INNOVATION FOR DIGITAL AUDIO BROADCASTING: AN INTERACTIVE TOOL FOR MONITORING COVERAGE OF THIS NEW TECHNOLOGY IN COLOMBIA

INNOVACIÓN PARA LA RADIODIFUSIÓN SONORA DIGITAL: HERRAMIENTA INTERACTIVA PARA EL MONITOREO DE COBERTURA DE ESTA NUEVA TECNOLOGÍA EN COLOMBIA

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ABSTRACT.

Over the last few years, digital audio broadcasting has been expanding worldwide, highlighting the need to migrate to this technology in countries that still use analog broadcasting. In Colombia, both the Ministry of Information and Communications Technologies and the Communications Regulation Commission (CRC) have expressed the need to standardize and expand digital audio broadcasting to modernize the sector and improve the quality of transmissions, as it is currently the only one.

In this context, the National Open and Distance University (UNAD) has carried out preliminary studies through a research project funded by the Ministry of Science, Technology and Innovation. These studies include detailed simulations using licensed software to collect data from key geographic coordinates. The resulting data from these simulations, which were initially in KMZ format, presented a challenge due to their unstructured nature and their location on a licensed software's server.
This project addresses this issue by creating a web application that collects and displays this data graphically and interactively. The proposed solution is a software prototype that consists of a dashboard developed with Power BI and a complementary web application. The Power BI dashboard allows for detailed visualization and global analysis of the coverage data, while the web application is responsible for efficiently managing, storing, and making these dashboards public.
This article showcases the design, implementation, and testing of this software prototype, demonstrating its viability to transform raw data into useful and accessible information. The successful implementation of this system validates a methodology for handling large volumes of geographic data and demonstrates a tangible contribution to the future implementation of these types of technologies in Colombia.

Keywords.
Dashboard; KMZ; Web Server; API; Visualization; Radio Coverage

RESUMEN.

En los últimos años, la Radiodifusión sonora digital se ha venido expandiendo en el mundo, esto último ha evidenciado la necesidad de migrar hacia esta tecnología en países donde aún se cuenta con la radiodifusión sonora análoga. En Colombia, tanto el Ministerio de Tecnologías de Información y Comunicaciones como la Comisión de Regulación de Comunicaciones (CRC) han expresado que existe una necesidad de estandarizar y expandir la radiodifusión sonora digital en Colombia para modernizar el sector y mejorar la calidad de las transmisiones y porque actualmente es el único. En este contexto, la Universidad Nacional Abierta y a Distancia (UNAD) ha llevado a cabo estudios preliminares mediante un proyecto de investigación financiado por el Ministerio de Ciencia, Tecnología e Innovación, que incluyen simulaciones detalladas en un software licenciado para recopilar datos de coordenadas geográficas clave. Los datos resultantes de estas simulaciones, que inicialmente estaban en formato KMZ, presentaban un desafío debido a su naturaleza no estructurada y a estar alojados en el servidor de un software licenciado. Este proyecto aborda este problema mediante la creación de una aplicación web que recopila y muestra estos datos de manera gráfica e interactiva. La solución propuesta es un prototipo de software que consiste en un tablero de datos (dashboard) desarrollado con Power BI y una aplicación web complementaria. El tablero de Power BI permite una visualización detallada y un análisis global de los datos de cobertura, mientras que la aplicación web se encarga de gestionar, almacenar y hacer públicos estos tableros de manera eficiente. Este artículo evidencia el diseño, la implementación y las pruebas de este prototipo software, demostrando su viabilidad para transformar datos crudos en información útil y accesible. La implementación exitosa de este sistema valida una metodología para el manejo de grandes volúmenes de datos geográficos y demuestra una contribución tangible a una futura implementación de este tipo de tecnologías en el país.

Palabras Clave.
Tablero de datos; KMZ; Servidor Web; API; Visualización; Cobertura de radio.

INTRODUCTION.

The adoption of digital technologies is a fundamental pillar for progress in telecommunications. In the field of audio broadcasting [1-3], the transition to a digital signal represents a qualitative leap in audio quality and the efficiency of the radio spectrum. However, this process is not without technical challenges, one of which is the visualization and analysis of signal coverage. A precise understanding of signal strength and range is crucial for optimizing the transmission network, identifying areas of low coverage, and ensuring a high-quality user experience.

Currently, coverage studies are based on simulations that generate large volumes of geospatial data in formats like KMZ. Handling and interpreting this data without specialized tools are complex and time-consuming tasks. The need for a tool that simplifies this process led this project to propose and develop a software prototype. This prototype seeks not only to process and visualize this data but also to do so in a way that is accessible to professionals and decision-makers in the sector.

The system is based on a robust client-server architecture, using modern technologies like Vue 3[4] for the front end, Laravel [5] for the backend, and MySQL [6] for database management. This technological approach allows for a scalable and high-performance application. Additionally, Power BI [7] was used to create data visualization dashboards, leveraging its powerful analytical capabilities. The goal is to provide a centralized platform that serves as a strategic tool for technical analysis and planning in the expansion of digital audio broadcasting in Colombia, contributing significantly to the modernization of the country's communications infrastructure.

This paper will show the methodology that was taken into account in the research project, the main results obtained, and some observations on future work, considering that the proposed software is a prototype with a TRL 3 [8] maturation level.

METHODOLOGY

The development of the software prototype followed a structured approach based on the PHVA (Plan, Do, Verify, Act) cycle [9]. This iterative and cyclical methodology allowed for efficient project management and continuous improvement of the product.

PLAN

In this phase, the foundations of the project were defined. In addition, an exhaustive investigation was carried out on the needs of the Colombian environment for the transition to digital radio. Functional requirements (dashboard management, data visualization) and non-functional requirements (security, performance) were identified. It was determined that the main data source would be KMZ files generated by coverage simulations. The methodology for extracting and processing information from these files was planned. Finally, the client-server architecture was designed, and the most suitable technologies (Vue 3, Laravel, MySQL) were selected to guarantee the scalability and performance of the prototype and milestones and deadlines were established for each development phase, from data extraction to final testing.

DO

This phase was focused on the practical implementation of the solution. First the user interface was built with Vue 3. Modular components were created for the different sections of the application, such as dashboard visualization, user authentication, and file management. Special attention was paid to the user experience (UX) design to make navigation intuitive. In addition, the backend was implemented with Laravel. Data models for the database, controllers to manage HTTP requests, and API routes were created. Functionalities such as file upload, user management, and communication with the frontend were implemented. Finally, power BI was used to develop the visualization dashboards. A process was implemented to import and clean geospatial data from KMZ files. Interactive visualizations were created, including heat maps and scatter plots showing signal strength in different locations.

VERIFY

In this stage, it was evaluated whether the project results met the objectives defined in the planning phase. First, the different modules of the system (frontend, backend, database) were tested together to ensure that communication between them worked without errors. It was verified that the front end could correctly consume the data provided by the backend API. Also, manual tests were performed for each use case, such as uploading a new dashboard, visualizing data on the map, and managing access permissions. The errors found were corrected, and performance was optimized. The data visualized on the dashboard was compared with the original data to guarantee the accuracy and integrity of the information.

ACT

This phase was focused on continuous improvement and final deployment. Although the project is a prototype, this phase included preparation for a possible large-scale deployment. In this stage: A detailed report was drafted describing the methodology, technologies used, and results obtained. The potential of the prototype to be implemented as a complete solution in a real environment was evaluated, considering aspects such as scalability and security. The steps for an eventual deployment on a UNAD server were planned, which would allow a wider audience to access the tool.

RESULTS.

Dashboard Design

A dashboard is a data visualization tool that presents key metrics and data in a consolidated manner. Its main objective is to facilitate decision-making by allowing users to identify complex trends and patterns briefly [10]. The characteristics of a good dashboard include:

- **Relevance:** Displaying only the most important information for the user.
- **Clarity:** Using easy-to-understand charts and tables.
- **Interactivity:** Allowing the user to filter and drill down into the data.
- **Simplicity:** Avoiding information overload.

In this project, Power BI, one of the leading Business Intelligence tools, was used to create dashboards that show signal coverage on geospatial maps, in addition to key metrics such as signal strength.

Data Extraction and Transformation Process

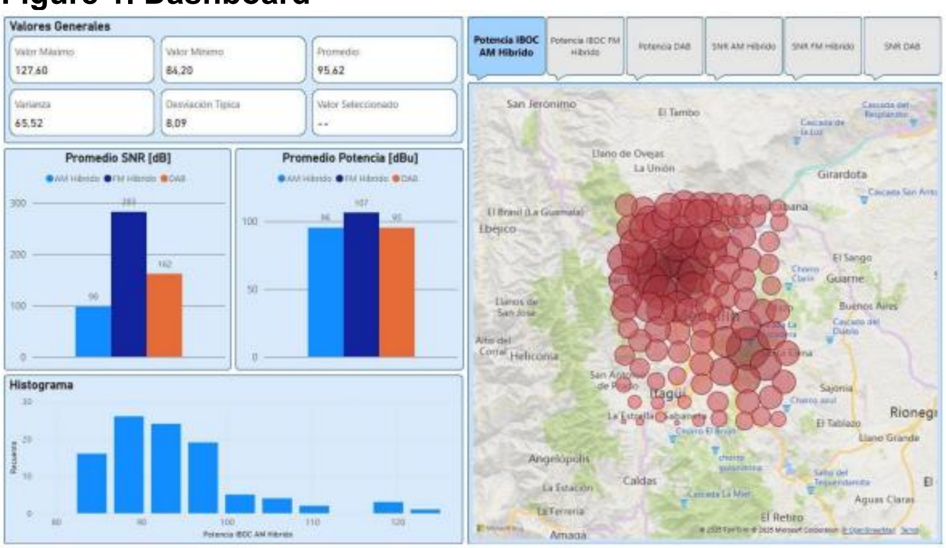
The process of going from raw data to a functional data dashboard was one of the most challenging parts of the project. The process is detailed below:

1. **Data Acquisition:** Coverage data was obtained from digital radio simulations, generating files in KMZ format.
2. **Data Extraction:** Software tools were used to parse the KMZ file and extract the geographic coordinates (latitude, longitude) and signal strength values.
3. **Cleaning and Transformation:** The extracted data was cleaned to remove outliers or measurement errors. It was transformed into a table format (CSV or Excel) suitable for import into Power BI.
4. **Modeling in Power BI:** The data was imported into Power BI. Relationships were created between the tables, and geospatial visualizations (heat maps) and bar charts were designed to show signal distribution.
5. **Publishing:** The Power BI dashboard was published to the Power BI service, which allowed the web application to access and display the dashboard through its interface.

Dashboard Creation with Power BI

One of the most significant results was the development of a semi-automated process for creating a data dashboard from KMZ files. The simulation files, which contain coverage data, were processed and transformed into a suitable format for Power BI. This included the extraction of geographic coordinates, signal strength, and other relevant parameters. The resulting dashboard offers a dynamic and detailed visualization of signal coverage, allowing users to interact with the data through filters and selections. Figure 1 shows the dashboard implemented.

Figure 1. Dashboard



Note: The figure shows the dashboard implemented by Authors

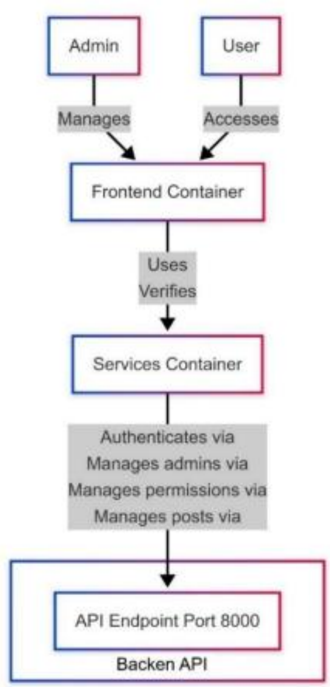
Web Development Technologies

The web application was built using a modern technology stack, which includes:

- **Vue 3[11]:** A progressive JavaScript framework for building user interfaces. Its component-based architecture allows for efficient modularity and code reuse.
- **Laravel[12]:** A robust PHP framework for developing web applications. Laravel simplifies common tasks such as routing, authentication, and database management, which speeds up the development process.
- **MySQL[13]:** A widely used relational database management system. It is known for its reliability and performance, making it an ideal choice for storing coverage data and user information.

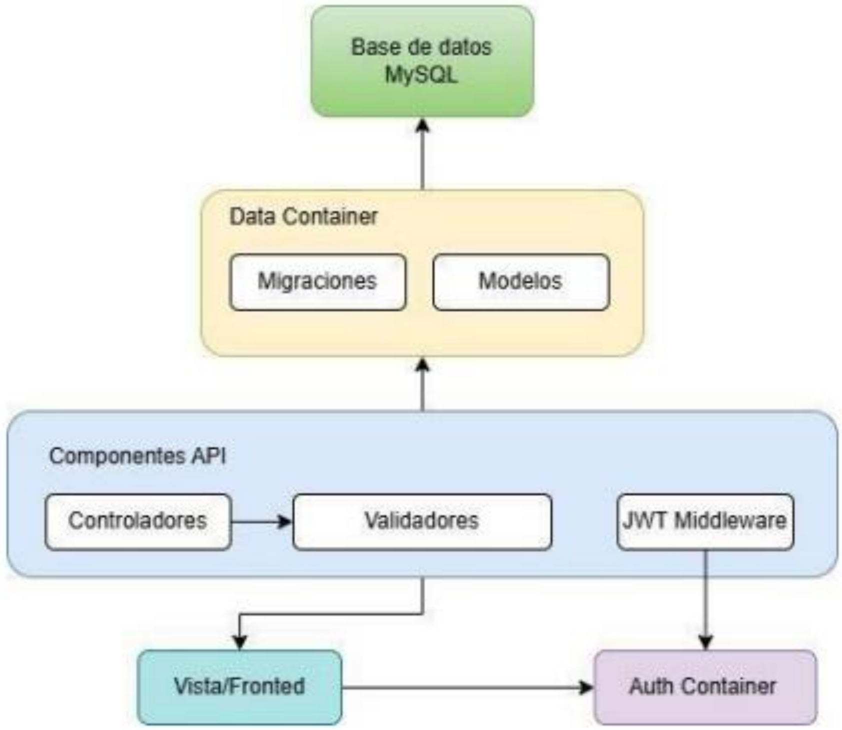
Then the software prototype was designed with a client-server architecture that clearly divides responsibilities. The front-end, developed with Vue 3, is responsible for the user interface, allowing for an interactive and dynamic experience. This presentation layer is responsible for data visualization, navigation, and interaction with dashboard elements. The back-end, built with the Laravel framework, acts as the brain of the system. Its main function is to manage business logic, including user authentication and authorization, data dashboard storage, and file management. A RESTful API was implemented to facilitate communication between the front-end and the back-end, which allows both to be developed and maintained independently. The MySQL database stores critical system information, such as user data (username, encrypted passwords, roles) and data dashboard metadata (title, description, file ID). This relational data structure guarantees the integrity and consistency of the information. Figures 2 and 3 shows the design of front-end and back-end

Figure 2. Front-end



Note: The figure describes the block diagram of Front-end. Authors

Figure 3. Back-end



Note: The figure describes the block diagram of Front-end. Authors

System Architecture

The prototype follows a client-server architecture, where the application logic is distributed between the user's web browser (the client) and the central server. The user interface (Client- Frontend), developed with Vue 3, is responsible for interacting with the user and making requests to the server. The server backend developed with Laravel, the server manages client requests, interacts with the database (MySQL), processes the data, and returns the appropriate responses. This includes user management, dashboard storage, and authentication. The database in MySQL stores user data and dashboard metadata in a structured manner. A set of rules allows the web application to communicate with the server makes up the API (Application Programming Interface).

This architecture separates responsibilities, which facilitates system maintenance, scalability, and security. The use of a RESTful API ensures that the frontend and backend can evolve independently, as long as the communication interface is maintained.

Web Application Functionality

The web application prototype, built with Vue 3 and Laravel, meets all the defined functional requirements.

- **Dashboard Management:** The application allows users with administrator permissions to upload new files and associate them with a data dashboard. The dashboards can be easily managed, updated, and deleted from a control panel.
- **Public Visualization:** A public interface was implemented that shows the data dashboards enabled for viewing. Users can browse a list of available dashboards and access the visualizations interactively.
- **Security and Authentication:** A user authentication system was implemented that ensures only administrators can access the management panel. Access permissions to the dashboards are managed securely.

Figure 4 shows the web application of the dashboard developed.

Figure 4. Web Applicative

Note: The figure describes the dashboard integrated with the Web application. Authors

Integration and Testing

The integration of the different system components (frontend, backend, database, and Power BI) was successful. Functionality and integration tests confirmed the stability and correct operation of the system. It was verified that the application responded efficiently to user requests and that the data was displayed accurately on the dashboards. The system's ability to manage multiple dashboards without performance degradation was one of the main conclusions of the tests.

Several tests were carried out to ensure the quality and correct functioning of the prototype.

- **Usability Tests:** The user interface was evaluated to ensure that it was intuitive and easy to use. A group of users was asked to navigate the application and perform specific tasks, such as uploading a file.

- **Load Tests:** The system's performance was evaluated under a simulated user load to ensure that it could handle multiple simultaneous requests without degradation.
- **Security Tests:** Tests were performed to detect vulnerabilities, such as SQL injection and cross-site scripting (XSS) attacks. The authentication system was verified to be robust and that access permissions worked correctly.
- **Maintenance Tests:** The ease of code maintenance was evaluated. The modular architecture of the system, with the use of established frameworks, showed that future updates and bug fixes would be easier to implement.

CONCLUSIONS.

The software prototype for visualizing digital radio coverage in Colombia was successfully developed, achieving its main objectives and demonstrating the viability of the solution. The results can be divided into several key areas, from dashboard creation to web application functionality.

The developed software prototype has proven to be an effective and viable solution to address the challenge of visualizing digital radio coverage in Colombia. By integrating modern web development technologies with powerful data analysis tools like Power BI, a robust and easy-to-use platform has been created that transforms complex data into understandable and actionable information.

The developed application offers a valuable tool for telecommunications professionals and regulatory bodies. It allows for the visualization of signal quality in real-time, facilitating the identification of problematic areas and informed decision-making to optimize the transmission network. The system's architecture is modular and scalable, which guarantees its ability to adapt to the future needs of the sector.

The project validates the PHVA methodology as an effective approach for the development of this type of solution. The planning phase laid the foundation for success, the implementation was carried out in an orderly manner, and the tests confirmed the quality of the final product. The prototype not only meets its technical objectives but also contributes significantly to the modernization of the communications infrastructure in Colombia, promoting the country's technological and socioeconomic advancement.

Other important results of the project can be indicated as follows: The system architecture allows for the addition of new modules and functionalities in the future. The separation of responsibilities between the client and the server, along with the use of established frameworks, facilitates code maintenance. The prototype serves as a solid foundation for future research on geospatial data visualization and the implementation of monitoring systems for digital radio.

The developed software prototype has significant implications for the telecommunications industry in Colombia. It offers a tool that can be used for: helps broadcasting companies plan the location of new antennas and optimize existing coverage. Allow regulatory entities to monitor the quality of the digital radio service in different regions of the country. Serves as a platform for future research, such as the integration of traffic data or the incorporation of artificial intelligence algorithms for network optimization.

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