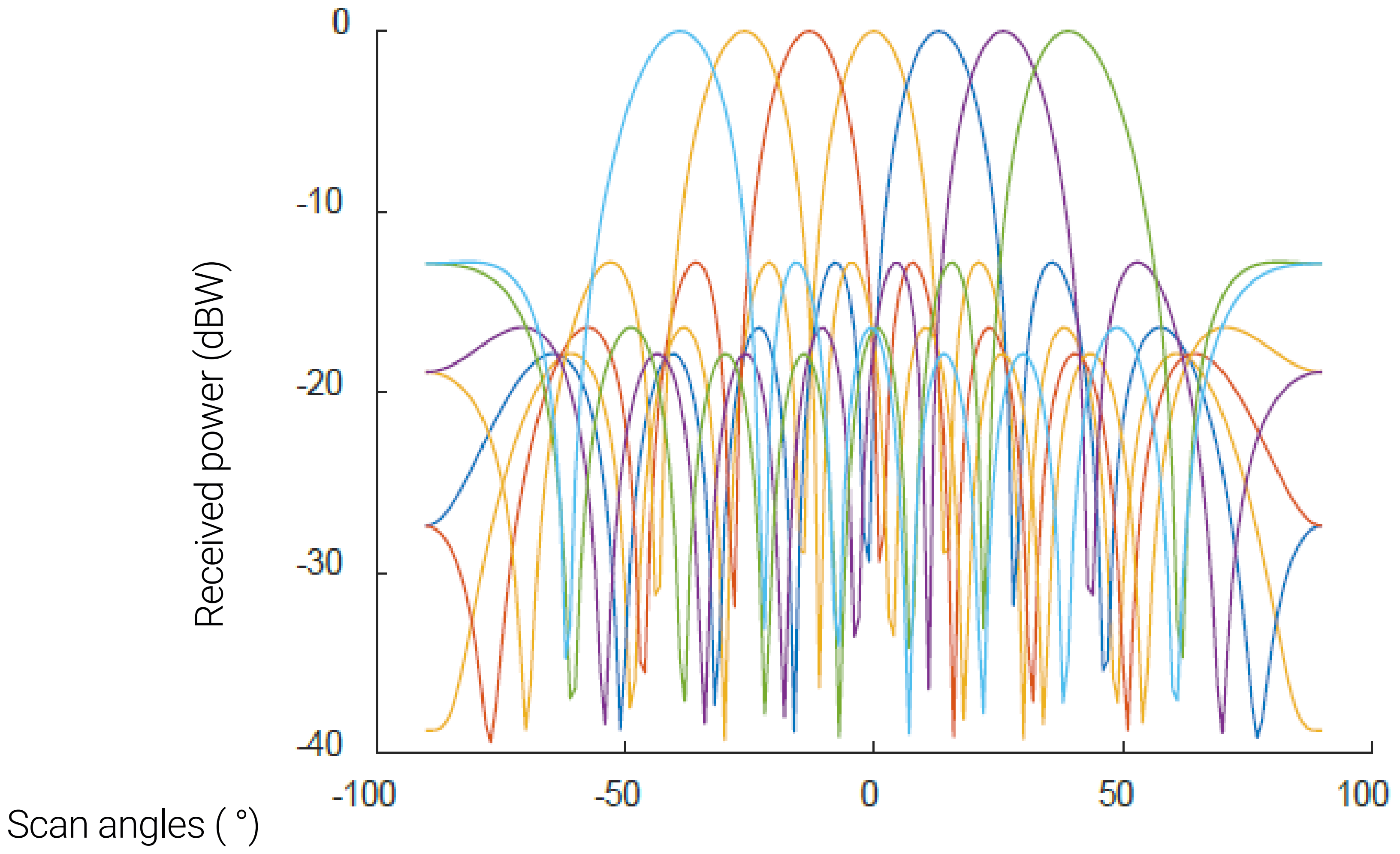


Figure 7. Directional characteristic of the system with multiple beams

Conclusions

The implemented system guarantees the formation of multiple, simultaneous, directional reception beams, making it suitable for use in a switched beam system. This paper presents the main technological elements that made its development possible. In addition to being applicable to smart antennas with beam switching, the proposed design architecture can adapt to complex antenna geometries. This is because forming the diagram with digital techniques only requires modifying the equation for determining the weights in the beamforming block. This same feature also enables the development of adaptive algorithms. These findings confirm the fulfillment of the objective proposed for the completion of the work.

The correct formation of the radiation pattern was verified in the performed measurements. The amplitude and phase errors measured in each reception channel were less than 0.3971% and 0.7538°, respectively. Consequently, the differences between the beams measured in the anechoic chamber and the simulated beams did not exceed 1.5 dB for the lower sidelobe level or 0.39° for the radiation angle.

Bibliographic references

Ahmed, T. H., Tiang, J. J., Mahmud, A., Gwo-Chin, C., & Do, D.-T. (2023). Evaluating the Performance of Proposed Switched Beam Antenna Systems in Dynamic V2V Communication Networks. SENSORS, 23(15), 1-20. doi:10.3390/s23156782

Almorabeti, S., Rifi, M., Terchoune, H., & Tizyi, H. (2018). Design and Implementation of a Switched Beam Smart Antenna For Wireless Power Transfer System at 5.8 GHz. *Paper presented at the 2018 Renewable Energies, Power Systems & Green Inclusive Economy* (REPS-GIE), Casablanca, Morocco.

Bailleul, P. K. (2016). *A New Era in Elemental Digital Beamforming for Spaceborne Communications Phased Arrays*. 104, 623-632. doi:10.1109/JPROC.2015.2511661

Chen, Z., & Haas, H. (2015). Space division multiple access in visible light communications. *Paper presented at the 2015 IEEE International Conference on Communications* (ICC), London, UK.

Delos, P. (2017). *Digital beamforming techniques for phased array system* [Webcast]. Retrieved from https://www.analog.com/en/education/education-library/webcasts/digital-beamforming-techniques-for-phased-array-system.html

Delos, P., Frick, C., & Jones, M. (2020). *Multichannel RF-to-Bits development Platform Enables Rapid Prototyping for Phased Arrays*. Retrieved from https://analog.com/en/design-notes/multichannel-to-bits-development-platform.html

Dikmese, S., Kucuk, K., Sahin, S., & Tangel, A. (2010). Digital signal processor against field programmable gate array implementations of space-code correlator beamformer for smart antennas. *IET Microwaves, Antennas & Propagation*, 4(5), 593–599.

HSMC ARRadio Daughter Car. Retrieved from https://www.terasic.com.tw/cgi-bin/page/archive.pl?Lenguage=English&CategoryNo=65&No=946&PartNo=1
Mailloux, R. J.(2018). Phased Array Antenna Handbook (3rd ed.): Artech House.

Ong, L. T. (2015). Adaptive Beamforming Algorithms for Cancellation of Multiple Interference Signals. *Progress In Electromagnetics Research*, 43(M), 109-118. doi:10.2528/PIERM15061202

Rodríguez, D. C., García, E., & Miller, R. B. (2017). Diseño e Implementación de un Beamformer Transmisor en una FPGA. 6. Retrieved from https://silo.tips/download/una-antena-tipica

Rosa, S. L., Supriyanto, E., Rahman, T. A., Rahim, S. K. A., & Moradikordalivand,

A. (2014). *Switched Beam Smart Antenna for Wireless Local Area Network. Paper presented at the International Conference on Electrical Engineering, Computer Science and Informatics (EECSI 2014)*, Yogyakarta, Indonesia.

S. Venkata Rama Rao, A. M. P., Ch. Santhi Rami. (2019). Antenna Array Weight Synthesis for Low Side Lobe Levels using Window Functions. *International Journal of Engineering and Advanced Technology*, 9(1), 8. doi:10.35940/ijeat.A1664.109119

Settawit Poochaya, P. U. (2016). Beam Tracking in Switched-Beam Antenna System for V2V Communication. International Journal of Antennas and Propagation, 2016(Special), 1-13. doi: http://dx.doi.org/10.1155/2016/4169619

Sharma, B., Sarkar, I., Maity, T., & Bhattacharya, P. P. (2014). An introduction to smart antenna system. *International Journal of Business and Engineering Research*, 8(11).

Stincer, E. P. (2001). *Antenas. Teoría general*. La Habana: ITM.

Yu, X. (2017). *Digital signal processor based real-time phased array radar backend system and optimization algorithms*. (Doctor of Philosophy). University of Oklahoma, Norman, Oklahoma. Retrieved from https://shareok.org/handle/11244/52417

Zhai, M. (2017). Smart Antenna Technology in Mobile Communication and Its Research Progress. *Paper presented at the International Conference on Computer Technology, Electronics and Communication (ICCTEC)*, Sanya, China.

Wireless Control of Heavy Rotating Platforms Based on Arduino and XBee Modules

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Abstract

This paper presents a system-based structure embedded for wireless control of heavy dual-degree-of-freedom rotating platforms. The design of a controller is proposed to allow remote access of operators through an XBee-based communication system, facilitating real-time automatic parameter adjustments. The wireless connection between the controller and the platform is established using an Arduino Leonardo board, eliminating dependence on Wi-Fi or TCP/IP protocols to enhance system robustness in industrial environments. The obtained results in a lab environment prove reliable platform control at distances up to 50 meters. Additionally, the link range can be increased by adding directional antennas compatible with the system hardware, optimizing remote control performance and reliability.

Keywords: Remote control; Arduino; XBee; Rotating platforms

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Introduction

Rotating platforms are used in a variety of applications such as communications, material handling, and cargo transport. These systems are currently limited by operational difficulties related to wired support, given the high installation costs, fragility of the environment, and inability to adapt to environmental changes. With the emergence of new technologies and the development of wireless devices, it is relatively easy to deploy them in environments where physical lines are a potential barrier. A viable solution to ensure remote control is the transmission of the control signal via radio frequency (RF) (Bernabé et al., 2024), being an affordable variant, those based on XBee from Digi International.

Novel researches apply the abovementioned modules in this field; some of them use it to check parameters in storage facilities through wireless RF chips and Zigbee protocol stacks (Wang, 2011). Ambikabhuvaneswari (2018) tracks e-bikes and retrieves information using LoRa and the XBee module. Another research (Adewasti *et al.*, 2018) deals with the development of a human-machine interface in LabVIEW so as to control a robot and observe the results of various environmental factors, such as temperature measurement, the presence of toxic gases, human presence detection, and can also transmit real-time video of that particular location wirelessly. The design development of a robot control system to monitor earthquake locations using Arduino based on XBee Pro is evidenced in (Shahzad *et al.*, 2017).

XBee Latency analysis with good results in the control of drone-mounted machines through remote channels is developed in XBee latency analysis for drone-mounted machine control over wireless communication channels (Sit *et al.*, 2021). Another study that evidences the reliability of XBee is (Gavra *et al.*, 2023), where an analysis of the characteristics of the mesh network topology is proposed to verify the range extension and how it affects the signal strength indicator and performance. The implementation of an unmanned vehicle system based on this technology is addressed in

(Karyemsetty *et al.*, 2015) and proves that it is possible to monitor the vehicle's travel route on Google Maps using the latitude and longitude transmitted by the GPS receiver. In maritime positioning systems (San Filippo, 2015), node positioning algorithms are applied to track and identify operational movements onboard the vessel. The engine control and observation of its parameters is found in (Floriduz *et al.*, 2015) with the description of a wireless temperature measurement system, intended for thermal analysis of rotating parts of electrical machines. The device was designed and manufactured to be installed on machines with a consumption less than 15 kW.

The abovementioned researches corroborate that XBee in combination with a programmable logic device can guarantee good quality in the wireless link. Furthermore, the reviewed studies show the advantage of implementing remote control solutions in areas or systems where the deployment of physical lines is complicated. This paper proposes a solution that uses an Arduino Leonardo board and an XBee S1 module as technical support (Hongyim, 2017). It consists of developing a wireless controller to increase the platform control range. The advantage lies in obtaining a system with the possibility of improving its performance regarding the parameters being tested and the accessibility without the need for wired support. The use of the TCP/IP protocol offers scalability, stability, security, and interconnection between different networks and devices (Hongyim, 2019). Due to its operating principle, the proposed wireless control is an option for IoT applications.

Materials and Methods

To achieve the established objectives, a market analysis was carried out focused on identifying the most accessible technologies from an economic and documentary perspective. A systemic analytical method was applied to extract key elements from the reviewed literature in order to develop a proposal that fits the system's needs. Given the existing technological restrictions in the country, particularly in the manufacture of printed circuits and the importation of electronic components, it was decided to choose for the use of open-source hardware and software as much as possible. This choice not only reduces associated costs but also promotes the sustainability and adaptability of the proposed system.

General System Structure

This paper proposes the implementation of a system with the structure shown in Figure 1. Its definition starts from the need to achieve remote communication between the control center and the platform. As can be seen, the actuator mechanism is equipped with an external control element composed of an Arduino Leonardo board and an XBee module, to guarantee the wireless connection. The control board is connected via a radio frequency link in the 2.4 GHz band to the management and control server which can be a desktop PC or mobile handset.

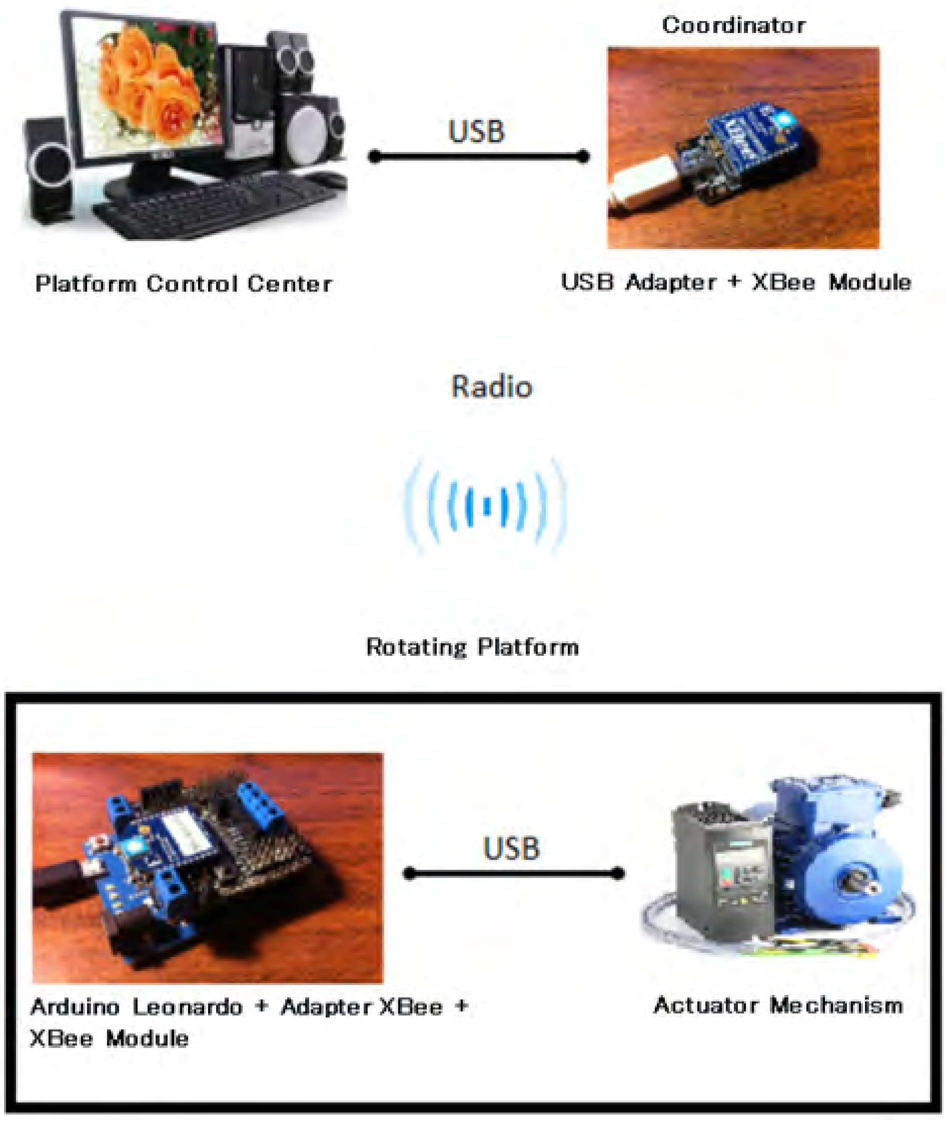

Figure 1. Block diagram of the proposed control system

The programmable controller is developed under the premise of using open hardware, which implies that the designs and specifications are publicly accessible. This characteristic allows the creation of the system at a reduced cost and promotes collaboration and innovation in the design of automated systems. To guarantee its functionality, the controller must include input interfaces that allow the connection of external devices, as well as the ability to integrate wireless modules.

The coupling elements are fundamental to adapt the controller to various industrial applications and facilitate its interaction with other systems.

Regarding the actuator mechanism of the rotating platform, it consists of a frequency drive (VFD). This device is crucial to carry out the conversion between the control signal (0 V - 10 V) and the voltage/current levels required by the alternating current motor (ACM), which is equipped with an encoder. The use of the VFD allows a precise control over the speed and motor torque, thus optimizing system performance (Matondang & Adityawarman, 2018).

Selected Hardware

During the component selection process for the design, the requirements established in the general system structure were considered. The use of Arduino as the main device is determined by competitive acquisition costs, ease of programming, and versatility in input interfaces, compared to other alternatives such as FPGA, PIC, or other microcontrollers. This choice is based on the need for an accessible and adaptable development environment that satisfies the specific project requirements.

Arduino Leonardo Development Board

The Arduino Leonardo, shown in Figure 2, is a development board distinguished by integrating an ATmega32U4 microcontroller, which has original USB capabilities. This characteristic allows the Leonardo to communicate directly with a computer, facilitating to emulate devices such as keyboards or peripherals through the USB-HID protocol (Penttinen, 2013). The board has 20 digital input/output pins, of which 7 are used as PWM outputs and 12 as analog inputs. Its crystal oscillator operates at a frequency of 16 MHz, ensuring adequate performance for various applications. Furthermore, it has 32 KB of flash memory for program storage, as well as a micro USB connector that simplifies connection and power supply.

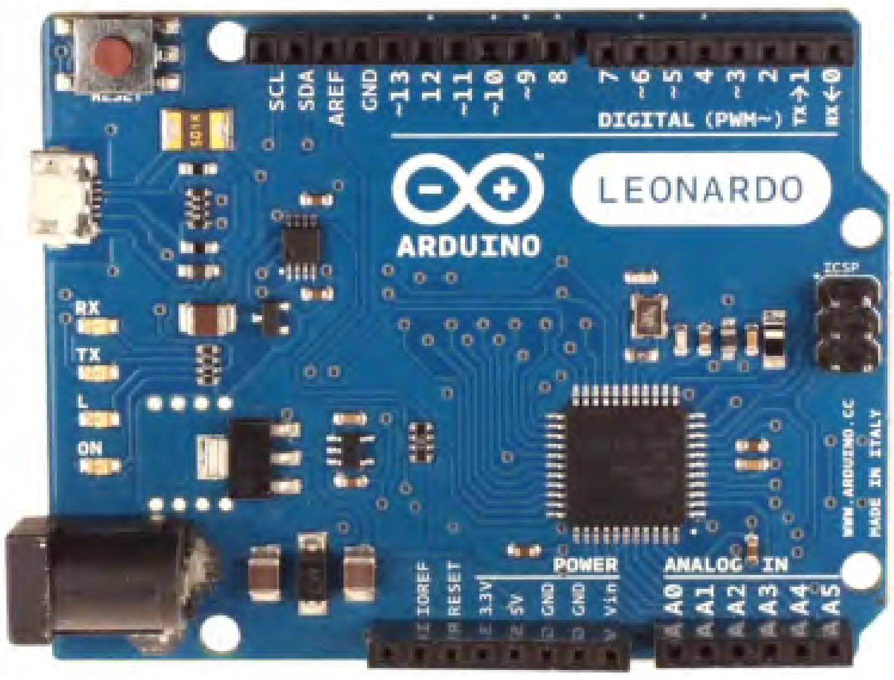

Figure 2. Arduino Leonardo Development Board

XBee S1 Module

The XBee S1 module, shown in Figure 3, is a wireless communication device designed for applications requiring connectivity in personal area networks. It operates in the 2.4 GHz ISM frequency band and uses the 802.15.4 protocol (Weatley, 2018), allowing low energy consumption and low latency connections. It provides a transmission power of 1 mW (0 dBm), achieving a range of up to 100 meters under direct visibility conditions, making it suitable to be implemented in industrial and urban environments. It is characterized by its ability to operate in an industrial temperature range, from -40°C to 85°C, guaranteeing its functionality in various environmental conditions. The module interface allows a data rate of up to 115.2 Kbps, facilitating efficient information transmission between devices. Furthermore, its compact design and variety of antenna options, including embedded antennas and connectors for external antennas, provide flexibility in system implementation.

Figure 3. Wireless Module Used

Wireless Controller Programming

The link programming was performed using the Arduino integrated development environment (IDE) in its version 1.8.2, which provides an accessible and versatile environment to develop applications based on microcontrollers. The network connection establishment is carried out via the XBee and XBee Arduino Library, which are fundamental to simplify the remote automation implementation, remote control, and the collection of relevant data about the surrounding environment.

The XBee library provides support for API mode, which enables the transmission of structured data and the handling of AT commands (Wang & Tang, 2011), in addition to allowing dynamic configuration of module parameters. This is particularly useful in applications where precise control over connected devices and effective network management is required. Moreover, it simplifies the programming of the wireless link, but also allows users to implement advanced features such as power management in battery-powered devices, which is crucial to lengthen the system lifecycle. The wireless link programming algorithm is shows in Figure 4.

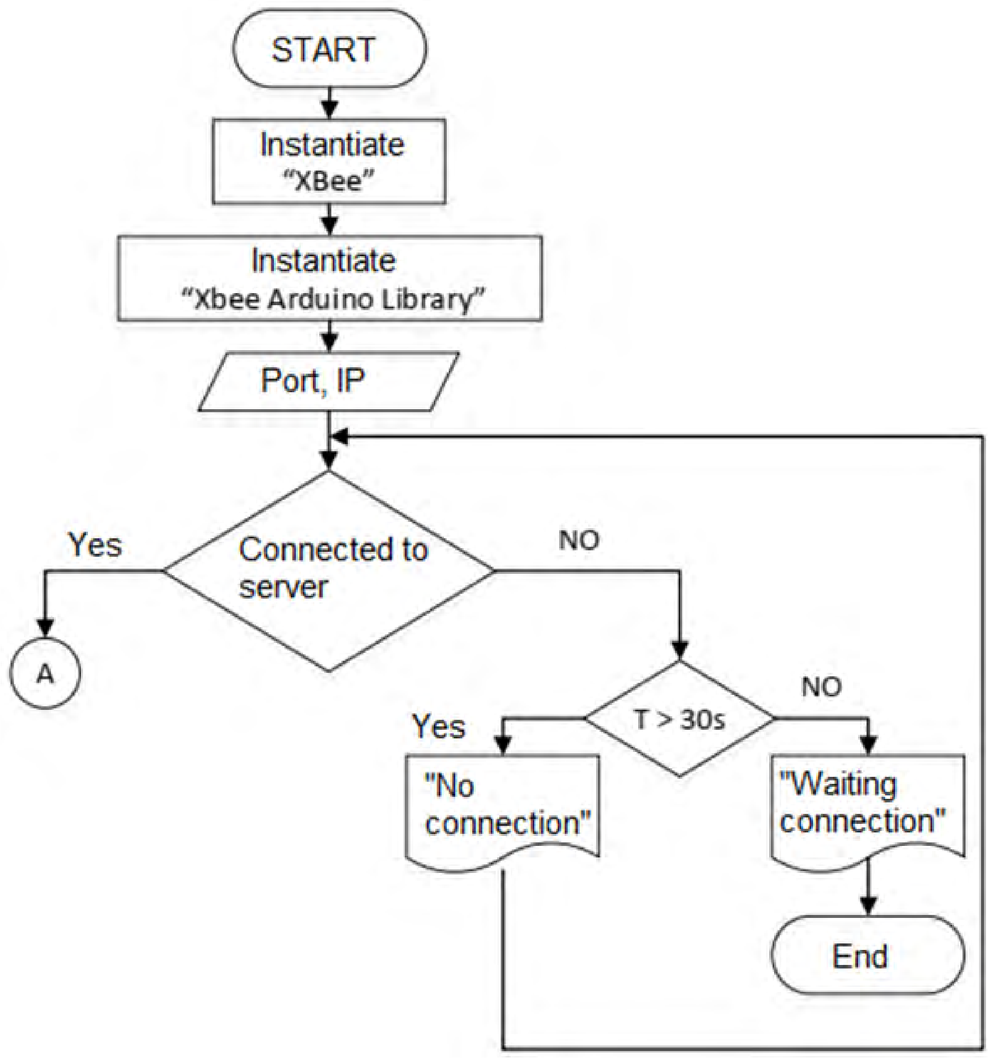

Figure 4. Wireless Link Programming Algorithm

Management and Control Application

In the development of the management and control application was taken into account the possibility of wireless connection via

WiFi or wired over Ethernet, as well as cross-platform with the aim of installing it both from a desktop computer with Windows OS® or Linux operating system, and on mobile devices with Android operating system. That is why, the QtCreator5.7 framework (Qt Creator, n.d.) was selected. This research is limited to describing only the application development process in Windows ® and Android, differing only by the inclusion of the corresponding compilation tools. In (Touil *et al.*, 2020), the relevant configurations in the framework options to perform the compilation for the Android operating system are explained.

Considering the hardware architecture, the client-server model was used for application programming, where the Arduino Leonardo board operates as the client and the management and control software is the server. The protocol used in the transport layer of the architecture was TCP, as being connection-oriented, it provides a reliable means for bitstream between applications (Penttinen, 2013). Considering that large volumes of data will not be transmitted, the package delivery will not imply a significant delay. For server development, the QTcpServer and QTcpSocket libraries were used. The proposed programming algorithm is shown in Figure 5.

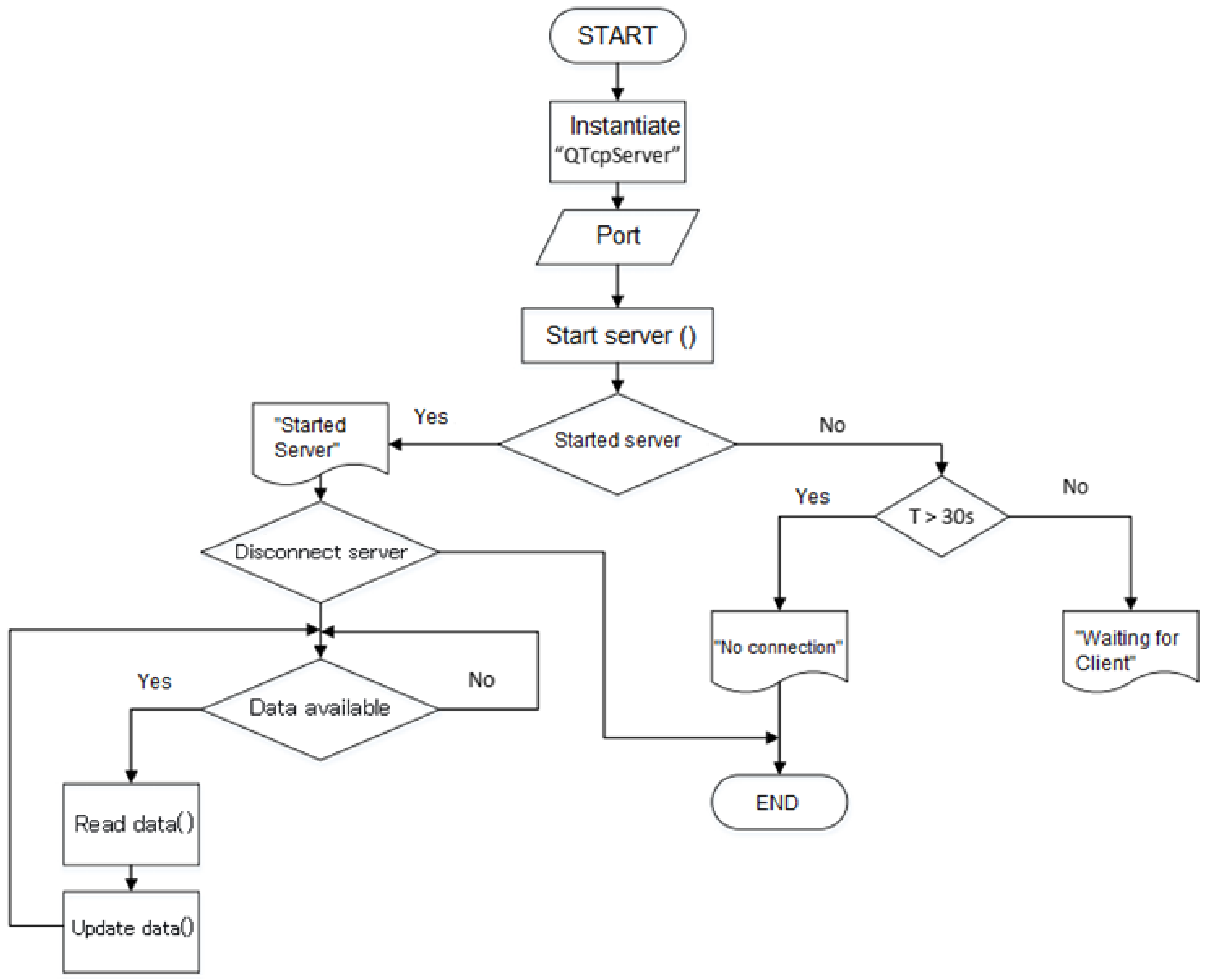

Figure 5. Programming Algorithm implemented in QtCreator

Control Technique Implementation

The implemented control technique is a PID controller - Proportional, Integral and Derivative - which is based on the regulation of proportional, integral and derivative parameters to manage system dynamics. This approach allows an effective response to variations in the reference signal, ensuring precise control over the process. The digital system design is carried out using the multidomain simulation platform Simulink, proprietary to MATLAB. This tool offers a set of libraries that allow the model to be exported to C language, enabling its implementation in embedded environments. The resulting scheme for validation is shown in Figure 6.

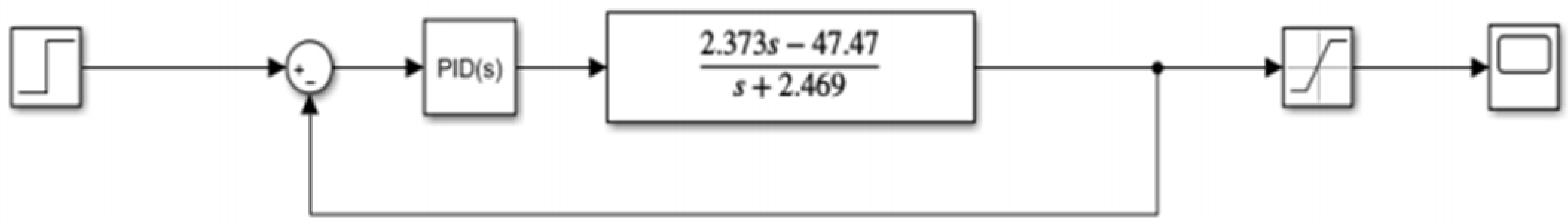

Figure 6. Simulink Scheme of the PID Controller

The system introduces the PID controller parameters to calculate the proportional, integral and derivative components of the error. This allows generating the control signal applied to the analog input of the frequency drive. The programming algorithm in Arduino corresponding to the PID controller is shown in Figure 7.

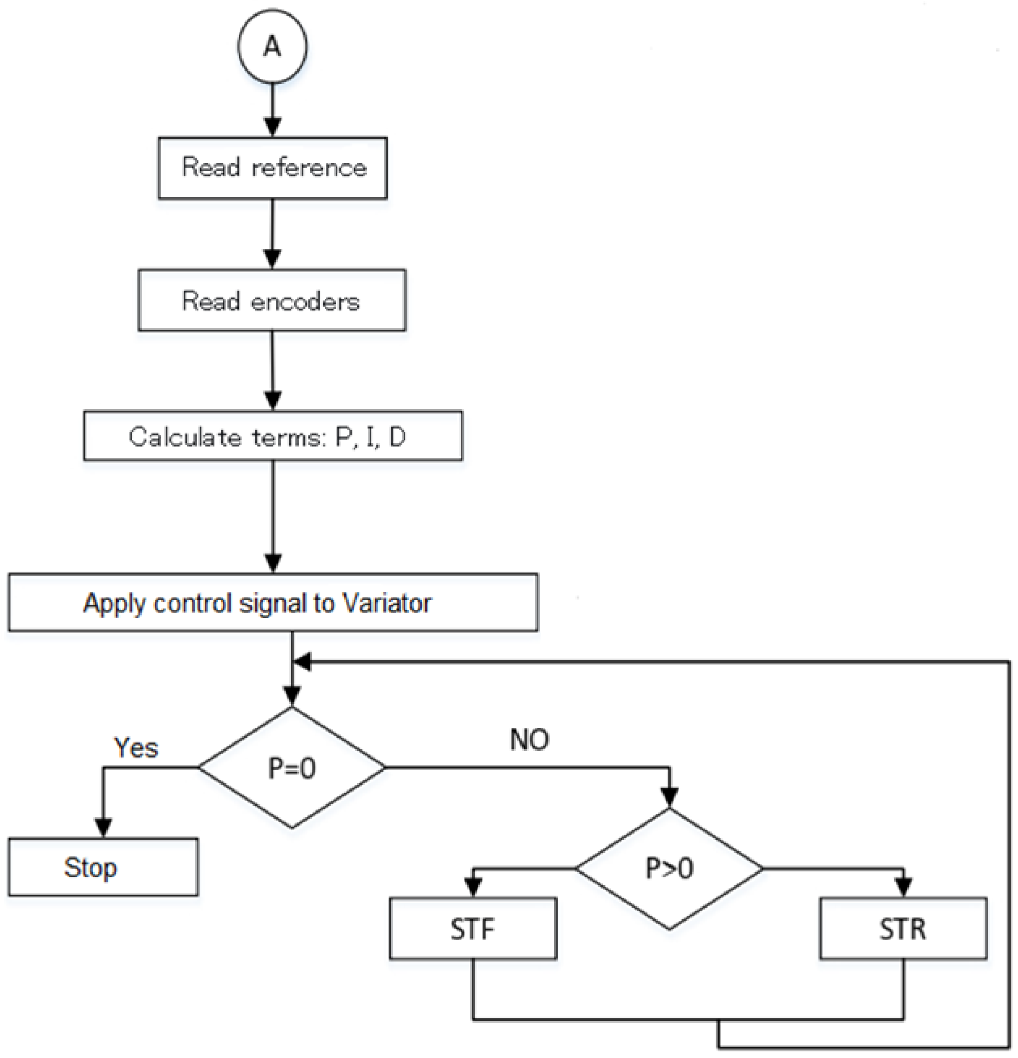

Figure 7. PID Controller Programming Algorithm

Results and Discussion

For the development of the experimental tests, the scheme shown in Figure 8 was designed. The sending of the data frame coming from the management and control server is performed at a frequency of 2.4 GHz. For the digital to analog conversion of the error signal, an AD 5626 converter with communication via Serial Peripheral Interface (SPI) and 12-bit resolution was used.

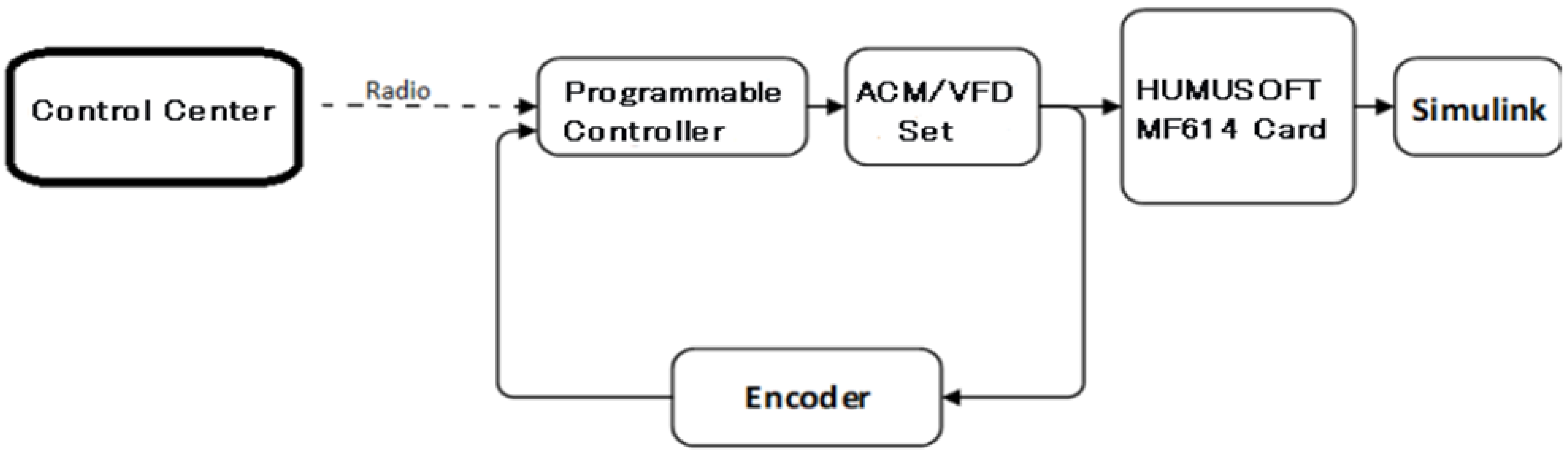

Figure 8. Wireless Controller Verification Scheme

The equipment used, in addition to the implemented controller, are listed below:

- Frequency drive and reference FR-A722 from Mitsubishi brand.
- Three-phase induction engine with 3 horsepower and nominal speed of 1500 rpm from ECCHOP brand.
- Incremental encoder with 12-bit resolution from DENMARK brand.
- HUMUSOFT MF614 acquisition card (Touil et al., 2020) to, via Real Time Target toolbox from MATLAB, check in Simulink the system output signal.
- PC with AMD E-300 Dual Core CPU 1.30 GHz processor, WINDOWS 10 PRO 64-bit operating system, 6 GB of RAM.

In the wireless connection, key parameters in link characterization are: the received power, the antenna gain, and the environmental noise level (Hongyim, 2019). Therefore, the system performance was assessed at different distances, using the antenna integrated into the wireless module. Table 1 shows the dependence of the received power against the distance to the server access point.

Distance (m)	Power (dBm)	Frequency (GHz)	Gain (dBi)
1	-35	2.4	10
5	-40	2.4	9
10	-45	2.4	7
20	-50	2.4	6
30	-55	2.4	5
40	-60	2.4	3
50	-70	2.4	2
55	-75	2.4	1

Table 1. Dependence of the received power on the distance

It can be noted that for distances greater than 50 meters the received power is significantly reduced, making the connection unstable. This measurement allows determining the maximum distance at which the control point can be located using the embedded access point. To improve the obtained results, a higher version of the wireless module can be used or add antennas with greater use of transmitted power.

A comparison was made of the results achieved on the platform with incorporated PID with the values established by the manufacturer in the original system manual. Measuring instruments used are the equipment's own parameter indicators. The obtained results are shown in Table 2.

Parameter	System	Measurement Plane	
		Horizontal	Vertical
Load Power (W)	Original	1200 ±500	1100 ±500
	With wireless control	1150	970
Dynamic Error (min)	Original	20±2	15±2
	With wireless control	18	13
Maximum Speed (rpm)	Original	1500 ±200	500 ±100
	With wireless control	1400	450
Full Rotation Time(s)	Original	20±5	12±5
	With wireless control	18	10

Table 2. Obtained Results

With the calculated value, an average of 1050 W of power necessary for the induction asynchronous motor was obtained, which describes the support capacity of the set combined by the alternating current motor and the frequency drive used, since they exceed that figure. The performance of the heavy platform was assessed, obtaining an improvement in compliance with the parameters established by the original system manufacturer, which corroborates that replacing the wired connection does not affect the platform control and increases the system capacity.

Conclusions

The results obtained show the fulfillment of the research objective by achieving the implementation of a wireless control system to ensure the control of a heavy rotating platform based on Xbee. Through the use of open hardware and software, high technological independence is achieved, lowering manufacturing costs. The adopted configuration allows above all flexibility and scalability, making its deployment possible in areas where a wired connection is impossible, as well as the addition of new nodes without significantly impacting the original design.

Even though the tests are satisfactory, if control distances greater than 50 meters are required, it is necessary to use another XBee module such as the PRO version or add a directional antenna to the RF connector embedded on the board.

Bibliographic references

Adewasti, R., Febriani, R., Sholihin, E., Susanti, E., & Hesti, E. (2018). XBee Pro module application in organizing and monitoring earthquake disaster location with the robot control system. *International Conference on Information and Communications Technology* (ICOIACT) (pp. 651-655). IEEE. https://doi.org/10.1109/ICOIACT.2018.8350811

Ambikabhuvaneswari, C., & Muthumari, M. (2018). Design and realization of radio communication using LoRa & XBee module for an e-Bike. *IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)* (pp. 1-4). IEEE. https://doi.org/10.1109/ICCIC.2018.8782420

Bernabé, P., Gotlieb, A., Legeard, B., Marijan, D., Sem-Jacobsen, F. O., & Spieker, H. (2024). Detecting intentional AIS shutdown in open sea maritime surveillance using self-supervised deep learning. *IEEE Transactions on Intelligent Transportation Systems*, 25(2), 1166–1177. https://doi.org/10.1109/TITS.2023.3322690

Floriduz, A., Bassi, E., Benzi, F., Secondo, G., & Termini, P. S. (2015). Wireless temperature sensing in electrical motors with XBee modules. *IEEE Workshop on Electrical Machines Design, Control and Diagnosis (WEMDCD)* (pp. 304-308). IEEE. https://doi.org/10.1109/WEMDCD.2015.7194544

Gavra, V.-D., Pop, O. A., & Dobra, I.-M. (2023). Performance analysis of XBee modules in a mesh network. *46th International Spring Seminar on Electronics Technology (ISSE)* (pp. 1-4). IEEE. https://doi.org/10.1109/ISSE57496.2023.10168505

Hongyim, N. (2019). Designing and implementation wildlife tracking system using APRS protocol. *5th International Conference on Engineering, Applied Sciences and Technology (ICEAST)* (pp. 1-4). IEEE. https://doi.org/10.1109/ICEAST.2019.8802541

Hongyim, N., & Mithata, S. (2017). Designing and implementation exploration vehicle remote controller using APRS protocol. *21st International Computer Science and Engineering Conference (ICSEC)* (pp. 1-5). IEEE. https://doi.org/10.1109/ICSEC.2017.8443845

Karyemsetty, N., Samatha, B., & Rao, K. H. (2015). Diseño e implementación de un sistema de seguimiento de vehículos en VANETs utilizando XBee Pro: Modelo prototipo. *Conferencia Internacional sobre Redes de Comunicación* (ICCN) (pp. 97-100). IEEE. https://doi.org/10.1109/ICCN.2015.20

Matondang, J., & Adityawarman, Y. (2018). Implementation of APRS network using LoRa modulation based KISS TNC. *International Conference on Radar, Antenna, Microwave, Electronics, and Telecommunications (ICRAMET)* (pp. 37-40). IEEE. https://doi.org/10.1109/ICRAMET.2018.8683928

Penttinen, J. T. J. (2013). Modulation and demodulation. En J. T. J. Penttinen (Ed.), *The telecommunications handbook: Engineering guidelines for fixed, mobile and satellite systems* (pp. 261-280). Wiley. https://doi.org/10.1002/9781118678916.ch10

Qt Creator (Versión 5.7) [Software]. (s. f.). *The Qt Company*. https://www.qt.io/download-qt-installer

Sanfilippo, F., & Pettersen, K. Y. (2015). XBee positioning system with embedded haptic feedback for dangerous offshore operations: A preliminary study. *OCEANS 2015-Genova* (pp. 1-6). IEEE. https://doi.org/10.1109/OCEANS-Genova.2015.7271241

Shahzad, M. U., Khan, A. Q., Bukhari, S. M. R., Aslam, A., & Zaib, M. O. (2017). Wireless control robot using XBee module with multiple sensor acknowledgment on HMI. *International Symposium on Recent Advances in Electrical Engineering* (RAEE) (pp. 1-4). IEEE. https://doi.org/10.1109/RAEE.2017.8246034

Si, D., Edwards, R. M., & Geng, Y. (2021). XBee latency analysis for drone mounted machine control over wireless communication channels. *15th European Conference on Antennas and Propagation (EuCAP)* (pp. 1-4). IEEE. https://doi. org/10.23919/EuCAP51087.2021.9411478

Touil, H., Akkad, N. E., & Satori, K. (2020). Text encryption: Hybrid cryptographic method using Vigenere and Hill ciphers. *International Conference on Intelligent Systems and Computer Vision (ISCV)* (pp. 1-6). IEEE. https://doi. org/10.1109/ISCV49265.2020.9204095

Wang, J., & Tang, J. (2011). Design and implementation of WSN monitoring system for grain depot based on XBee/XBee Pro. *International Conference on Electric Information and Control Engineering* (pp. 4872-4874). IEEE. https://doi. org/10.1109/ICEICE.2011.5777512

Weatley, M. (2018). PSKCore.*DLL software specification and technical guide* (See. 1.41) [Software Manual].

Transfermóvil, 10 Years With Us

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Abstract

Transfermóvil is a project developed by ETECSA in 2015. Since then, it has become the primary digital payment platform in Cuba, with over 5.6 million users at the end of July 2025. During Covid-19, its usage grew significantly as it facilitated service payments and product purchases at a time when queues and crowds were being avoided due to health risks. For this reason, in addition to offering ease with e-payments, it contributed to preserving the lives of millions of people in Cuba.

Throughout these 10 years, it has always been available to users with stable and secure access 24/7. Its simple operation allows people who are not experienced with new technologies, including the elderly, to quickly become familiar with the application.

For companies and businesses, it facilitates e-payments for utilities, such as electricity and telephone services. It will also allow integration with any platform offering products or services that require a payment method.

Its recent innovations include the MiTransfer Wallet (2022) and the Online Payment Service (2019), as well as payments for telecommunications and utility services in general. This paper will review the past 10 years, which have been full of challenges, changes, and updates for the project, requiring infinite perseverance, creativity, and teamwork.

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Keywords: Transfermóvil, online payment, MiTransfer wallet, mobile, e-payment

Introduction

At the end of the 20th century, cellular telephony emerged and experienced an exponential technological advance that transformed the global paradigms of communication, trade and other key aspects of society. In the contemporary world, mobile devices—including tablets and portable computers—have become an indispensable tool deeply integrated into both personal and professional spheres. Meanwhile, the Internet evolved from a rudimentary information network into a critical infrastructure that underpin modern socioeconomic interactions. This technological convergence paved the way for the emergence of digital payment systems in the early years of the 21st century, transitioning them from conceptual frameworks to widespread adoption. By the first decade of the new millennium, electronic transactions had replaced cash-based exchanges in many economic sectors, marking a significant shift towards financial digitization. Pioneering platforms such as PayPal, eBay, and Mercado Libre established key architectures for secure cashless transactions, thereby catalyzing the proliferation of e-commerce and innovations related to it. Now, these developments is combined with the use of crypto assets, which have revolutionized the financial world. This has also changed the way we understand money and the separation of these financial operations from the banking system.

Advancements in information and communication technologies (ICT) have given rise to new payment systems for financial transactions between businesses and their customers. Specifically, these systems emerged as solutions to problems associated with handling physical currency (Tamayo, 1999):

- The need to reduce the cost of money and existing payment methods.
- Provide flexibility for small purchases and instant payments.
- Increase security and protection against fraud.
- The very rise of e-commerce and online payments on the Internet.

As an integral part of the digital transformation of the Cuban society, the progressive expansion of Internet access let to the growth of e-commerce across the country, both at the state and private sectors, through digital platforms and social media. In its early stages, this fledgling digital ecosystem lacked the infrastructure to process online payments, limiting transactions to the physical cash exchanges. This scenario experienced significant progress in 2015 with the launch of Transfermóvil, the first fully Cuban-developed digital payment platform, which marked a turning point in the nation's financial modernization.

In the first half of 2020, the figure of 950,000 active users was exceeded, and of these, 45% had joined in that same year, showing the importance that this platform was acquiring in Cuba. In this period, an average of 70 million operations were carried out, which represented a growth of more than 50% compared to the same period in 2019, and close to twenty services were implemented. All these indicators grew geometrically in the following years: services tripled to more than seventy; operations multiplied by ten, exceeding 700 million in the first half of 2025; and the number of users reached 5.6 million.

Every day of this first decade represented a challenge of development, innovation, and persistent will to move forward in order to offer Cuban society a financial digital transformation.

Making a quick review of Transfermóvil's project evolution timeline, it is worth mentioning some moments of particular relevance:

- **May 2007** – The first proposal for electronic payments emerged, using the Propia card as a debit card to pay the telephone bill, but it could not be achieved.
- **July 21st, 2014** – The conception and implementation of Transfermóvil began, linking it to the rise of mobile telephony in Cuba. The initial architecture of this platform was designed, but with a long-term strategy. (Virtualization, Webservices, short-code usage, layer and modular architecture).

- **February 10th, 2015** – The Transfermóvil Pilot Test begins (Telephone Bill Payment, through Telecommunications Agents at the Príncipe Telephone Exchange Center with approximately 50 TA).
- **March 18th, 2015** – Meeting with *Banco Popular de Ahorro* (BPA, for its acronym in Spanish) in which the development of the mobile banking module within the Transfermóvil project was agreed to begin as of September 2015.
- **November 30th, 2015** – The capability to make payments and transfers using Transfermóvil with BPA cards was put into practice. Integration with an accounting system.
- **February 23rd, 2016** – The Pilot Test for Mobile Top-Ups and Nauta Voucher Top-Ups begins through Telecommunications Agents at the Águila Telephone Exchange Center with approximately 45 TA. Launching of the first both APKs: Transfermóvil 1.160224 and ETECSA.
- **March 24th, 2017** – The capability to make payments and transfers through Transfermóvil using the BANDEC cards was put into practice.
- **March 31st, 2017** – The capability to make payments and transfers through Transfermóvil using the BANMET cards was put into practice.
- **March 2018** – Within the framework of the International Fair Informática 2018, a new version of Transfermóvil (1.180230) was released, capable of being updated via mobile data and integrating a dozen new services.
- **November 2018** – Within the framework of the Havana International Fair, the top-up service for mobile phone lines via bank cards (BPA, BANDEC, BANMET) was implemented.
- **August 2019** – A dozen new services were launched (Nauta top-up, microtop-ups, sending remittances, among others).
- **October 8th, 2019** – The first real digital payment using a QR code was carried out at the market located in the Sierra Maestra building.

- **February 2020** – The possibility of purchasing products by paying through Transfermóvil was extended throughout Cuba by means of Tuenvio, a virtual store chain under the charge of the CIMEX corporation.
- **March 2020** – A new Transfermóvil version was released, which included the ability to top up Propia cards. The new functionality Mis Cuentas was introduced.
- **August 2020** – A new version was launched with the following options: payment of the Nauta Hogar fee, improvements to electricity bill payment, and payment of taxes to the National Tax Administration Office of Cuba (hereinafter, ONAT, for its acronym in Spanish).
- **September 3rd, 2020** – Transfermóvil reached one million users.
- **January 12th, 2021** – The MiTransfer Boulevard was launched at Coppelia ice cream parlor in Havana. (ETECSA-GET).
- **March 2021** – Transfermóvil received the CITMA award, along with nine other works completed in 2020 with the greatest social and scientific impact.
- **April 26th, 2021** – Transfermóvil reached two million users (just in seven and a half months).
- **May 2021** – Transfermóvil received the ANIR National Award.
- **June 2021** – A new Transfermóvil version was released including the possibility to pay traffic fines and infringements.
- **December 27th, 2021** – A new Transfermóvil version was released with the following services: purchase of digital fuel vouchers, postage stamp, Caja Extra, and an update to the ONAT paragraphs.
- **January 29th, 2022** – The MiTransfer Boulevard surpassed 12,000 businesses.
- **February 17th, 2022** – Transfermóvil reached the third million users (just in 10 months).
- **February 27th, 2022** – Transfermóvil received a Special Award from CITMA due to its economic impact.
- **March 2022** – A new Transfermóvil version was released, improving its accessibility for visually impaired individuals.

- **March 2022** – In collaboration with the international company Óptima, the capability for its points of sale to sell through Transfermóvil was implemented.
- **March 2022** – Transfermóvil received the Grand Jury Prize at the International Fair Informática 2022.
- **August 19th, 2022** – La Bolsa MiTransfer was launched.
- **December 27th, 2022** – The payment of document tax (stamp duty) is implemented.
- **February 28th, 2023** – The Cuban mobile wallet was launched, and Transfermóvil reached 4 million users.
- **April 26th, 2023** – Transfermóvil received the Excellence Award in the Popular Vote category.
- **May 17th, 2023** – Transfermóvil obtained a prestigious special international mention, REMTECH 2023, which was withdrawn days later due to blockade-related issues.
- **October 2023** – A new Transfermóvil release was launched with several services aimed at telecommunications agents.
- **December 2023** – This was the most productive year in Transfermóvil's history up to that point, with seven APK releases, over fifteen new services and improvements, and nearly one billion transactions. The implementation of the document tax payment solution is beginning to be widespread.
- **January 2024** – Through the payment option to those users selling their Parranda beer bottles, the Cuban Brewery collected more than 1 million bottles.
- **February 2024** – More than 4 million digital stamps for procedures were exceeded, facilitated by the Transfermóvil solution.
- **March 2024** – The MiTransfer mobile wallet received a special award at the International Fair Informática 2024.
- **April 2024** – The new product MITPV was launched: a 100% Cuban point-of-sale solution.
- **April 2024** – Transfermóvil received recognition from the Ministry of Finance and Prices for its contribution to tax payments.

- **June 24th, 2024** – The digital on-boarding page was launched, enabling legal entities and self-employed workers (TCP, for its acronym in Spanish) to receive payments via Transfermóvil in their businesses and stores.
- **June 29th, 2024** – the Transfermóvil platform reached 5 million users, with over 80,000 businesses having the capability to receive e-payments.
- **October 15th, 2024** – A new product was launched within Transfermóvil: MiTurno, for booking appointments to purchase foreign currency at the currency exchange office (CADECA, for its acronym in Spanish). APK version: 1.241002.
- **November 27th, 2024** – Commercial procedures associated with liquefied gas in Holguín were incorporated into MiTurno. It then spread to almost all provinces.
- **December 2024** – New heritage views from different provinces were implemented within the Transfermóvil APK. A joint effort with the Office of Procedural Formalities Facilitation for the Payment of Contributions (OFA, for its acronym in Spanish).
- **December 17th, 2024** – A new financial operations module for users of Banco Financiero Internacional (BFI, for its acronym in Spanish) was implemented. Release: 1.241211.
- **February 10th, 2025** – Transfermóvil's 10th Anniversary. The APK Release 1.250210 was launched, including a logo change and new services such as Alternative Fixed Telephony (TFA, for its acronym in Spanish) top-up and payment of the heritage contribution through the MiTransfer wallet.
- **February 20th, 2025** – Transfermóvil received the popular vote award at the Excellence awards.
- **April 21st, 2025** – A new Transfermóvil version was released, including payment, transfer, and query operations for the *Clásica* card through the MiTransfer mobile wallet.
- **May 8th, 2025** – Implementation of new offers for heritage tours: Bus Tour, together with OFA and TRANSTUR.

- **May 10th, 2025** – Start of the pilot test using the sales terminals: MITPV from Transfermóvil for the liquefied gas sale in Cienfuegos.
- **June 29th, 2025** – Transfermóvil received a recognition from ONAT for its contribution to the digital transformation in tax payment.

This chronological data illustrates the technological contributions of the Transfermóvil project through the implementation of new services. The project is not only a digital payment platform, but also a social project focused on the needs of Cuban society. For every societal demand driven by a need, the Transfermóvil team has come up with a technological solution associated with improving a process, contributions that have resulted in sustainable solutions over time and have not always been confined to the financial world. Notable examples include the first-time implementation of payment for product purchases in Cuba in February 2020, just days before the country declared the start of the Covid-19 pandemic. This was a joint effort with CIMEX for online payments in the TuEnvío stores, which enabled millions of virtual purchases, avoiding physical contact and preserving citizen health. Until then, purchasing products from virtual stores with digital payments using Cuban bank cards was unthinkable in Cuba. The purchase of postage stamps was another service that was implemented through digital payment at a time when paper stamps were not available for legal procedures. In less than a month, a solution was developed in conjunction with the Ministry of Communication (MINCOM, for its acronym in Spanish), the Post Office of Cuba, the Ministry of Justice (MINJUS, for its acronym in Spanish), and other institutions. Collaboration between entities, whether state or private, has been among the project's development strategies. The linkage between entities, where each contributes to a high-impact final product with time-efficient execution, has been widely used for creating new Transfermóvil services.

Forty percent of the implemented services are the result of user recommendations and suggestions. This reflects the project's popularity. A team of communication professionals and technical specialists monitors and participates in various social media groups. Recommendations and comments about current services or potential new ones are taken into account.

The great success of the application, responsible for all the aforementioned results, lies with the specialists who have worked, frequently uniting days and nights, throughout these 10 years. This team has gained experience, always ensuring the protection of the legacy so that it continues advancing and remains sustainable.

The implementation of digital strategies (such as the expanding online stores and widely adopting QR codes in state and private entities) drove the development of mobile commerce (M-Commerce). Currently (2025), Transfermóvil has established itself as a multifunctional platform, integrating essential services with significant social impact. One of the most valuable Transfermóvil's products is the MiTransfer wallet (formerly Bolsa MiTransfer), which is referred below. These features reflect Transfermóvil's contribution to the process of financial computerization in the country, positioning it as a key tool in the digital transformation of the local economic ecosystem. In Cuba, more than 70% of digital operations are carried out through Transfermóvil.

Materials and methods

To complete this paper, research on related texts, observations, analyses, and data reviews were used. Furthermore, interviews with Transfermóvil specialists from various media outlets were utilized.

Results

Transfermóvil: Evolution, technique, challenges and improvements in the Cuban mobile payment app

As previously mentioned, the digitization of financial services has been a significant milestone in the global economy, and Cuba is no exception. With the launch of Transfermóvil, Cuba now boasts its first mobile payment app.

As previously explained, the digitization of financial services has been a significant milestone in the global economy, and Cuba is no exception of this digital transformation. The emergence of Transfermóvil marks the arrival of Cuba's first mobile payment application.

The evolution of Transfermóvil can be divided into three phases. During the first phase (2015-2019), the application needed to increase its user base in order to cover e-payments for public services. This solved one of the main problems that Cuban society had at that time, which was the long lines for cash payments that had to be made monthly. However, this growth was slow because users had to gradually adapt to the digital transition and gain confidence and security.

During the second phase (2020-2023), significant progress was made globally in developing online stores and remote payment systems for products that were then delivered to homes. The first steps in this direction were taken in 2019 and materialized at the end of that year and the beginning of 2020. This evolution was timely, as the development of online shopping became decisive in the coming years due to the proximity of a pandemic. Despite the limited experience in this area, their ability to adapt to changes contributed to the project's success. Overall, the balance was positive. For the first time in Cuba's history, Cubans could shop in a virtual store and pay online through Transfermóvil and their products were delivered to their homes. At that time, the integration standards with Transfermóvil were established for any store or business to implement online payments. The number of users grew exponentially, causing virtual stores to face an overload due to the relationship between demand and supply. Going back to Transfermóvil, it also had to promptly guarantee greater scaling of the platform through bigger infrastructure. Many optimizations were also made at the code and database level, enabling the implementation of dozens of new services and supporting the growth of millions of users.

In its most recent phase (2023-to the present), the MiTransfer wallet was created, a process that began back in 2022. Of all the products created, the wallet has the greatest potential and scope. With the MiTransfer wallet, financial services and processes are decoupled from banking functions related to users, allowing non-banking entities to handle these payment functions. Each person has virtual accounts in the wallet, that are topped up via payments made with bank cards within Transfermóvil. In the case of the USD account, top-up comes from abroad via remittances.

The MiTransfer wallet's strength lies in its ability to function without direct banking operations if the money is already in virtual accounts. It also represents an opportunity for the unbanked persons and provides an alternative in the event of financial system failures. Very few countries have 100% national wallets. Currently, there are challenges and opportunities, such as the increasing prevalence of crypto assets in today's world. This is a point of evolution for projects such as Transfermóvil.

It is essential to continue on teaching new technologies not only for senior citizens, but to anyone who are interested in acquiring this knowledge. Regarding this matter, several studies have consistently shown that platform usage is not age-dependent which is a positive result that has remained consistent over the years and highlights the application's (APK) ease of use. An interesting finding reveals that women use Transfermóvil more frequently than men, while 10.6% of users are aged over 60. Figure 1 shows the growth of Transfermóvil

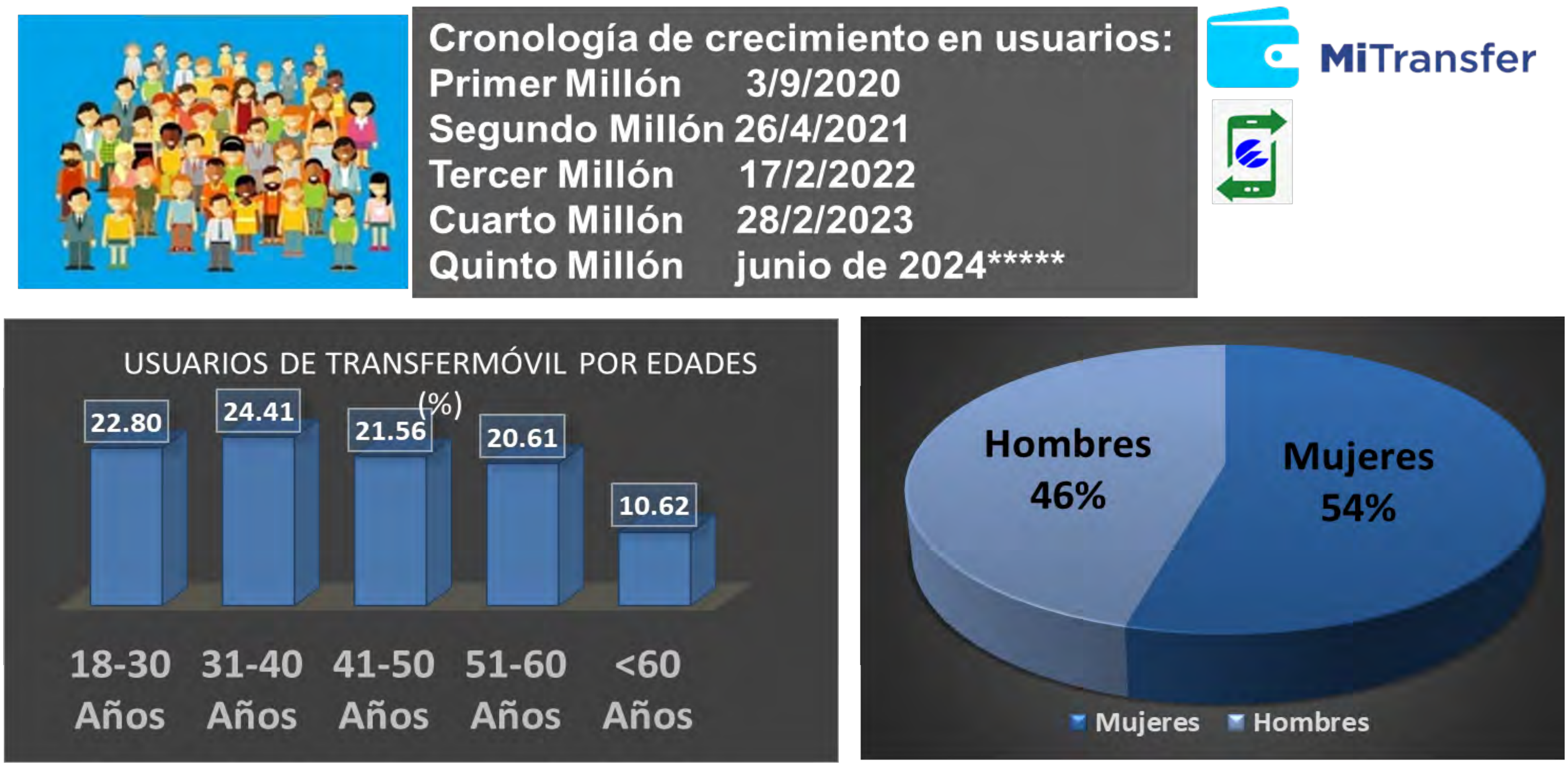

Figure 1. Chronology of user growth by age group and gender using the platform. Author's own work.

users over time and their distribution by age and gender. —a highly positive and sustained outcome over the years, which highlights the user-friendly nature of its application

Transfermóvil processes approximately 130 million transactions per month, averaging 48 transactions per second. Throughout its 10-year history, the platform has not experienced any security breaches that compromised the service. This is a positive aspect for a platform that handles money.

Table 1 shows the geometric growth of operations within Transfermóvil's core services. This sustained growth underscores

	2020	2021	2022	2023	2024	2024VS 2023
Pago Factura de Electricidad	3.3 M	5.5 M	9.52 M	12.74 M	22.9 M	180%
Pagos de la ONAT	120 K	400 K	1.29 M	3.56 M	6.7 M	188%
Pagos en línea (comercio Electrónico)	1.4 M	4 M	5.13 M	6.5 M	12.8 M	196%
Pagos de servicios de telecomunicaciones	15 M	50 M	150 M	173 M	190 M	109%
Transferencias	9 M	15 M	68.5 M	95 M	135 M	142%
Total de Operaciones	140 M	340 M	785 M	977 M	1323 M	135%

Table 1. Geometric growth of essential services in Transfermóvil. Author's own work

the platform's increasing popularity and usage. Today, Transfermóvil is part of every Cuban's daily routine and represents an essential technological tool in everyday life.

1. Online payment

On Transfermóvil, people can make online payments for purchases

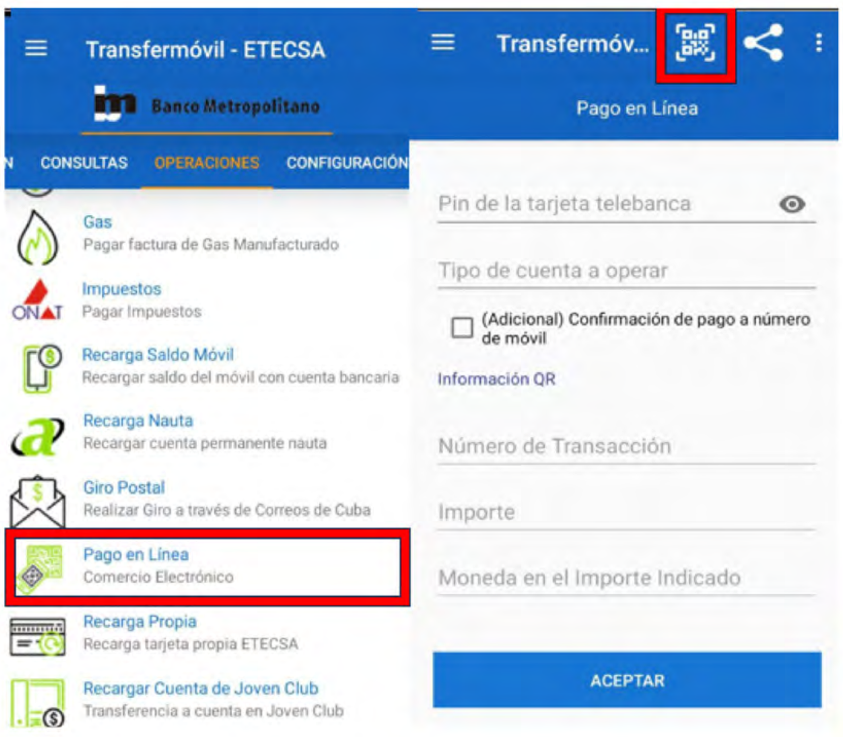

Figure 2. Online payment service on Transfermóvil. Taken from the application

at private or state-owned establishments. This payment method includes the merchant's details. It can offer bonuses, has no payment amount limits, and only requires scanning the QR code and entering the PIN for authentication, as shown in Figure 2.

On Transfermóvil, online payments are classified based on the nature of QR code:

- Static QR: This QR code has a fixed format and is exclusively issued by the MiTransfer Boulevard platform. It contains the business's details, but not information regarding the specific product or service to be acquired.
- Dynamic QR: This QR code varies based on the product or service the customer wishes. Generated by a business, it includes transaction-specific data, such as the transaction number, amount, and currency.

Online payments have grown significantly over the past five years, with an average annual growth rate of 54.7% between 2020 and 2024. 2024 saw the highest growth rate, with transactions exceeding 107%. Several variables have impacted this outcome. First, the successful policy of encouraging online payments has

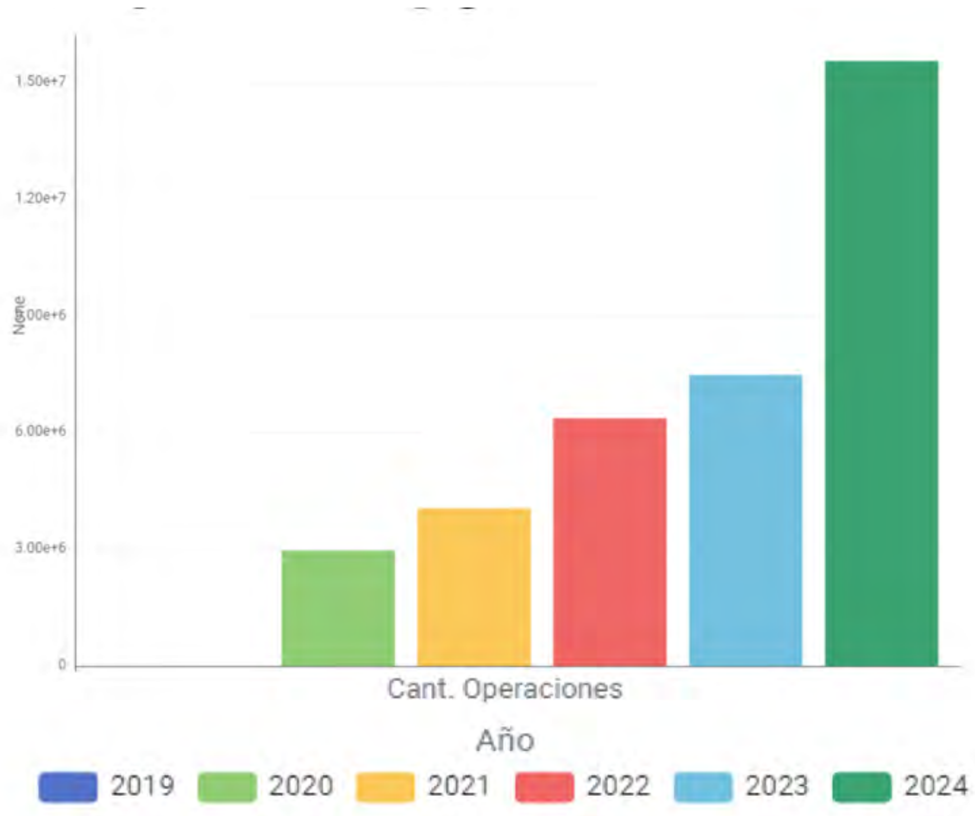

Figure 3. Online Payment Amount (2020-2024). Taken from the analysis of online payment behaviors on Transfermóvil

contributed to this increase, as has the difficulty of obtaining cash. Additionally, electronic payments reduce operating costs associated with transferring, protecting, and securing money. Figure 3 shows the growth of online payments from 2020 to 2024.

There are good examples of these electronic payment policies being implemented. The first case study is ETECSA, which offers all its services via electronic payments. More than seven years ago, it became the first entity to eliminate long lines at its offices by digitally transforming all its service processes. Transfermóvil played a leading and fundamental role in this transformation, covering all payments related to the entity's services within the APK. This platform generates more than 85% of the company's revenue.

With the Caja Extra service, customers make digital payments to the entity and receive cash in return. This service originated due to the lack of ATMs in our society. Once again, Transfermóvil has provided a technological solution that allows Cubans to obtain cash at no additional cost. The population has been very pleased with this service. ETECSA was a pioneer in this area, as it reduces operational costs related to transportation and security since most of the time, commercial offices close without cash because it is dispensed through the Caja Extra service.

Another example is TRD Caribe chain store. Based on a successful strategy, it extended online payments to its entire chain of stores, which now represent an important volume of its revenues in millions of pesos.

During the first years of its use, from 2020 to 2021, dynamic QR codes were the most popular, but in subsequent years, static QR codes became more prevalent due to their versatility of usage and the fact that they don't require technology; only a material (paper, plastic, etc.) with the QR code. The following graph (Figure 4) shows the evolution of online payments.

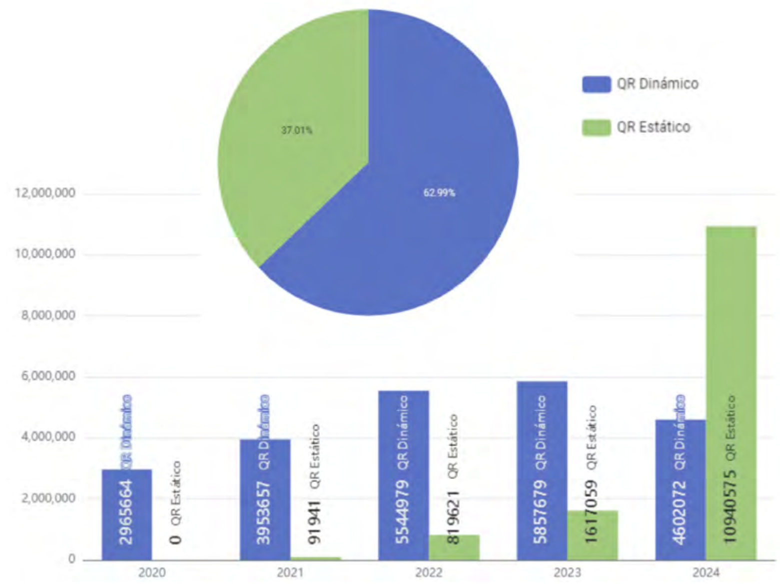

Figure 4. Online payment evolution. Taken from Analysis of online payment behaviors on Transfermóvil

The MiTransfer Boulevard platform was jointly developed with the Computing Services for Tourism Company (GET, for its acronym in Spanish). This platform is in charge of generating QR codes for the different merchants and allows both their management and reconciliation of their financial operations.

Currently, more than 250,000 businesses and commerce accept online payments via Transfermóvil. This is an additional development strategy that has been successful for over four years and has grown exponentially in terms of results.

Although the statistics obtained regarding e-payments can be evaluated as good, the percentage of online payments compared to the total payment operation capacity is far from the desired level. This indicates that efforts must continue to mitigate non-technological factors affecting the achievement of desired online payment indicators.

The inter-account transfer service remains the most popular feature of Transfermóvil. Online payments doubled, and the Caja Extra service quintupled in 2024, indicating their growing popularity. For every fifteen transfers, one online payment is made. For every Caja Extra transaction, 3.5 online payments and 53 transfers are carried out. Figure 5 shows the distribution of online payments through Transfermóvil by province.

Figure 5. Distribution of online payments through Transfermóvil by provinces. Author's own work.

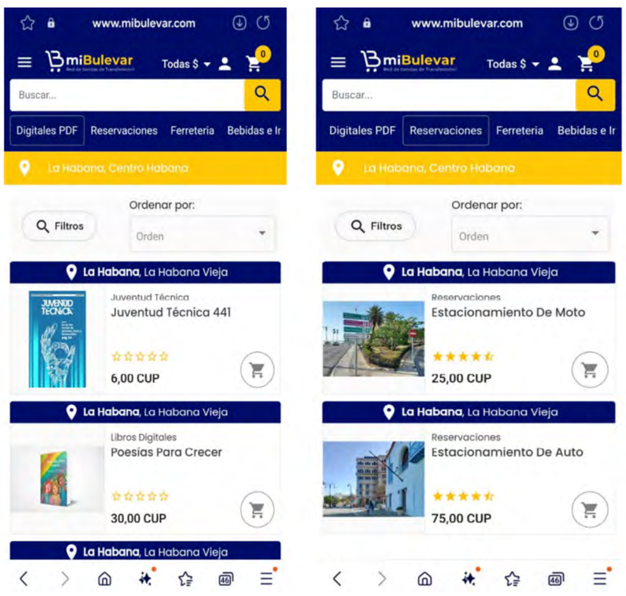

Figure 6. Transfermóvil's online store galleries

Transfermóvil, in collaboration with Avangenio, offers another solution: The Point-of-Sale Terminal (MITPV, for its acronym in Spanish):

1. Payment for products and services purchased. At the customer's request, specific services, such as Caja Extra, can be added.
2. This method can be used for self-service payments. Customized service.
3. Multiple payment options: Transfermóvil, Visa and Mastercard, Cash, etc.
4. Each payment is classified by product and quantity.
5. Refunds. This option is editable in multiple languages.
6. Ability to connect to an accounting or inventory system.

Figure 7 shows the MiTransfer Point-of-Sale Terminal.

Figure 7. MiTransfer Point-of-Sale Terminal

Transfermóvil has laid the groundwork for future innovations in Cuba's e-commerce ecosystem. In summary, the data shows that the App has solved immediate problems of financial access and operational efficiency. It is also driving a structural transformation in the Cuban economy, providing tangible benefits to citizens, private businesses, and the State. Its continuous evolution suggests that it will remain a key driver of digitalization in Cuba in the coming years.

2. MiTransfer Wallet

Since its launch on August 19, 2022, as a complement to Transfermóvil, it has transformed the Cuban financial landscape and reached nearly one million active users. This digital wallet operates independently of the banking network and is experiencing a growing trend in operations and users. It has enabled tens of thousands of unbanked individuals to participate in the Cuban e-commerce ecosystem, despite not having bank cards, by facilitating them to make digital payments. It is a Transfermóvil's product that has not yet reached maturity due to various non-technological causes. Therefore, a well-defined policy has been established to promote its use by offering new services that are attractive to both banked and unbanked users. As its use is strengthened with new services, MiTransfer will become a better alternative to bank cards. Currently, the MiTransfer wallet has two virtual accounts: one in CUP and one in USD. However, it has the ability to have other virtual accounts. With the CUP account, you can receive money from bank cards through the wallet top-up option in each bank-associated APK. The USD account receives money from abroad through remittances. The MiTransfer wallet offers a similar service portfolio to other banks: online payments, transfers, and utility payments can be made.

The maximum amount of money in each virtual account in this wallet is 80,000 CUP for CUP accounts and 5,000 USD for USD accounts. To register for the Transfermóvil APK, you only need to own a mobile telephone line and enter your identity card information and set your PIN.

The telecommunications agent module, the first independent module of Transfermóvil in 2015, is within the mobile wallet. Since 2024, it has been integrated into the wallet, giving these economic players a greater range of service options to offer: payment of telephone bills, mobile top-ups, Nauta top-ups, Nauta Hogar payments, Propia card top-ups, Alternative Fixed Telephony top-ups, (known as TFA, for its acronym in Spanish) and purchase of plans and data packages.

In 2025, the MiTransfer wallet included the option for individuals to use the Cuban Clásica card. This allows users to make transfers between Classic cards, check their account balances, view recent transactions, and make online payments. This is another example of collaboration between entities.

Currently, there are several lines of development open for new services associated with the wallet. These services are expected to be launched this year and, due to their societal impact, should encourage its use.

Conclusions

Transfermóvil has established itself as a fundamental tool in the digitization of financial and commercial services in Cuba. Its evolution from a simple fixed phone bill payment application to an all-encompassing digital payment platform reflects its commitment to the Cuban people. Over the past 10 years, Transfermóvil has contributed to the economic, social, and technological development of various sectors of Cuban society. It has been a pioneer in transforming the digital society with substantial significance especially in the financial sector. It is a platform offering more than 70 IT services and products that facilitate financial transactions. The most notable include the MiTransfer wallet, MiTransfer Boulevard, MiTurno, the telecommunications agent module, and MITPV, among others.

There is still much to be done and technological challenges and obstacles to overcome. The project's sustainability and its role in the transformation of digital society are priorities in the project's strategy for the coming years. Teamwork and technological networking with other economic actors will be paramount in developing new services. The digital transformation of a society is not a destination but a path to be followed, one that must be consistent in every new service design. This digital transformation will yield better results to the extent that strategic, timely, and rapid decisions are made.

In the context of economic reforms, implementation is key to achieving Cuba's technological and financial sovereignty. Its success depends on the ability to scale solutions that balance innovation, accessibility, and security while addressing the real needs of the population. Transfermóvil is more than an APK; it is a symbol of how Cuba can adapt technology to its particularities. It shows that inclusive digital alternatives can be built even in complex environments. Its evolution will serve as an indicator of computerization progress in Cuban society in the coming years.

Bibliografía

Anaya, A., & Lopez, I. (2014). *La tecnología NFC en teléfonos celulares, sus retos y aplicaciones.*

Avances en la informatización de la sociedad cubana. (s.f.). Recuperado el 7 de Septiembre de 2015, de Cubadebate: http://mesaredonda.cubadebate.cu/temas/ciencia-y-tecnologia-temas/2015/09/17/avances-en-la-informatizacion-de-la-sociedad-cubana/

Aydin, N., Cozkun, V., & Osdenizci, B. (2009). *Exploring underlying values of NFC applications, in Proc. of International Conf. on Management Technology and Applications* (ICMTA 2010), Singapur, pp. 10–12.

Bernardos, A. (2008). *Modelo de integración de tecnologías para la provisión de servicios móviles basados en localización y contexto.* Tesis Doctoral.

Buellingen, F., & Woerter, M. (2004). *Development Perspectives, Firm Strategies and Applications in Mobile Commerce, Journal of Business Research.*

Camacho Casado, L. (2014). *Nuevas Inversiones para afianzar la banca electronica.*

Chaparro, G. (2010). Mobile Financial Services - *An Integrated Solution*, Gemalto.

Cujin, D., & Gerrero, L. (2014). *Analisis de la factibilidad para la implementación de la billetera móvil en la ciudad de cuenca.*

Empresa de Telecomunicaciones de Cuba S.A. (s.f.). Obtenido de *Portal del Trabajador*: http://www.portal.etecsa.cu/

Gartner. (2013). G*artner Says Worldwide Mobile Payment Transaction Value to Surpass $235 Billion in 2013*, Stanford, Connecticut.

Hanouch, M., & Chen, G. (2015). *La importancia del USSD en la promoción de la competencia en los pagos por móvil.*

Huang, H. (2007). *Diffusion of Mobile Commerce Application in the Market, IEEE Innovative Computing, Information and Control.*

Kadhiwal, S. (2007). *Analysis of mobile payment security measures and different standards. Computer Fraud & Security.*

Liebana-Cabanillas, F. (2012). *El papel de los medios de pago en los nuevos* *entornos electrónicos. Tesis Doctoral, Departamento de Comercialización e Investigación de Mercados.*

Masamila, B., Mtenzi, F., Said, J., & Tinabo, R. (2010). *A Secured Mobile Payment Model for Developing Markets, Communications in Computer and Information Science.*

Nambiar, S., Chang, T., & Liang, L. (2004). *Analysis of Payment Transaction Security in Mobile Commerce. IEEE Information Reuse and Integration.*

Revista Nro. 3, *Telebanca*. (2007). Revista del Banco central de Cuba.

Reyes, L. (2025). *Análisis de comportamiento de los pagos en línea en Transfermóvil,* Msc. Tesis de la Facultad de Ingeniería Informática, Universidad Tecnológica de La Habana José Antonio Echeverría.

Rivera, C. (2011). Servicios de Transacciones Económicas de dinero móvil entre usuarios de las operadoras del servicio móvil avanzado en el ecuador.

Rivera, C. (2012). *Implementación del sistema de pagos y transacciones a través de las redes del servicio móvil avanzado para atender a la población sin acceso a la banca formal en el Ecuador.*

Schwiderski, S., & Knospe, H. (2011). Secure M-Commerce.