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DEVELOPMENT OF PORTABLE 4G AND 5G NETWORK BASIC SIGNAL ANALYSIS DEVICE FOR PHILIPPINE CELL SITES

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Abstract

The ever-evolving landscape of mobile communication technologies, exemplified by the rapid progression of 4G and 5G networks, underscores the critical need for sophisticated signal analysis tools. This necessity is particularly pronounced in regions like the Philippines, where a resilient telecommunications infrastructure is indispensable for societal and economic progress. Responding to this imperative, the present study embarked on the development of a bespoke solution: a portable 4G and 5G Network Basic Signal Analysis Device meticulously crafted for deployment across the Philippine archipelago.

To ensure a thorough and effective development process, the study outlined specific objectives. Firstly, it sought to engineer a portable device utilizing readily available and cost-effective components, thereby fostering accessibility and affordability, crucial factors in the context of resource-constrained environments. Secondly, emphasis was placed on crafting a user-friendly interface facilitating intuitive real-time measurement and visualization of pivotal signal parameters. These included not only technical metrics such as signal strength and quality but also geographical data like longitude, latitude, and altitude. Additionally, the device boasted rudimentary data logging capabilities essential for capturing and storing fundamental signal analysis metrics.

Field testing emerged as a linchpin in this endeavor, with extensive evaluations conducted at various cell sites throughout the Philippine archipelago, with particular focus on the city of Sorsogon. Through meticulous on-site testing, the study aimed to amass empirical data, thereby illuminating nuanced insights into the performance of 4G and 5G networks. Such insights are pivotal for devising informed strategies to optimize network performance and efficacy, thus enhancing overall connectivity and user experience.

Central to the study's objectives was the demonstration of the simplicity and accessibility of 4G and 5G signal analysis facilitated by the developed hardware tool. Furthermore, the study sought to gauge the system's quality against the rigorous standards delineated by ISO/IEC 25010:2011. This encompassed a multifaceted evaluation spanning functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability.

The validation phase constituted a culmination of the study's efforts, involving meticulous scrutiny by a panel comprising esteemed experts from pertinent domains. This included two IT specialists, a Telecommunications engineer, and two RF engineers hailing from the esteemed National Telecommunications Commission (NTC) Region 5. Their rigorous evaluation not only attested to the robustness, accuracy, and

practicality of the developed device but also underscored its efficacy in addressing the idiosyncratic challenges inherent to signal analysis in Philippine cell sites.

Key Words:
4G, 5G, Aemilianum College Inc., Cell Sites, Connectivity, Device, Field Testing, Geographic Data, Geographical Information, Network Performance, Real-time Measurement, Signal Analysis, Telecommunications.

Introduction

Communication stands as a foundation of our society, essential for every human effort. From primitive methods like sounds and drawings to more sophisticated means such as imperial communication and pigeon posts, early humans devised various ways to bridge distances (Gascoigne, 2019). However, it was the monumental invention of the telephone by Alexander Graham Bell on March 7, 1876, that ushered in a new era. This transformative device enabled instantaneous conversations across vast distances, reshaping global communication. Its emergence required the establishment of intricate telephone networks, paving the way for subsequent innovations like cellular phones and the Internet. This breakthrough not only facilitated personal dialogues but also revolutionized business interactions while significantly enhancing the efficiency of emergency services, ultimately saving numerous lives.

As technology advanced, cellular networks became the backbone of communication, allowing mobile devices to establish connections. Behind the scenes, a complex system of base stations and cell sites relayed information seamlessly, enabling real-time conversations, multimedia access, and network mobility. The rise of mobile technology transcended traditional communication boundaries, turning our devices into versatile pocket-sized computers. Before the COVID-19 pandemic, these devices primarily supported daily tasks such as browsing, social networking, and accessing various apps. Network traffic patterns followed predictable routines, peaking during daytime and localized events.

However, the pandemic wrought significant changes in how cellular networks were utilized. Lockdowns and remote work led to a surge in demand for data and video conferencing services. Mobile networks had to adapt rapidly, facing increased daytime congestion as people relied on them for remote work, online education, virtual meetings, and entertainment. Cellular providers responded by adjusting configurations, allocating more bandwidth, and optimizing infrastructure to ensure stability and quality of service. This period underscored the flexibility and resilience of cellular networks, vital for critical communications and emergency services.

Moreover, the pandemic accelerated the digital transformation globally. Online education, health services, e-commerce, and remote work gained unprecedented momentum, emphasizing the pivotal role of the Internet. Mobile internet became a lifeline in low- and middle-income countries, connecting people to vital information and services during lockdowns. This accelerated transformation reflected the evolution of wireless technologies, which began with simple radio transmissions and progressed to advanced wireless networks, making our world smaller and more connected.

The evolution of wireless technologies, from first-generation (1G) to fifth-generation (5G), marked a remarkable journey. Each generation brought significant advancements. The 4G era, in the late 2000s, revolutionized mobile communication with faster data speeds and HD video streaming. It laid the groundwork for the ongoing 5G deployment, initiated in the late 2010s. 5G promises ultra-fast data speeds, minimal latency, and support

for cutting-edge applications, positioning it as a transformative technology.

According to Ericsson (2023), its projection to the global forecast for 5G subscriptions has been revised due to delayed spectrum auctions and challenging economic conditions. It is now anticipated that there will be 4.6 billion 5G network subscriptions worldwide by the end of 2028, accounting for over 50% of all mobile subscriptions. This indicates that 5G will emerge as the primary mobile access technology in 2028. Concurrently, 4G network subscriptions continue to rise, reaching 5.2 billion during Quarter 1 of 2023. However, these subscriptions are expected to decline to approximately 3.8 billion by the end of 2028 as users transition to 5G networks.

As the Philippines enters its journey towards integrating 5G networks into its telecommunication landscape, the need to ensure robust network performance and connectivity gains great importance.

As of April 2023, 105 cities in the Philippines have 5G network coverage, an increase from the same month last year. All three telecommunication providers have been rolling out 5G networks nationwide to offer better network services to their clients and to maximize the potential of such technology. However, this transition is not without its challenges. The unique geographical and infrastructural characteristics of the Philippines introduce hurdles in deploying and optimizing 5G networks to cater to diverse urban and rural environments.

The rapid deployment of 5G networks is reshaping the telecommunications landscape, promising faster data speeds and lower latency for users. However, this rapid advancement poses a substantial challenge, the absence of a user-friendly and accessible solution for assessing and understanding 5G signal strength and quality at specific cell sites across the country. Traditional signal analysis tools, designed for technical experts, are often complex and lack accessibility for non-technical users, including business owners and the broader population.

This lack of accessible analysis tools hampers efficient network optimization, troubleshooting, and data-driven decision-making, affecting both telecommunications providers and users. With the critical need to evaluate and enhance 5G network performance, the Philippines requires a practical solution that bridges the gap between technical and non-technical users. This project seeks to address this problem by developing a portable and user-friendly device, making basic 4G and 5G signal analysis accessible to a wider audience, and ensuring that the promise of 4G and 5G technology is realized through reliable and high-quality connectivity experiences for all.

This innovative undertaking aims to address a crucial need in the telecommunications field. It aspires to simplify the complex process of 4G and 5G signal analysis by creating an accessible and intuitive tool. This hardware device facilitates straightforward, real-time measurement and visualization of 4G and 5G signal strength, empowering users, regardless of their technical expertise, to engage in effective signal analysis. Additionally, the project incorporates essential data logging capabilities for capturing signal strength metrics, further enhancing its utility in assessing and optimizing 4G and 5G network performance.

The project leverages widely available and affordable hardware components, ensuring feasibility and scalability in the context of Philippine cell sites. The devices' design places a great emphasis on user-friendliness, boasting a user-friendly interface that simplifies signal strength measurement and offers real-time visualization. Furthermore, the project implements basic data logging functionalities, enabling the capture and storage of vital signal strength data. Rigorous on-site testing, conducted in a specific location within the Philippines, forms a crucial part of the methodology, evaluating the device's performance and usability in its intended environment.

On top of these aims yields results of paramount significance. The project presents

a comprehensive analysis of 4G and 5G signal strength, contextualized within the unique setting of Philippine cell sites. These insights are derived from data collected using the device, underscoring its important role as an accessible tool for signal strength monitoring. The user-friendly interface seamlessly translates raw data into understandable visualizations, contributing to a holistic understanding of 4G and 5G network performance in the chosen location. This project underscores the simplicity and accessibility that a dedicated hardware tool can bring to the realm of 4G and 5G signal analysis.

As the Philippines strives to bridge the digital divide and embrace the potential of 5G technology, this project contributes to the ongoing discourse surrounding telecommunications advancements. The outcomes of this research hold to achieve and activate the growth of an interconnected digital ecosystem that empowers industries and enriches lives.

General Objective

The general objective of the study was to develop a portable 4G and 5G Network Basic Signal Analysis Device, specifically tailored for use at cell sites in the Philippines.

Specific Objectives

The specific objectives of this study were as follows:

1. Design and construct a portable 4G and 5G Network Basic Signal Analysis device, incorporating widely available and affordable components.
2. Create a user-friendly interface for the device, enabling straightforward real-time measurement and visualization of 4G and 5G signal parameters such as network service provider, access technology, signal strength, signal quality, cell site information, longitude, latitude, and altitude of the location.
3. Implement basic data logging capabilities within the device for capturing and storing essential basic signal analysis matrix.
4. Conduct on-site testing of the device at cell sites in the Philippines specifically in the city of Sorsogon to evaluate its performance and usability within the local context.
5. Analyze and present the collected data to gain insights into 4G and 5G network performance in the selected Philippine cell sites.
6. Demonstrate the simplicity and accessibility of 4G and 5G signal analysis using the hardware tool.
7. Determine the systems' quality based on ISO/IEC 25010:2011 in terms of

    7.1 Functional Suitability
    7.2 Performance Efficiency
    7.3 Compatibility
    7.4 Usability
    7.5 Reliability
    7.6 Security
    7.7 Maintainability
    7.8 Portability

8. The device be validated by two (2) IT experts, one (1) Telecommunications engineer, and two (2) RF engineers from National Telecommunications Commission (NTC) Region 5.

Scope and Delimitation

The study has set specific boundaries to define the scope and capabilities of the developed hardware device. First, its focus was strictly localized to the Philippines, limiting the generalizability of findings to regions with distinct network infrastructures, regulations, and environmental conditions. Second, the device concentrated on basic

signal analysis, intentionally excluding more advanced features that might provide deeper insights into the overall performance of 4G and 5G networks. This project aimed to maintain reliability and simplicity. Additionally, the study did not delve into regulatory aspects, omitting considerations related to the legal and compliance dimensions of deploying such devices.

Furthermore, the device's software interface was designed exclusively for Windows operating systems, restricting accessibility for users with Linux, macOS, or other operating systems. Compatibility with diverse operating systems was not within the scope of this study. Lastly, the device's module adapter featured a single nano SIM card slot, requiring users to manually change the SIM card to test different cellular networks. This limitation may impact the efficiency and user-friendliness of individuals needing to switch between various networks during testing.

In terms of validation, the developed hardware device underwent a rigorous evaluation process by experts in the field. The device's functionality and performance were validated by two (2) IT experts, ensuring that the technology adhered to established standards in information technology. Additionally, one (1) Telecommunications Engineer assessed the device's capabilities, ensuring its compatibility with prevalent network infrastructures and protocols. Furthermore, two (2) RF engineers from the National Telecommunications Commission (NTC) Region 5 offer insights into the functionalities and technical aspects of the project. This varied group of evaluators possessed extensive experience, allowing them to examine the device comprehensively from different technical perspectives. The evaluation concentrated solely on technical excellence since the device was not meant for deployment, excluding considerations related to regulatory compliance.

Significance of the Study

This study is deemed significant for the following:

Aemilianum College Inc. The project's association with innovative research enhances the school's attractiveness to prospective students. It may attract individuals interested in pursuing degrees or careers in technology-related fields, contributing to increased enrollment.

Telecommunications Service Providers. Telecommunications companies operating in the Philippines stand to gain significant benefits from this study. The data of portable 4G and 5G Network Basic Signal Analysis give insights and real-time basic signal analysis capabilities that will assist these providers in optimizing 4G and 5G networks, enhancing service quality, and ensuring a more seamless connectivity experience for their customers.

Network Engineers and Technicians. Professionals responsible for maintaining and enhancing 4G and 5G networks, including network engineers and technicians, find value in this study. The device's user-friendly interface and straightforward basic signal analysis tools can simplify their tasks, making network management more efficient and effective. Engineers and technicians can use the device for quick field assessments of 4G and 5G network coverage and performance, aiding in network optimization and troubleshooting.

Businesses and Enterprises. Businesses and enterprises reliant on the accuracy and reliability of 4G and 5G connectivity benefited from this study. They can use this to monitor the quality of network connections, ensuring uninterrupted operations and improved customer experiences.

Government Regulatory Bodies. Regulatory bodies overseeing telecommunications in the Philippines can leverage the findings of this study to inform policies and regulations related to 4G and 5G technology. It provides valuable data on network performance and usability, aiding in the formulation of informed decisions and standards.

Academic and Research Communities. Researchers and academics in the fields of telecommunications, network engineering, and technology benefited from the data that was gathered throughout the study and the accuracy of the device. It serves as a practical reference for future research endeavors in 4G and 5G technology and basic signal analysis.

Students and Educators. Educational institutions teaching telecommunications, networking, or related fields can use the device as a practical teaching tool to demonstrate real-world 4G and 5G signal analysis.

Network Administrators. IT professionals can employ the device to identify and address 4G and 5G signal issues in corporate networks, ensuring that employees have reliable connectivity.

General Users. Every day consumers can use this device to check the 4G and 5G signal strength at homes, workplaces, or other locations. It helps identify areas with weak signal reception and potentially optimize their connectivity experience.

Travelers. Travelers can carry the device to assess 4G and 5G signal availability and quality at different destinations, helping to plan the connectivity needs during trips.

Researchers. Researchers studying 4G and 5G technology and network performance may use the device to collect data for studies and analyze signal strength trends in various locations.

Gap Bridged by the Study

In the world of 4G and 5G technology research, there is a clear need for a simple and user-friendly tool that can analyze technology signals effectively. Think of it as a Portable 4G and 5G Network Basic Signal Analysis device. While some researchers have explored advanced decoding algorithms for 4G and 5G and others have set up 5G testbeds, these efforts often focus on specialized aspects of 5G research.

What is missing is a tool that is accessible to everyone and easy to use. This is where the work of Herrera, J. A., Muro, A. A., Tuason III, P. L., Alpano, P. V., & Pedraza, J. R. comes in. They have pioneered millimeter-wave radar sensing to help the deaf and hard-of-hearing community in the Philippines.

Additionally, Panaligan, N. A. P., Aringo, M. Q., & Ella, V. B. are exploring Wireless Sensor Networks (WSN) for agriculture, but there is still a gap in creating a versatile and user-friendly device for simplifying 5G signal analysis.

The portable 5G basic network analysis aims to fill this crucial gap by making 4G and 5G network basic signal analysis accessible and easy to understand. This aligns with the broader trends in 5G technology research and innovation discussed in the synthesis.

Conceptual Framework

The conceptual framework of a Portable 4G and 5G Network Basic Signal Analysis Device, Agile

project methodology was implemented. The process began with the definition of project requirements, outlining essential functionalities, user interface features, and performance criteria tailored to specific use cases and the local context.

The design phase emphasized the incorporation of widely available and cost-effective components, coupled with the development of a user-friendly interface that enables real-time measurement and visualization of key 4G and 5G signal parameters. Employing agile development principles, the iterative construction of the device ensured flexibility to adapt to evolving project needs throughout the development process.

Comprehensive testing, including functional and performance assessments, was followed by on-site testing at specific cell sites in the Philippines to evaluate adaptability and performance in real-world scenarios.

Analysis of on-site testing data provided insights into 4G and 5G network performance, while a review against ISO/IEC 25010:2011 standard ensured adherence to high-quality benchmarks. Validation involves scrutiny by IT experts, Telecommunications Engineer, and Radio-Frequency engineers from the National Telecommunication Commission (NTC).

Following successful validation, the official launch of the device initiated ongoing maintenance processes to address post-launch issues, incorporating user feedback and leveraging technological advancements for continuous improvement. This approach ensured the sustained reliability and adaptability of the device in response to evolving network requirements.

Hardware Requirements

To design a portable 4G and 5G signal analysis device, careful consideration of hardware components is crucial. Balancing mobility and high-performance data processing is essential. The following outlines the key hardware requirements for effective analysis of 4G and 5G signals.

Table 3.1 Hardware Requirements

Hardware	Specifications	Sample Image	Quantity	Price
Quectel RM500U-CN	Product Type**:** 5G NR Sub-6GHz Module (M.2) 5G Support: 3GPP Release 15 NSA/SA, Sub-6 GHz (n1/n28*/n41/n77/n78/n79) LTE Support: FDD (B1/B2/B3/B5/B7/B8/B20/B28), TDD (B34/B38/B39/B40/B41) WCDMA Support: B1/B2/B5/B8 Data Rates**:**5G SA Sub-6: DL 2Gbps, UL 1Gbps 5G NSA Sub-6: DL 2.2Gbps, UL 575Mbps LTE: DL 600Mbps, UL 150Mbps UMTS: DL 42.2Mbps, UL 11Mbps Interfaces: UART, PCIe, (U)SIM, USB 2.0/3.0, SDIO, SPI, PCM/I2S, I2C, Ant Software Support: USB Drivers: Win 7/8/8.1/10, Linux 2.65.12, Android 4.x11.x PCIe Drivers: Linux 3.10~5.12 RIL Drivers: Android 4.x~11.x USB RNDIS/ECM/NCM, MBIM Drivers Temperature Range: -30°C ~ +60°C Dimensions: 30.0 × 52.0 × 2.3mm Weight: ~8.9g		**1**	**6,159.24**
XT-XINTE Network Adapter	3G/4G/5G Module to Type C/USB 3.0 Adapter Supports USB 3.0/3.1 interface of M.2 cards (socket 2 ssic-base WWAN) Compatible with 2G GSM, GPRS, 3G, CDMA, WLAN, WWLAN, MODEM HSPA, GPS, 4G WiMAX, LTE, M.2 5G modules NANO SIM Card Slot 2.4G/5G Antenna included USB 3.0 Type A Male to Desktop or Notebook PC Supports key card size B 3042/3052 M.2		**1**	**1,571.00**

GT-U7 GPS module	Size 27.6x26.6 can be inserted in line or select patch (with positioning hole) 2. Working voltage: 3.6V-5V (or direct usb power supply) 3. Working baud rate: 9600 (can be modified by yourself) 4. With IPEX antenna interface, default distribution of active antenna for quick positioning Onboard E2PROM can save parameter data		**1**	**360.00**

Table 3.1 presents the essential components required for the development of the 4G and 5G network basic signal analysis device, featuring the Quectel RM500U-CN 5G NR Module as the core technological component. This module, in a compact M.2 form factor, seamlessly integrates into the device's hardware framework and offers versatility by supporting 5G NR, 4G LTE, and 3G WCDMA technologies. With compatibility across various frequency bands for 5G NR and multiple LTE bands, it ensures effective signal capture from diverse cellular networks.

The Quectel RM500U-CN module impressively provides a range of interfaces, including UART, PCIe, USB 2.0/3.0, SDIO, SPI, and I2C, facilitating smooth communication and data exchange with other hardware components. Its operational temperature range (-30°C to +60°C) enhances adaptability for deployment in diverse environmental conditions.

In addition to the Quectel module, the XT-XINTE Network Adapter serves as a bridge to external devices, supporting M.2 cards for 2G, 3G, 4G, and 5G technologies. With a USB 3.0 Type A Male interface, it ensures high-speed data transfer, enhancing signal analysis efficiency. The adapter includes a Nano SIM Card Slot for cellular connectivity and is equipped with 2.4G/5G antennas for improved signal reception, ensuring accurate and consistent signal capture in challenging network environments.

To further enhance the device's functionality, the GT-U7 GPS module is incorporated. This module, with a size of 27.6x26.6, can be inserted in a line or select patch (with a positioning hole). Operating at a voltage range of 3.6V-5V (or direct USB power supply) and a working baud rate of 9600 (modifiable by the user), it features an IPEX antenna interface and comes with an active antenna for quick positioning. The onboard E2PROM allows the module to save parameter data, contributing to its overall utility in signal analysis and location-based applications.

The combination of Quectel RM500U-CN 5G NR Module, XT-XINTE Network Adapter, and GT-U7 GPS module enhances the portable signal analysis device's capabilities, enabling professionals to capture, analyze signals, and obtain location data reliably in diverse operational scenarios.

Software Requirements

This section outlines the software requirements essential for designing the portable 4G and 5G network basic signal analysis device.

Table 3.2 Software Requirements

Software	Specification
Quectel USB Driver	Supports Quectel modules. Facilitates communication between the modules and the system.

Microsoft Visual Studio 2022	Integrated development environment (IDE) by Microsoft. Supports multiple programming languages. Offers a comprehensive set of tools for software development.
Microsoft Access Database Engine	32-bit and 64-bit versions. Supports access to various Microsoft Office file formats, including Access (.accdb), Excel (.xlsx), and others. Provides ODBC (Open Database Connectivity) and OLEDB (Object Linking and Embedding, Database) drivers for connecting to Access databases.

Table 3.2 outlines software components that complement the hardware, playing integral roles in data acquisition, management, analysis, and user interaction. The Quectel USB Driver assumes a critical role in establishing efficient communication with Quectel modules, serving as a link in connecting and interacting with the Quectel RM500U-CN module. This drivers' significance lies in its ability to facilitate smooth data acquisition, management, and analysis processes, forming the backbone of the system's functionality. The reliability of the communication facilitated by the Quectel USB Driver is important for ensuring the accurate and timely exchange of information between the software and Quectel hardware.

Microsoft Visual Studio 2022 serves as the central hub for developing and managing the core application logic in the software development lifecycle. As an Integrated Development Environment (IDE), Visual Studio offers tools for writing, debugging, and managing Python code, ensuring effective coordination with the Quectel and GPS modules.

Additionally, the Microsoft Access Database Engine integrates seamlessly into this software ecosystem, enhancing data storage and retrieval capabilities.

Stakeholders

This section consists of various individuals, groups, and organizations who have an interest in or can be impacted by the project. It provides a comprehensive overview of the diverse stakeholders involved.

Table 3.3 Stakeholders

Stakeholders	Stakeholders' Subgroups	Task
Aemilianum College Incorporated	Mathematical Ideas Nurtured and Develop through Science (MINDS) ZerOne	To secure and maintain the testing device for project planning, data collection and analysis, device development, and report generation. The institution will also coordinate collaborations with other stakeholders and provide academic guidance.
System Administrators	Anyone entitled to administer the system	To secure and maintain the device that holds the legacy of the developers.
Telecommunication Companies	Globe Telecom Smart Communication Dito Telecommunity	To collaborate in terms of data collection at cell sites, providing insights into network configurations, and potentially implementing recommendations for network optimization.
Government	Department of Information and Communications Technology (DICT) National Telecommunications Commission (NTC)	To provide data and findings related to 5G network performance in the Philippines.

Telecom operators	Telecom Engineers and Technicians	To provide fast and more reliable network speed.
IT experts	Any Information Technology (IT) experts	To check and maintain the condition of the device, and study for further innovation.
Academic and Research Institutions	Any researcher who would like to take the device as a basis for research purposes	To assist in data analysis, offer research guidance, and possibly use the device for their studies, thereby contributing to the academic community's understanding of 5G networks.
Users	Anyone who benefits from this device	To use the device for benefits

Table 3.3 shows the stakeholders, and stakeholder subgroups along with their potential tasks and roles.

Aemilianum College Incorporated. As the institution leading this study, Aemilianum College Incorporated plays an important role in securing and maintaining the testing device essential for project planning, data collection, analysis, device development, and report generation. The institution also serves as a coordinator for collaborations with other stakeholders and provides academic guidance, ensuring the study's successful execution and integration into the academic community.

System Administrators. System administrators, encompassing anyone entitled to administer the system, bear the responsibility of safeguarding and maintaining the device holding the legacy of the developers. Their task is critical in ensuring the continued functionality and integrity of the system, preserving the knowledge and insights gained from the project.

Telecommunication Companies. These telecommunications giants are key collaborators in the study. They actively engage in data collection at cell sites, offering valuable insights into network configurations. Additionally, they have the potential to implement recommendations stemming from the study for network optimization. Their involvement is important in improving 5G network performance in the Philippines.

Department of Information and Communications Technology (DICT). The DICT assumes a pivotal role in furnishing essential data and findings relevant to 5G network performance. Its contributions are instrumental in shaping regulatory decisions and policies, thereby influencing the development and compliance of the telecommunications infrastructure within the country. The DICT's active involvement underscores its commitment to advancing information and communications technology for the overarching benefit of the nation.

National Telecommunications Commission (NTC). The NTC, as a key government entity, significantly contributes pertinent data and insights about 5G network performance. Its engagement is critical in guiding regulatory decisions and formulating policies that ensure the effective development and adherence of the telecommunications infrastructure in the Philippines. The NTC's role exemplifies its responsibility in overseeing and regulating the telecommunications sector, with a focus on promoting efficiency, fairness, and technological advancement for the collective progress of the nation.

Telecom Engineers and Technicians. Telecom engineers and technicians are tasked with the mission of delivering fast and more reliable network speeds. Their expertise is crucial in implementing the recommendations and enhancements derived from the study, ultimately benefiting consumers and businesses relying on efficient telecommunications services.

IT Experts. A broad category encompassing any Information Technology (IT) experts, these individuals are entrusted with the responsibility of monitoring and maintaining the device's condition. Furthermore, they engage in continuous study and innovation, exploring ways to enhance the device's capabilities and contribute to the evolution of 5G technology.

Academic and Research Institutions. Academic and research institutions, represented by researchers interested in leveraging the device for research purposes, form a collaborative network. They assist in data analysis, offer research guidance, and may use the device as a foundation for their studies. This collective effort enhances the academic community's understanding of 5G networks, fostering innovation and knowledge dissemination.

Users. Lastly, the end-users, comprising anyone who benefits from this device, are the ultimate beneficiaries. Their role is to utilize the device for various purposes, benefiting from the improved 5G network performance and connectivity made possible through this comprehensive study.

Table 3.5 Schedule and Timeline of the Capstone Project Development

Activity	Month																					
	1				2				3				4				5				6	
Requirements																						
Cost																						
Assumption																						
Risk																						
Dependencies																						
Success Metrics																						
Timelines																						
Design																						
Scope of the Project																						
General traffic flow of each component																						
Integration points																						
Development																						
Programming																						
Testing and Deployment																						
Review and Validation																						
Launch and Maintenance																						

Table 3.5 shows the schedule and timeline which provide a comprehensive overview of the project's structure and progression, ensuring that each phase aligns with the project's objectives and contributes to its successful completion.

Requirements Phase

During the Requirement Phase, a systematic approach was employed to achieve specific objectives within a designated timeframe in the development of the Portable 4G and 5G Network Basic Signal Analysis Device. The researchers diligently adhered to all requirements essential for the formal processing of the project. To initiate this process, the researchers sought title approval from the panelists, actively engaging in soliciting suggestions and recommendations. This collaborative effort laid the groundwork for a well-informed project, ensuring alignment with academic standards and objectives.

Simultaneously, acquiring the necessary components played an integral role in this phase. The researchers proactively managed the procurement process, including seeking approval and gathering information from the Regional National Telecommunications Commission (NTC-V) and local telecom providers. Contacting these entities allowed the researchers to inquire

about the availability of 4G and 5G technology within the region. This strategic move aimed to gather important information about the readiness of 4G and 5G infrastructure in the area, adding a practical dimension to the project. The timeliness of the study was influenced not only by the lead times associated with purchasing and arrival of the components but also by the need to incorporate the latest technological advancements.

Furthermore, thorough examination and verification of each hardware requirement were conducted to ensure compatibility with other necessary components

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Design Phase

After gathering requirements, researchers' focus shifts to crafting a project design. This involved detailing technical specifications, planning system architecture, and creating user-friendly interfaces.

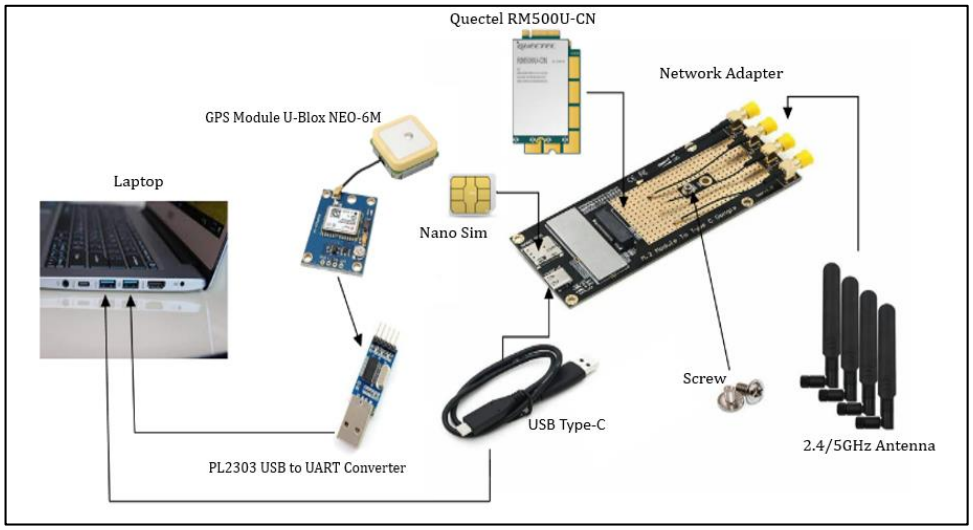

Figure 4.1 Block Diagram of the Device

Figure 4.1, which showed the Block Diagram of the Device, illustrated the systematic approach to designing the Portable 4G and 5G network basic signal analysis device. The key component of the device was the Quectel Rm500u-cn, the 5G module attached to a network adapter to convert M2 to USB type-C for compatibility with the 5G module to transfer data. It was attached with screws to avoid removal. Additionally, a 2.4/5GHz antenna was connected to the network adapter to capture signals from the cell sites. Next, the adapter was connected to USB type-C to allow data transfer from the 5G module to the laptop.

Furthermore, the GPS module U-blox Neo-6m was connected to the laptop using the PL2303 to UART converter to facilitate communication between the laptop and the GPS module. This was done to determine the location during onsite testing. This meticulous integration and connection setup form a foundation for the subsequent phases, ensuring the reliability and effectiveness of the Portable 4G and 5G Network Basic Signal Analysis Device.

Development Phase

The Development Phase of the Portable 4G and 5G Network Basic Signal Analysis Device project commenced with the implementation of the meticulously crafted design. Utilizing the specifications and architecture outlined in the design phase, the researchers engaged in the actual construction and coding of the system

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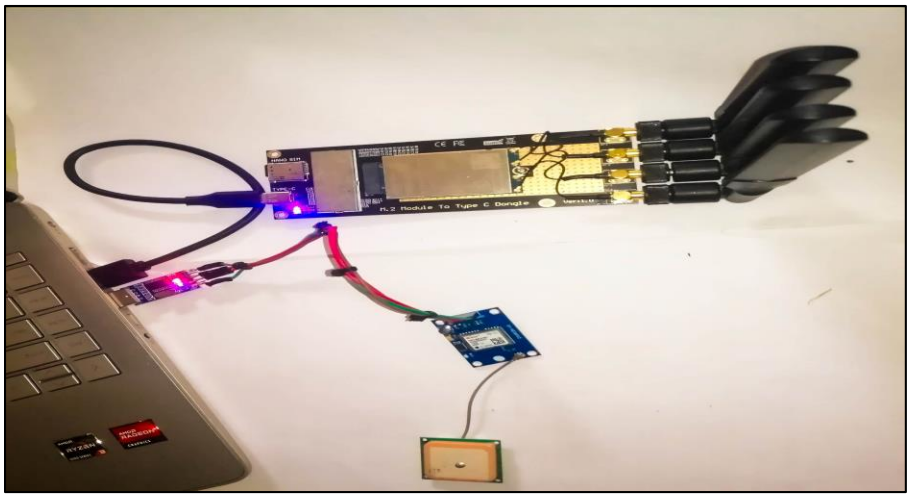

Figure 4.2 Actual Connection of the Device

Figure 4.2 showed the successful connection of the device, showcasing a seamless integration of all components as initially planned during the design phase. The compatibility of each element has been confirmed, validating the well-thought-out decisions made earlier in the design process. Following the connection of hardware requirements, the actual coding phase was implemented.

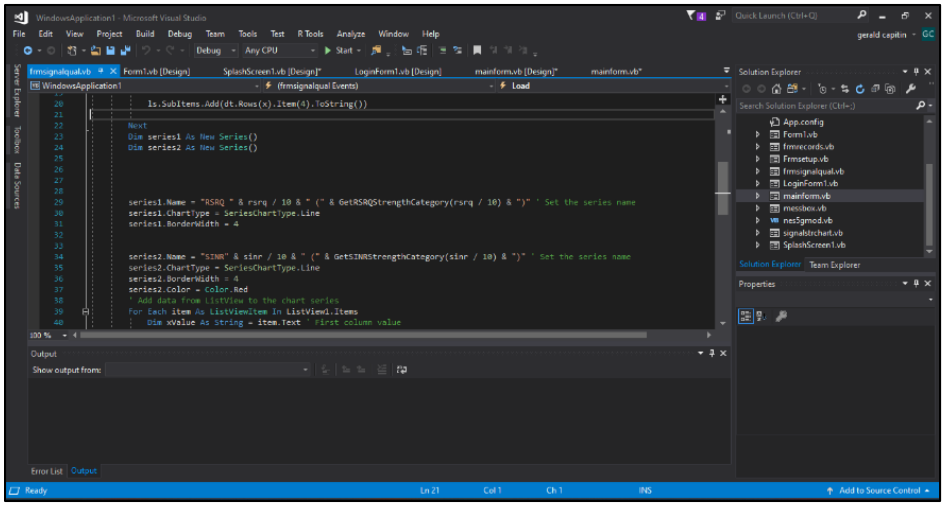

Figure 4.3 Coding

Figure 4.3 displayed an overview of the coding process in bringing the designed Portable 4G and 5G Network Basic Signal Analysis Device to life. This phase involved the translation of specified requirements and architectural plans into executable software, marking the transition from conceptualization to practical functionality. This iterative coding process, coupled with rigorous testing, ensures the accuracy, reliability, and user-friendliness of the system as it progressed toward meeting its defined objectives.

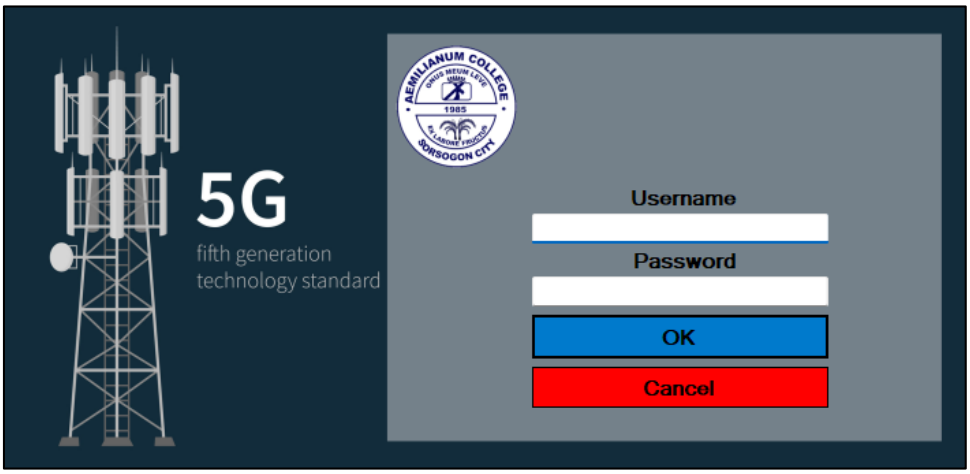

Figure 4.4 Login Form

Figure 4.4 reflected the accessibility login form of the Portable 4G and 5G Network Basic Signal Analysis Device. This login feature was designed to provide controlled access to the device's functionalities. Users, both professionals and general users alike, can access and explore the collected information. The login was implemented to ensure responsible usage and protect the privacy of information related to the tested cell sites. In essence, the login form serves as a security measure, contributing to the overall confidentiality and integrity of the acquired testing data.

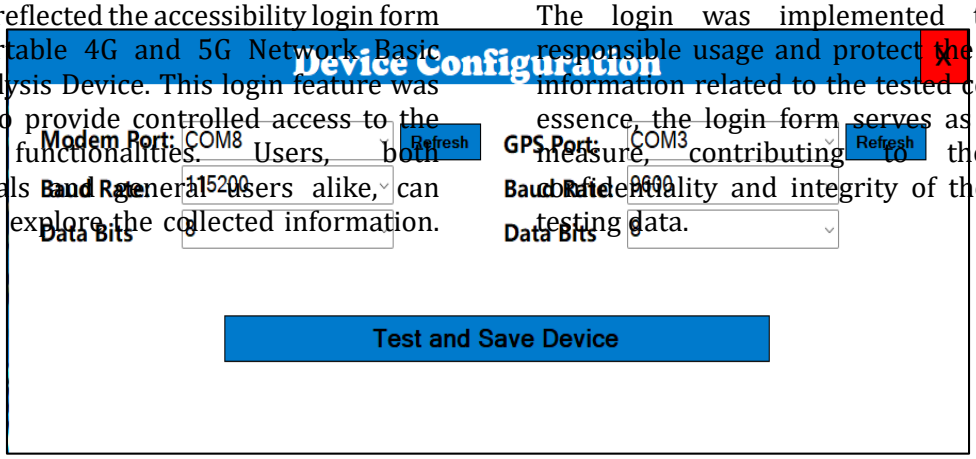

Figure 4.5 Device Configuration Form

Figure 4.5 displayed the interface for selecting the appropriate device configuration. At this stage, the user can choose the specific communication ports to which the device is connected. The correct device configuration is important, as an improper configuration can lead to a lack of communication between the laptop and the device. After selecting the proper ports, the network testing process can proceed
.

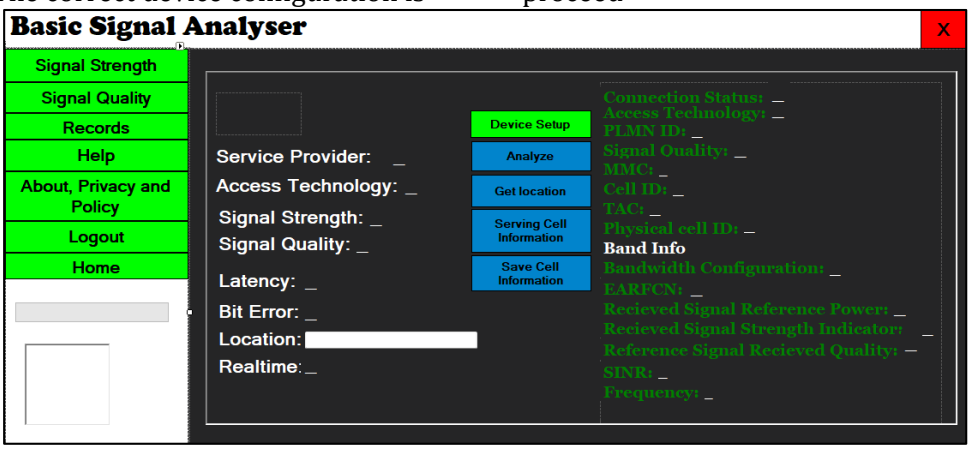

Figure 4.6 Main Dashboard of the System

Figure 4.6 served as the main dashboard of the software, presenting the basic signal parameters in this section. The gathered information provides insights into the performance offered by a specific telecommunication company and pinpoints the exact location where the device is conducting tests.

Testing and Deployment Phase

The testing phase was initiated to evaluate the functionality of the developed portable 4G and 5G network basic signal analysis device and its software. During this phase, testing procedures were employed to assess the device's performance according to the software program's intended features.

The researchers found that the device operated following the programmed features, demonstrating accuracy and reliability in signal analysis.

Review and Evaluation Phase

Upon Review and Evaluation Phase of the portable 4G and 5G basic signal analysis device, valuable feedback was received. The panelists recommended several enhancements to ensure the device's optimal functionality as both an analysis tool and an analyzer. The panelists suggested changes to the terms used in the user interface to enhance clarity and avoid potential confusion for users. Adjustments shall made to align the language with industry standards and the specific objectives of the researchers. To improve user experience, modifications were proposed for the appearance of the user interface. The changes aimed to enhance the visual representation of signal data, providing users with a more intuitive and informative display.

The panelists emphasized the importance of a real-time display of signal data for immediate analysis. In response to this

recommendation, the researchers implemented enhancements to enable a dynamic and instantaneous presentation of signal metrics.

Upon receiving valuable feedback and recommendations from the panelists during the testing and evaluation phase, the researchers recognized the importance of incorporating these insights to enhance the developed portable 4G and 5G network basic signal analysis device.

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Design Phase 2

Following Agile principles, the researchers embraced the flexibility to iterate and improve by returning to the design phase. This phase allowed for a reevaluation of the initial design, considering the panelists' recommendations and ensuring that the device's features align seamlessly with the researchers' specific objectives.

During the design refinement phase, adjustments were made to the device's architecture, user interface, and functionalities. The team worked collaboratively to implement changes that would address the recommendations, focusing on optimizing the device for efficient signal analysis and aligning it more closely with industry standards.

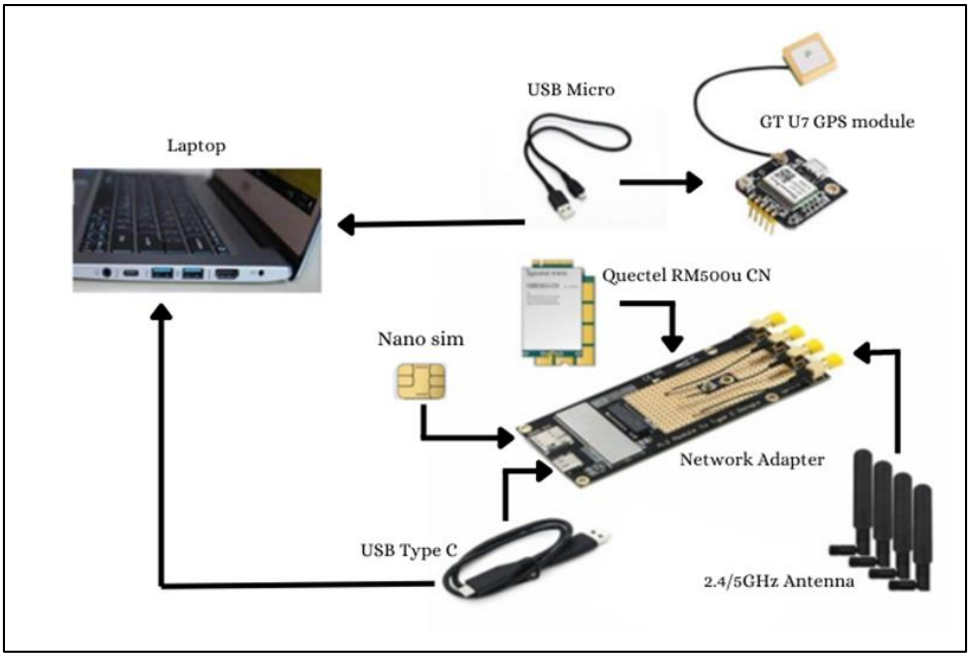

Figure 4.7 Block Diagram of the Device 2

Figure 4.7 illustrated the redesigned block diagram of the device. Notably, the GPS module has been upgraded to the GTU 7, and the connection method has been modified to USB Micro, diverging from the previous UART-based connection used by the U-Blox Neo-6M GPS module. This change was motivated by the superior sensitivity of the GTU 7 compared to the U-Blox Neo-6M GPS module, providing enhanced precision in location data acquisition.

Development Phase 2

Recommendations of the panelists aimed to guide the redevelopment process, addressing specific areas for improvement in the user interface, signal analysis precision, connection stability, code efficiency, real-time display, user feedback, and iterative testing. Implementation of these recommendations ensures that the device evolves to meet the highest standards of functionality and user satisfaction.

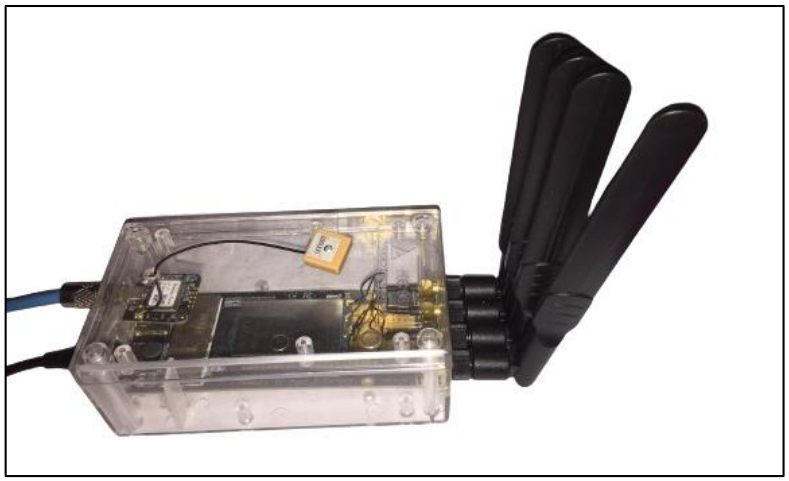

Figure 4.8 Actual Connection of the Device 2

Figure 4.8 displayed the physical connections and layout of the redeveloped device. This includes the integration of components, the enclosure design, and the placement of key modules. The plastic enclosure served as the protective housing for the device, safeguarding its internal components. The choice of materials ensured durability while maintaining the necessary transparency for signal reception, especially for the GPS module.

The GPS module was strategically placed over the SIM card slot of the 5G module adapter. This placement optimized space utilization within the device while maintaining a compact and efficient layout. It also ensured that both modules coexist harmoniously, contributing to a streamlined design. The GPS antenna was strategically positioned over the device enclosure. This placement was chosen to maximize signal reception without compromising the structural integrity of the device. It contributes to the device's ability to acquire precise location data.

```
End If

' serialPort.WriteLine("AT+QSPN" & vbCrLf)
ProgressBar1.Value = i
' Wait for a short period to receive the response
SendATCommand("AT+QSPN" & vbCrLf)
Progressbar1label.Text = "getting provider.."
Me.lblprovider.Text = knownetwork(rtdiag.Text)
```

```
'ProgressBar1.Value = i * 10
SendATCommand1("AT+QENG=" & ControlChars.Quote & "servingcell" & ControlChars.Quote & vbCrLf)
Dim servingCellInfo As ServingCellInfo = qengservice(rtdiag1.Text)
' Me.lbltime.Text = servingCellInfo.Rssi
Dim ls As New ListViewItem
'ProgressBar1.Value = i
```

Figure 4.9 AT Commands

In Figure 4.9, the essential AT commands for retrieving network information were presented. The AT+QSPN command was utilized for querying the Service Provider Name (SPN) information. It played an important role in obtaining details about the current network provider. The AT+QENG command was employed to access engineering mode and retrieve comprehensive network-related information. This command provided a deeper insight into network parameters for analysis and optimization.

These AT commands were integral to the functionality of the developed device, enabling the retrieval of network data for analysis and monitoring.

```
3 references
Public Function qengservice(response As String) As ServingCellInfo
    Try


        Dim servingCellInfo As New ServingCellInfo()

        Dim qengIndex As Integer = response.IndexOf("+QENG:")
        Dim okIndex As Integer = response.IndexOf("OK")

        If qengIndex <> -1 AndAlso okIndex <> -1 Then
            ' Extract the substring containing the serving cell information
            Dim servingCellData As String = response.Substring(qengIndex, okIndex + 2 - qengIndex)

            ' Remove +QENG: and OK from the extracted substring
            servingCellData = servingCellData.Replace("+QENG:", "").Trim()

            ' Split the values using commas as separators
            Dim valuesArray As String() = servingCellData.Split(","c)

            ' Assign values to the ServingCellInfo object
            servingCellInfo.Networkstat = valuesArray(1)
            servingCellInfo.NetworkType = valuesArray(2)
            servingCellInfo.DuplexMode = valuesArray(1)

            servingCellInfo.PlmnCountryCode = valuesArray(4)
            servingCellInfo.PlmnNetworkCode = valuesArray(5)
            servingCellInfo.CellId = valuesArray(6)
            servingCellInfo.PhysicalCellId = valuesArray(5)
            servingCellInfo.TrackingAreaCode = valuesArray(4)
            servingCellInfo.PhysicalCellIdentifier = Integer.Parse(valuesArray(7))
            servingCellInfo.bandwidthcon = valuesArray(10)
            Dim ads As Integer
```

Figure 4.10 Coding & Parameters

Figure 4.10 served as a visual representation, unveiling the recoding of the system where AT commands seamlessly intertwine with the Graphical User Interface (GUI). Each element within this figure reflected the intentional crafting of a user-centric and functionally streamlined interface. The integration of AT commands with the GUI represented a paradigm shift in system design,

where the user experience was not only considered but optimized.

Central to this integration were the carefully defined parameters employed in this study. These parameters, meticulously chosen and implemented, play a pivotal role in shaping the user interface and determining the responsiveness of the system to AT commands. The deliberate selection of these parameters signified a commitment to a precise understanding of user interactions within the system.

Table 4.1 Signal Status Rubrics

Signal Status	Description
Excellent	The Signal Strength is exceptional, providing optimal performance and reliability.
Very Good	The Signal Strength is very strong, offering reliable performance with minor issues.
Good	The Signal Strength is good, with occasional fluctuations and minor issues.
Fair	The Signal Strength is fair, with noticeable fluctuations and occasional issues.
Poor	The Signal Strength is poor, resulting in unreliable performance and frequent issues.

Table 4.1 provides a qualitative assessment of the signal strength, categorizing it into different levels with corresponding descriptions. Signal Status refers to the current condition or strength of a signal being transmitted or received by a device. This classification is instrumental in evaluating the performance and reliability of the network signal, a critical aspect in the context of your portable 4G and 5G network basic signal analysis device. The basis of this information is derived from the Metageek Signal Status Basics.

Table 4.2 Reference Signal Received Quality (RSRQ)

RSRQ Range (dB)	Status	Description
Greater than -10	Excellent	Excellent signal quality, optimal connectivity
-10 to -15	Good	Good signal quality, reliable connectivity
-15 to -20	Fair	Fair signal quality, may experience some issues.
Less than -20	Poor	Poor signal quality, connectivity may be unreliable.

Table 4.2 presents a classification of Reference Signal Received Quality (RSRQ) based on different dB ranges. RSRQ takes into account both the RSRP and the interference and noise level in the channel. This parameter is crucial for assessing the quality of the received signal, offering valuable insights into the performance and reliability of the network.

Table 4.3 Received Signal Strength Indication (RSSI)

RSSI (dBm)	Status	Description
>-70 dBm	Excellent	Very strong signal, optimal connectivity
-70 dBm to -80 dBm	Good	Strong signal, reliable connectivity
-86 dBm to -100 dBm	Fair	Moderate signal, may experience some issues

<-100 dBm	Poor	Weak signal, connectivity may be unreliable
-100 dBm	No Signal	No detectable signal, likely out of range

Table 4.3 provides a classification of Received Signal Strength Indication (RSSI) based on different dBm ranges. RSSI is used to gauge the quality of the received signal and can help determine the strength of the wireless connection between devices. RSSI is a critical metric for evaluating the strength of the received signal, offering insights into the overall connectivity and performance of the network.

Table 4.4 Reference Signal Received Power (RSRP)

RSRP Range (dBm)	Status	Description
Greater than -80	Excellent	Very strong signal, optimal connectivity
-80 to -95	Good	Strong signal, reliable connectivity
-95 to -110	Fair	Moderate signal, may experience some issues
Less than -110	Poor	Weak signal, connectivity may be unreliable

Table 4.4 presents a classification of Reference Signal Received Power (RSRP) based on different dBm ranges. RSRP is a measurement used in LTE (Long-Term Evolution) and 5G wireless networks to indicate the power level of the reference signals received from the serving cell tower or base station at the user equipment (UE), such as a smartphone or modem. RSRP is a crucial parameter for assessing the power level of the received signal, providing insights into the strength and reliability of the network connection.

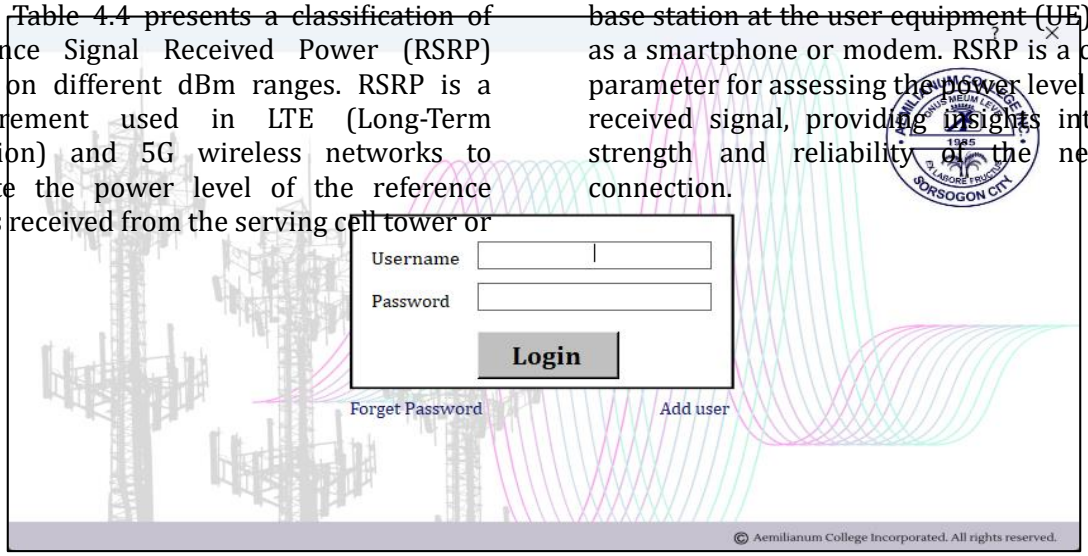

Figure 4.11 Login Form 2

In Figure 4.11, the redesigned log-in form represents a key component of the graphical user interface (GUI) where recommendations from panelists to enhance

user experience have been implemented. The log-in form was redesigned with a focus on user-friendliness. Panelist recommendations emphasized the importance of a clear and intuitive log-in process for seamless user interaction. The addition of a "Forgot Password" link provided users with a mechanism for account recovery. This feature was designed to assist users who may have forgotten their passwords, offering a straightforward and secured process for resetting their credentials. The introduction of an "Add User" functionality empowered administrators to manage user accounts efficiently. This feature was instrumental for system administrators, allowing them to create new user accounts and define access permissions.

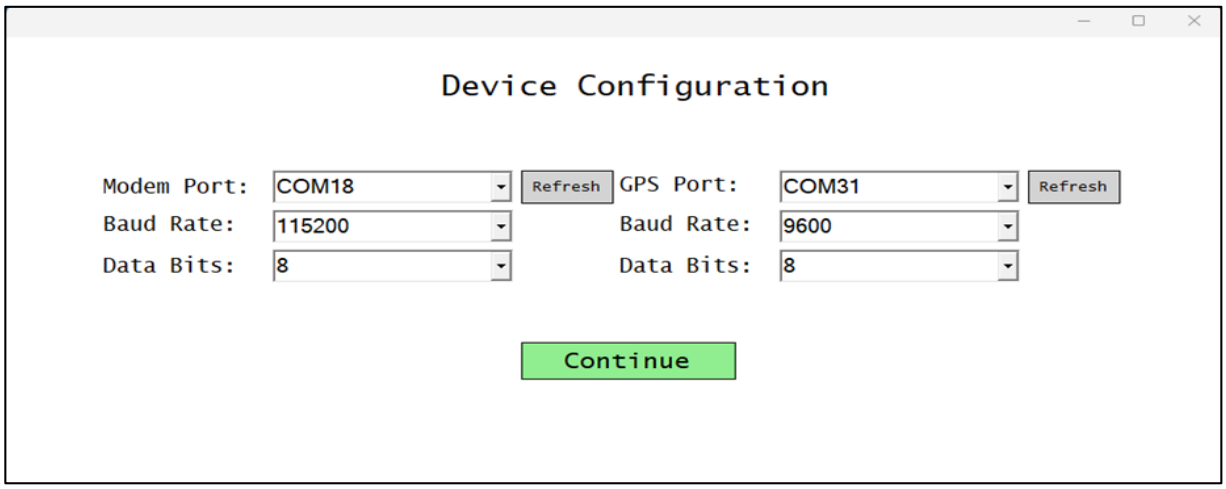

Figure 4.12 Device Configuration 2

In Figure 4.12, it can be observed the redesigned interface for choosing the suitable device configuration. At this point, users have the option to select the specific communication ports to which the device was currently linked. Ensuring the correct device configuration was important, as an inaccurate setup may result in communication issues between the laptop and the device. Once the appropriate ports were chosen, the network testing process can advance.

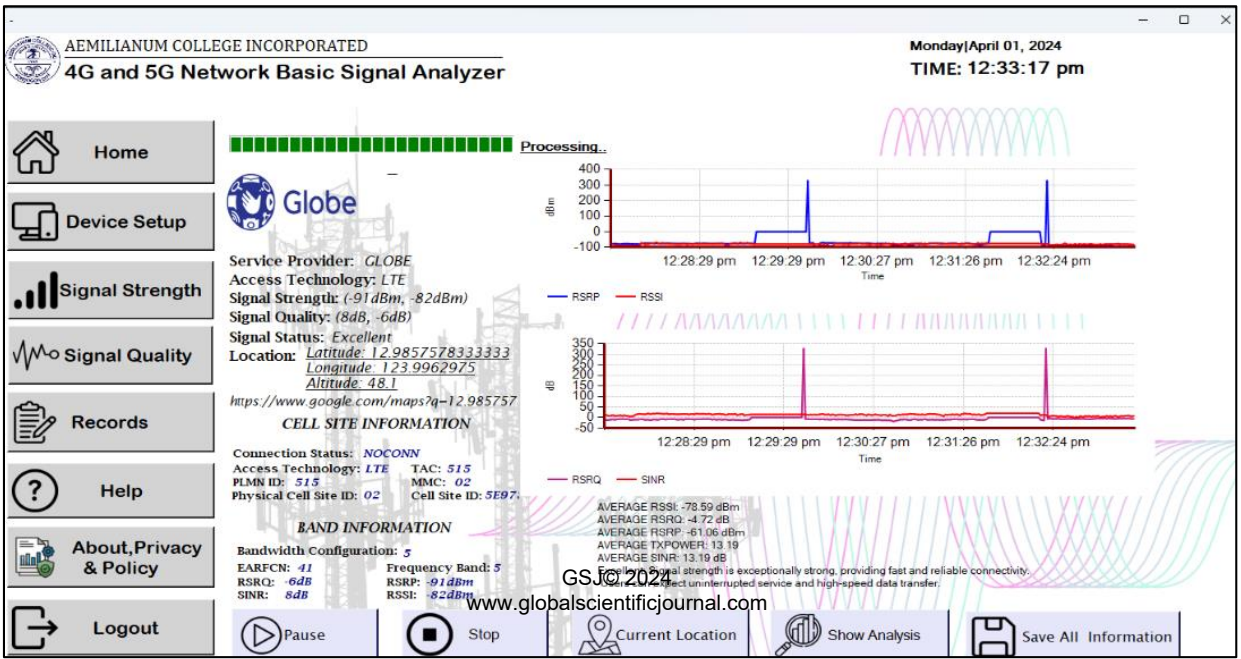

Figure 4.13 Main Dashboard of the System 2

Figure 4.13 acted as the primary dashboard for the device, showcasing fundamental signal parameters. In this section, essential changes have been implemented, aligning with the study's recommendations and objectives. Notable enhancements include real-time visualization of signals and a redesigned user interface. These modifications contributed to an enriched user experience and are in line with the evolving goals of the study. The presented information not only offered insights into the performance of a particular telecommunications company but also precisely identified the location where the device was performing tests.

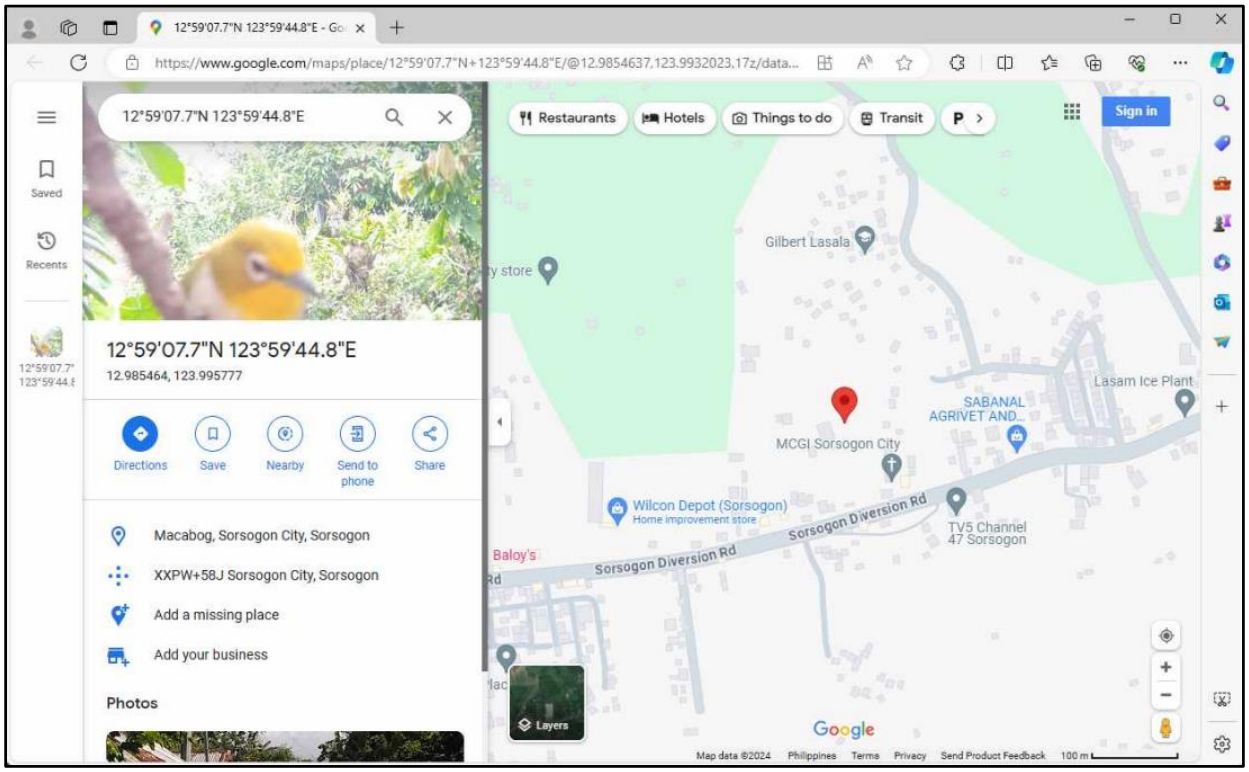

Figure 4.14 Location of the Device

Figure 4.14 displayed the Google Map interface, pinpointing the exact coordinates of its location. This feature enabled users to ascertain the geographical position of the device with precision, facilitating location-based services and enhancing user experience. By integrating Google Maps, users can visualize the device's whereabouts and leverage location-specific functionalities tailored to their needs.

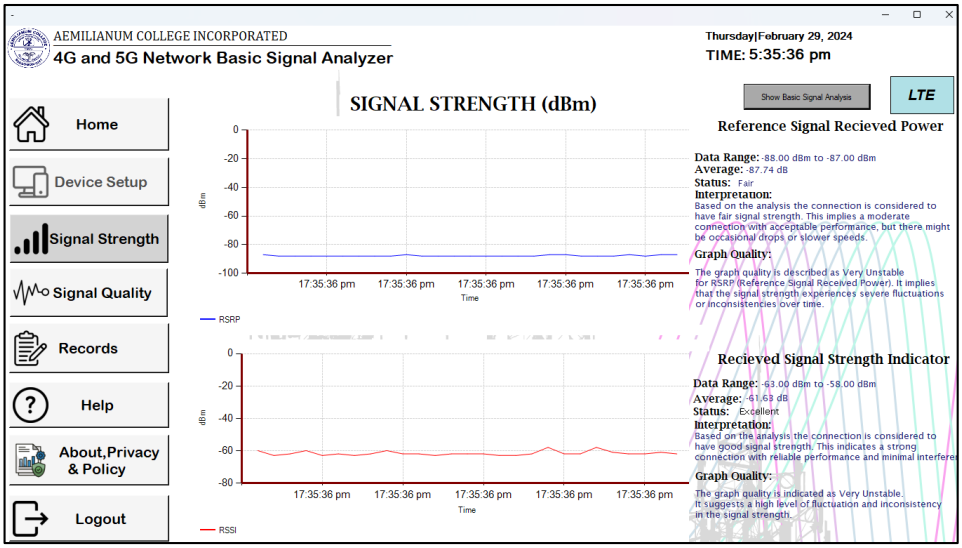

Figure 4.15 Signal Strength Form

In Figure 4.15, the Signal Strength section revealed a graphical representation of RSRP and RSSI. This section underwent enhancements as part of the study's objectives, now featuring real-time visualization of signal parameters. The presented graph offered a comprehensive analysis of the fetched data, providing valuable insights into the network's strength and signal reception. This graphical representation not only enhanced the user interface but also facilitated a more in-depth understanding of the signal performance, contributing to the device's overall analytical capabilities.

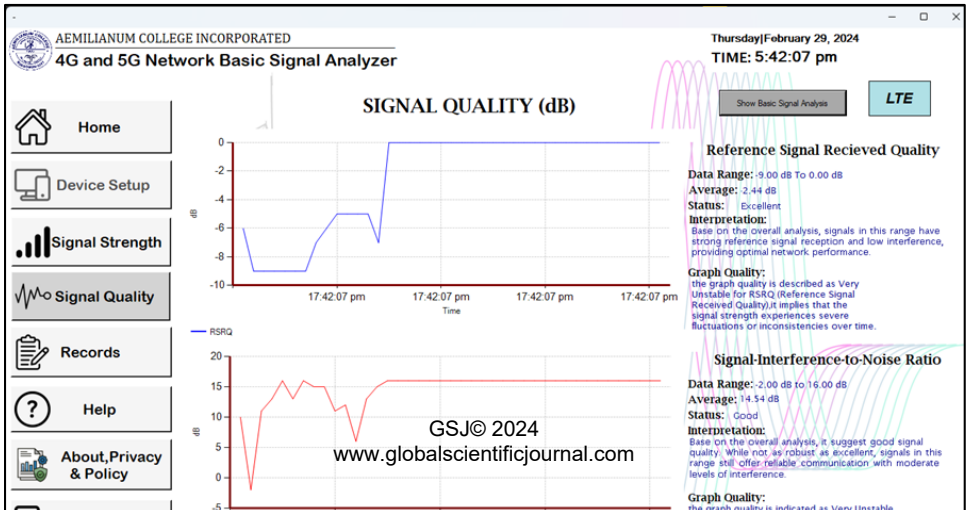

Figure 4.16 Signal Quality Form

In Figure 4.16, the Signal Quality section showcased the graphical representation of RSRQ and SINR. The graph provided a detailed analysis of the fetched data, offering insights into the quality of the network signals. The inclusion of RSRQ and SINR enhanced the device's analytical capabilities, contributing to a more comprehensive assessment of signal quality. This graphical representation not only refined the user interface but also aided users in gauging the effectiveness of the network, supporting informed decision-making during signal analysis.

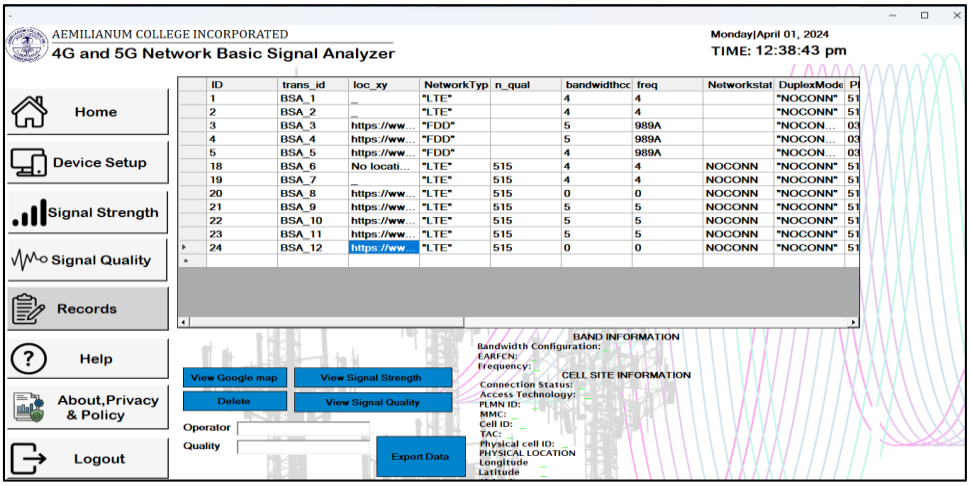

Figure 4.17 Records Form

In Figure 4.17 was a representation of the Records Form. It served as a central hub for storing and managing essential data captured by the portable 4G and 5G Network Basic Signal Analysis device. The section was meticulously designed to provide users with a comprehensive overview of recorded signal analysis matrices, including network parameters, signal strength, and geographical coordinates.

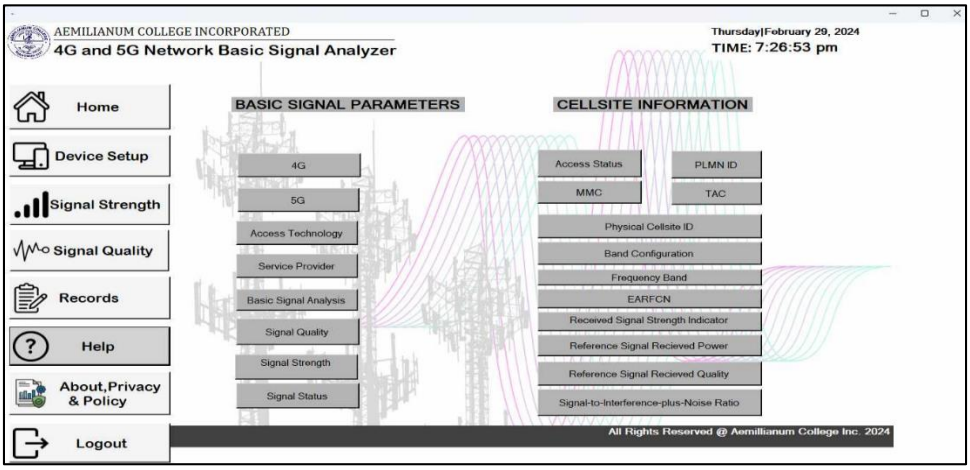

Figure 4.18 Help Form

Figure 4.18, presented the terminologies associated with basic signal parameters and cell site information. This section was crafted to align with the study's objectives, providing users with a clear reference point for understanding key terms. The inclusion of terminologies enhanced user knowledge, fostering a more informed and proficient user base. By presenting the intricacies of basic signal parameters and cell site information, this section served as an integral component in guiding users through the device's functionalities and promoting a user-friendly experience. The Help section not only enhanced the user interface but also acted as an educational tool, fostering an environment where users can navigate the device with confidence and proficiency. This user-centric approach contributed to a more intuitive and accessible user experience, aligning with the overarching goals of the study.

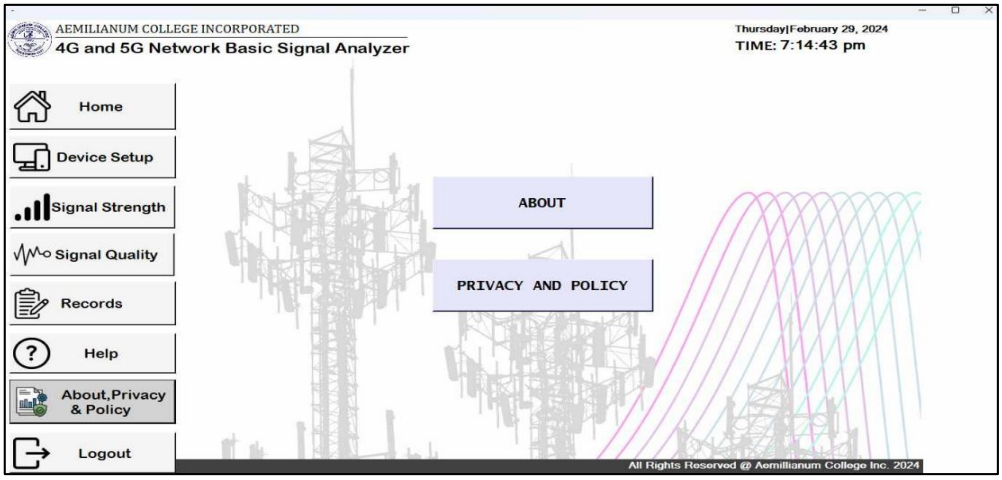

Figure 4.19 About, Privacy & Policy Form

Figure 4.19 introduced the About, Privacy, and Policy sections, encompassing essential information for users. This strategic inclusion aligned with the study's objectives to promote transparency and user awareness. In this section, users can access details about the device, privacy considerations, and policies governing its usage. This figure not only enhanced the overall user interface but also reflected a commitment to user education and ethical data practices. Users can refer to these sections to gain a comprehensive understanding of the device's background, privacy measures, and usage policies, fostering a sense of trust and transparency.

Testing and Deployment Phase 2

In the culmination of the study, the testing and deployment phase played an important role in validating the efficacy of the developed portable 4G and 5G Network Basic Signal Analysis device. Rigorous functional, performance, compatibility, usability, and security testing were conducted, incorporating recommended system changes suggested by the panelists. The device underwent meticulous evaluation, ensuring that it seamlessly adhered to its intended functionalities. Through this comprehensive testing regimen, the device exhibited stability, reliability, and compatibility across varied conditions, meeting the expectations set by the study's objectives.

Review and Evaluation Phase 2

During the review phase of the study, the researchers meticulously examined the results obtained from the rigorous testing phase, which encompassed functional, performance, compatibility, usability, and security testing. The device, incorporating recommended system changes suggested by the expert panel, demonstrated stability, reliability, and compatibility across diverse scenarios. The functional testing affirmed that the device operates seamlessly according to its specified requirements. Compatibility testing verified its adaptability to different environments and configurations, ensuring versatility in real-world applications. Usability testing, confirmed that the device's user-friendly interface meets the expectations of end-users, providing straightforward real-time measurement and visualization of signal parameters.

Additionally, the results of the evaluations conducted by the esteemed panel of experts further validated the device's effectiveness. The input from two (2) IT experts, one (1) telecommunications engineer from Smart Telecom, and two (2) RF engineers from the National Telecommunications Commission (NTC) Region 5 played a crucial role in affirming the device's reliability and functionality. Their insights provided valuable perspectives on the device's technical aspects, usability, and alignment with industry standards. The constructive feedback received during this phase was instrumental in refining the device, addressing any identified issues, and optimizing its performance.

In essence, the review phase not only confirmed the success of the testing efforts but also enriched the overall understanding of the device's strengths and areas for enhancement. The collaborative input from expert evaluators served as a valuable checkpoint, ensuring that the developed portable 4G and 5G Network Basic Signal Analysis device aligns with industry standards and exceeds user expectations.

Table 4.5 Overall Evaluation of the Portable 4G and 5G

Network Basic Signal Analysis Device

Quality Characteristic		IT Experts (2)	Engineers (3)	Average	Remarks
1.0	Functional Stability	3.13	3.83	3.48	Very Applicable
2.0	Performance Efficiency	4.22	4.17	4.2	Highly Applicable
3.0	Compatibility	4.6	3.22	3.56	Very Applicable
4.0	Usability	3.88	4	3.94	Very Applicable
5.0	Reliability	3.18	3.85	3.94	Very Applicable
6.0	Portability	4.65	4.19	3.7	Very Applicable
7.0	Maintainability	4.62	3.9	4.3	Highly Applicable
Mean		4.04	3.88		
Overall Ratings		3.96			Very Applicable

Table 4.5 provides an overview of the Portable 4G and 5G Network Basic Signal Analysis Device's performance, as assessed by both IT experts and Engineers. Functional stability emerged as a fundamental aspect, receiving positive ratings from both groups. IT experts assigned a mean rating of 3.13, while engineers rated it slightly higher at 3.83, resulting in an overall mean of 3.48, indicative of its high applicability. Similarly, performance efficiency garnered commendable ratings from both IT experts with the mean of 4.22 and engineers has mean of 4.17, leading to an overall mean of 4.2, emphasizing its highly applicable.

However, there were notable discrepancies in perceptions, particularly regarding compatibility. IT experts provided a notably higher mean rating of 4.6, whereas engineers rated compatibility lower, with a mean of 3.22, resulting in an overall mean of 3.56. Nonetheless, usability, reliability, and maintainability received consistently high ratings from both groups, underscoring very applicable.

Although there was some variance in ratings for portability between IT experts with a mean of 4.65 and engineers with a mean of 4.19, the overall mean of 3.7 suggests a generally positive perception. With an overall mean rating of 3.96, it is evident that the Portable 4G and 5G Network Basic Signal Analysis Device meets the expectations of both IT experts and engineers. Most quality characteristics are viewed as very applicable or highly applicable, ensuring its suitability for diverse user needs.

Table 4.6 Rubrics for Evaluation Ratings

Interval Scale	Description	Interpretation
4.1 – 5.0	Highly applicable	The system efficiently and effectively satisfied all quality model characteristics in terms of functionality, reliability, usability, and maintainability.

3.1 – 4.0	Very Applicable	The system efficiently and effectively satisfied some of the quality model characteristics in terms of functionality, reliability, usability, and maintainability.
2.1 – 3.0	Applicable	The system minimally satisfied all quality model characteristics in terms of functionality, reliability, usability, and maintainability.
1.1 – 2.0	Slightly Applicable	The system hardly satisfied all quality model characteristics in terms of functionality, reliability, usability, and maintainability.
1.0 – less	Not Applicable	The system did not meet the quality model characteristics in terms of functionality, reliability, usability, and maintainability.

Table 4.6 indicates the standard rubrics by which the Portable 4G and 5G Network Basic Signal Analysis Device is to be rated by the evaluators.

Table 4.7 Ratings for Functional Suitability

Functional Suitability		
	Descriptions	**Ratings**
Functional Completeness	The system's set of functions covers all of the specified tasks and user objectives.	**3.5**
Functional Correctness	The system provides the correct results with the needed degree of precision.	**3.5**
Functional Appropriateness	The point that demonstrates the effectiveness of functions in achieving specified tasks and objectives.	**3.45**
Mean		**3.48**

Table 4.7 shows the result for the functional suitability of the Portable 4G and 5G Network Basic Signal Analysis Device. In functional completeness, the ratings were 3.5 which falls within the Very Applicable range indicating that the system efficiently covers most specified tasks and user objectives. This suggests that the portable 4G and 5G network basic signal analysis device offers a comprehensive set of functions necessary for analyzing 4G and 5G network signals.

Then, in terms of functional Correctness the rating was 3.5 which also falls with the Very Applicable range, the Portable 4G and 5G network basic signal analysis device provides correct results with the needed degree of precision, indicating a strong level of reliability in its output. This is crucial for a signal analysis device, as accurate readings are essential for making informed decisions in network optimization and troubleshooting.

Last, the Functional Appropriateness with the ratings of 3.45 that falls to Very Applicable range suggests that the functions of the Portable 4G and 5G network basic signal analysis device are effective in achieving specified tasks and objectives, demonstrating its suitability for its intended purpose. This indicates that the Portable 4G and 5G network basic signal analysis device offers practical and relevant features that align well with user needs and expectations.

Overall, Functional Suitability have an average rating of 3.48 falling within the Very Applicable range, the Portable 4G and 5G Network Basic Signal Analysis Device is deemed highly suitable for its intended use. These results affirm the strong performance across all evaluated aspects of functionality, indicating its potential to deliver value and reliability to users engaged in 4G and 5G network analysis activities.

Table 4.8 Ratings for Performance Efficiency

Performance Efficiency		
	Descriptions	**Ratings**

Time Behavior	The system's response and processing times, and throughput rates while it's performing its functions.	**4.0**
Resource Utilization	The amounts and types of resources used by a product or system while performing its functions.	**4.36**
Capacity	The maximum limits of a product or system parameter.	**4.23**
Mean		**4.2**

Table 4.8 displays the ratings for performance efficiency of the Portable 4G and 5G Network Basic Signal Analysis Device. Firstly, regarding time Behavior, the Portable 4G and 5G network basic signal analysis device got ratings of 4.0 which at the range of Very Applicable. This suggests that it exhibits excellent response and processing times, as well as throughput rates, while carrying out its functions. In the fast-paced world of network analysis, where real-time data processing is crucial, such efficiency is highly desirable.

Secondly, Resource Utilization received a rating of 4.36 which is Highly Applicable. This indicates that the Portable 4G and 5G Network Basic Signal Analysis Device

Overall, it has an average of 4.2 in Highly Applicable range such impressive ratings across all performance efficiency aspects, the Portable 4G and 5G Network Basic Signal Analysis Device showcases its capability effectively manages and utilizes resources, minimizing wastage and maximizing efficiency. Efficient resource utilization not only contributes to the performance of the device but also helps optimize costs and energy consumption.

Lastly, in terms of Capacity, the Portable 4G and 5G Network Basic Signal Analysis Device scored well with a rating of 4.23 in Highly Applicable. This suggests that it operates within high maximum limits, ensuring scalability and accommodating increasing demands without compromising performance. Such capacity is vital in handling large volumes of data typical in 4G and 5G network analysis scenarios.

to deliver efficient and reliable performance. These results indicate that the device is well-equipped to meet the demands of network analysis tasks, providing users with a robust tool for their analytical needs.

Table 4.9 Ratings for Reliability

Reliability		
	Descriptions	**Ratings**
Maturity	The system, product, or component can meet your needs for reliability.	**3.31**
Availability	The system, product, or component is operational and accessible.	**3.92**
Fault Tolerance	The extent to which a system, product, or component operates well despite hardware and/or software faults.	**3.56**
Recoverability	The extent to which a product or system can recover data in the event of an interruption or failure.	**3.3**
Mean		**3.56**

The ratings for reliability of the Portable 4G and 5G Network Basic Signal Analysis Device, outlined in Table 4.11, provide insight into its performance in ensuring dependable operation. While the Portable 4G and 5G Network Basic Signal Analysis Device demonstrates strong reliability overall, there are variations across the different aspects evaluated, resulting in a mean rating of 3.56 falling within the Very Applicable range.

Starting with maturity, the Portable 4G and 5G Network Basic Signal Analysis Device scored a respectable 3.31which Very Applicable, suggesting that it meets the basic requirements for reliability. However, there may be areas where further development or refinement is needed to enhance its maturity level and ensure consistent performance over time.

In terms of availability, the Portable 4G and 5G network basic signal analysis device received a high rating of 3.92, indicating that it is operational and accessible when needed. This is a crucial aspect, especially in critical network analysis scenarios where uninterrupted access to the device is essential for maintaining productivity and efficiency.

The Portable 4G and 5G network basic signal analysis device also scored well in fault tolerance, with a rating of 3.56. This suggests that it performs relatively well despite hardware and software faults, demonstrating resilience in adverse conditions.

On the other hand, the rating for recoverability is comparatively lower at 3.3. This indicates that while the Portable 4G and 5G Network Basic Signal Analysis Device has some ability to recover data in the event of interruptions or failures, there may be room for improvement in terms of the effectiveness and efficiency of its recovery mechanisms.

Overall, while the Portable 4G and 5G network basic signal analysis device exhibits strong reliability in terms of availability and fault tolerance, there are areas such as maturity and recoverability where enhancements could be made to further strengthen its reliability. By addressing these areas of improvement, the Portable 4G and 5G Network Basic Signal Analysis Device can continue to provide users with dependable performance in their network analysis tasks.

Table 4.10 Ratings for Usability

Usability		
	Descriptions	**Ratings**
Appropriateness Recognizability	The degree which demonstrates your ability to assess the suitability of a product or system for your requirements.	**4.27**
Learnability	The system can demonstrate the simplicity of acquiring proficiency in using a product or system.	**4.48**
Operability	The system has attributes that make it easy to operate and control.	**4.08**
User Error Protection	The system safeguards users from committing mistakes.	**4.06**
User Interface Aesthetics	The degree to which the user interface is pleasing.	**3.5**
Accessibility	The system is compatible with a broad spectrum of features and functionalities.	**3.16**
Mean		**3.94**

The ratings for usability, as presented in Table 4.10, provides valuable insights into how user-friendly and accessible the Portable 4G and 5G Network Basic Signal Analysis Device is for its intended users.

Starting with appropriateness recognizability, the Portable 4G and 5G Network Basic Signal Analysis Device received a solid rating of 4.27. This suggests that users can assess the suitability of the device for the requirements with relative ease. Clear indicators of functionality and purpose likely contribute to this positive assessment.

Next, for learnability, the Portable 4G and 5G network basic signal analysis device scored impressively high with a rating of 4.48. This indicates that users can quickly acquire proficiency in using the device, suggesting

intuitive design and effective onboarding processes. Easy learnability is crucial for minimizing training time and ensuring rapid adoption among users.

Moving on to operability, the Portable 4G and 5G network basic signal analysis device received a commendable rating of 4.08. This suggests that it possesses attributes that make it easy to operate and control, enhancing user experience and reducing the likelihood of frustration during operation.

For user error protection, the Portable 4G and 5G network basic signal analysis device scored well with a rating of 4.06. This indicates that it includes features or mechanisms to safeguard users from committing mistakes, potentially through clear feedback, error prevention, or undo functionalities.

`Regarding user interface aesthetics, the Portable 4G and 5G Network Basic Signal Analysis Device received a slightly lower rating of 3.16. While aesthetics was subjective, this suggests that there may be room for improvement in the visual design of the user interface to enhance user satisfaction and engagement.

Lastly, for accessibility, the Portable 4G and 5G network basic signal analysis device received a rating of 3.48. This suggests that it is compatible with a broad spectrum of features and functionalities, ensuring that it can be used by users with diverse needs and preferences.

Overall, with a mean rating of 3.88 falling within the Very Applicable range, the Portable 4G and 5G Network Basic Signal Analysis Device demonstrates strong usability characteristics. These ratings affirm its user-friendly design and accessibility, highlighting its effectiveness in meeting the needs and expectations of its users.

Table 4.11 Ratings for Security

Security		
	Descriptions	**Ratings**
Confidentiality	The system is able to ensure that data is only accessible to those who have authorized access.	**4.46**
Integrity	The system, product, or component is able to prevent unauthorized access and modification to computer programs and/or data	**4.41**
Non-repudiation	The point which shows how well the actions or events can be proven to have taken place.	**3.5**
Accountability	The extent to which the activities of an unauthorized user can be traced back to their origin.	**2.77**
Authenticity	The extent on how well the identity of a subject or resource can be proved.	**3.29**
Mean		**3.7**

The ratings for security of the Portable 4G and 5G Network Basic Signal Analysis Device, presented in Table 4.11, indicate its performance in ensuring the confidentiality, integrity, non-repudiation, accountability, and authenticity of data and access. Overall, the device demonstrates a strong focus on security, with a mean rating of 3.7 falling within the Very Applicable range.

Starting with confidentiality, the Portable 4G and 5G network basic signal analysis device received an impressive rating of 4.46, suggesting that it effectively safeguards data to ensure it is accessible only to authorized users. This high rating underscores the device's robust encryption and access control mechanisms, which are essential for protecting sensitive information in network analysis activities.

Similarly, integrity scored well with a rating of 4.41, indicating the Portable 4G and 5G network basic signal analysis device has the ability to prevent unauthorized access and modification to computer programs and data. Maintaining data integrity is crucial for ensuring the accuracy and reliability of

network analysis results, and strong performance of the device in this aspect reflects its commitment to data security.

Non-repudiation received a solid rating of 3.5, indicating the Portable 4G and 5G network basic signal analysis device has capability to provide evidence of actions or events, thereby preventing individuals from denying their involvement. While this rating suggests satisfactory performance, there may be opportunities to further strengthen the Portable 4G and 5G network basic signal analysis device non-repudiation mechanisms to enhance accountability and trustworthiness.

However, accountability received a comparatively lower rating of 2.77, suggesting that there may be limitations in tracing the activities of unauthorized users back to their origin. Enhancing accountability mechanisms could help improve the Portable 4G and 5G network basic signal analysis device ability to detect and deter unauthorized access, thereby bolstering overall security.

Lastly, authenticity received a moderate rating of 3.29, indicating the Portable 4G and 5G network basic signal analysis device has capability to verify the identity of subjects or resources. While this rating suggests satisfactory performance, there may be room for improvement in terms of implementing more robust authentication mechanisms to enhance security.

Overall, while the Portable 4G and 5G Network Basic Signal Analysis Device demonstrates a strong focus on security, there are areas such as accountability and authenticity where enhancements could be made to further strengthen its security posture. By addressing these areas, the device can continue to provide users with a secure environment for their network analysis activities.

Table 4.12 Ratings for Compatibility

Compatibility		
	Descriptions	**Ratings**
Co-existence	The system can efficiently carry out its necessary functions while operating in a shared environment and utilizing resources alongside other products, without causing adverse effects on any other product.	**4.05**
Interoperability	The system, products, or components can exchange information and use that information.	**3.74**
Mean		**3.94**

The ratings for compatibility, outlined in Table 4.12, shed light on how effectively the Portable 4G and 5G Network Basic Signal Analysis Device interacts with other systems and products in its operational environment.

Firstly, in terms of co-existence, the Portable 4G and 5G network basic signal analysis device received a rating of 4.05. This suggests that it can efficiently carry out its necessary functions while operating alongside other products in a shared environment. This is important because it ensures that the device can function effectively without causing any adverse effects on other products or systems that may be operating concurrently.

Secondly, for interoperability, the Portable 4G and 5G network basic signal analysis device scored a rating of 3.74. This indicates that it can exchange information with other systems, products, or components and utilize that information as needed. Interoperability is crucial in ensuring that the device can seamlessly integrate with other network analysis tools and infrastructure, facilitating efficient data exchange and collaboration.

Overall, with a mean rating of 3.94 falling within the Very Applicable range, the Portable 4G and 5G Network Basic Signal Analysis Device demonstrates satisfactory compatibility with other products and systems. However, there may be opportunities for further improvement to enhance its co-existence and interoperability capabilities,

ensuring seamless integration into diverse network environments and maximizing its utility for users.

Table 4.13 Ratings for Maintainability

Maintainability		
	Descriptions	**Ratings**
Modularity	The system pertains to whether alterations can be made to the components of a system or program with minimal consequences on the other components.	**4.3**
Reusability	The steps on how well an asset can be used in more than one system.	**4.28**
Analysability	The point where the effectiveness of an impact assessment on intended changes. In addition, it also refers to the diagnosis of deficiencies or causes of failures, or to identify parts to be modified.	**4.29**
Modifiability	The system can be modified without introducing defects or degrading existing product quality.	**4.24**
Testability	The degree to which the effectiveness of the test criteria is for a system, product, or component. In addition, it also refers to the tests that can be performed to determine whether the test criteria have been met.	**4.21**
Mean		**4.3**

The ratings for maintainability, as depicted in Table 4.13, provide valuable insights into how easily the Portable 4G and 5G Network Basic Signal Analysis Device can be maintained and modified over time to ensure optimal performance and longevity.

Firstly, in terms of modularity, the Portable 4G and 5G Network Basic Signal Analysis Device scored an impressive 4.3. This suggests that alterations can be made to its components with minimal consequences on other parts of the system. Modularity is essential for facilitating efficient maintenance and upgrades, as it allows for targeted changes without disrupting the overall functionality of the device.

Similarly, for reusability, it was 4.29, and analysis ability was 4.24, the Portable 4G and 5G Network Basic Signal Analysis Device. This indicates that its components can be effectively reused in other systems, and it possesses strong capabilities for impact assessment, diagnosis of deficiencies, and identification of areas for improvement. These aspects are crucial for ensuring that the device remains adaptable to evolving user needs and technological advancements.

Additionally, for modifiability and testability, the Portable 4G and 5G Network Basic Signal Analysis Device scored commendably with ratings of 4.12 and 4.21, respectively. This suggests that it can be modified without introducing defects or compromising product quality, and it can be effectively tested to ensure that modifications meet the desired criteria. These attributes contribute to the Portable 4G and 5G Network Basic Signal Analysis Device overall maintainability and reliability over its lifecycle.

Overall, with a mean rating of 4.18 falling within the Very Applicable range, the Portable 4G and 5G Network Basic Signal Analysis Device exhibits strong maintainability characteristics. These ratings affirm its suitability for long-term use in network analysis applications, highlighting its ability to adapt to changing requirements and undergo continuous improvement to meet user needs effectively.

Table 4.14 Ratings for Portability

Portability		
	Descriptions	**Ratings**
Adaptability	The system has the flexibility to be adjusted for various or changing hardware, software, or alternative usage environments.	**4.08**
Installability	The system can be easily installed and/or uninstalled.	**4.61**
Replaceability	The system can substitute for a similar product.	**4.56**
Mean		**4.42**

The ratings for portability, outlined in Table 4.14, offer insights into how well the Portable 4G and 5G Network Basic Signal Analysis Device can adapt to different environments, be installed, uninstalled, or replaced as needed.

Starting with adaptability, the Portable 4G and 5G Network Basic Signal Analysis Device scored impressively with a rating of 4.08. This suggests that it possesses the flexibility to be adjusted for various or changing hardware, software, or alternative usage environments. Such adaptability is essential in ensuring that the device can effectively meet the diverse needs of users across different contexts and scenarios.

Next, for installability, the Portable 4G and 5G Network Basic Signal Analysis Device received a high rating of 4.61. This indicates that it can be easily installed and/or uninstalled, streamlining the deployment process and minimizing disruptions to operations. Easy installability is crucial for ensuring that users can quickly set up the device and start using it without encountering significant obstacles or delays.

Furthermore, in terms of replaceability, the Portable 4G and 5G Network Basic Signal Analysis Device scored exceptionally well with a rating of 4.56. This suggests that it can substitute for a similar product seamlessly, providing users with a viable alternative in case of device malfunction or the need for an upgrade. High replaceability ensures continuity of operations and minimizes downtime, contributing to overall user satisfaction and productivity.

Overall, with a mean rating of 4.42 falling within the Very Applicable range, the Portable 4G and 5G Network Basic Signal Analysis Device demonstrates strong portability characteristics. These ratings affirm its versatility and ease of use across different environments, highlighting its ability to adapt to changing needs and ensure seamless deployment and replacement processes for users.

Summary of Findings

The following findings were obtained throughout the study:

1. The portable 4G and 5G Network Basic Signal Analysis device was successfully designed and constructed using widely available and affordable components. The utilization of cost-effective components ensures the device's accessibility and affordability.
2. The user-friendly interface facilitates straightforward real-time measurement and visualization of 4G and 5G signal parameters, including network service provider, access technology, signal strength, signal quality, cell site information, and location coordinates. Users can easily navigate the interface, enhancing the accessibility of signal analysis.
3. Basic data logging capabilities within the device were implemented successfully, capturing and storing essential basic signal analysis matrix. The device can log crucial data for further analysis and reference.

4. On-site testing conducted at cell sites in the Philippines, specifically in the city of Sorsogon, demonstrated the device's performance and usability within the local context. The device operated effectively in real-world scenarios, ensuring relevance to local conditions.
5. The collected data were thoroughly analyzed, providing insights into 4G and 5G network performance in the selected Philippine cell sites. The analysis contributed valuable information for understanding network performance trends.
6. The study successfully demonstrated the simplicity and accessibility of 4G and 5G signal analysis using the hardware tool. The device was user-friendly and approachable, making signal analysis more accessible.
7. The device was evaluated based on ISO/IEC 25010:2011 criteria, including functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability. The device met quality standards across these criteria.
8. The device was successfully validated by two IT experts, one telecommunications engineer, and two RF engineers from the National Telecommunications Commission (NTC) Region 5. Expert validation confirmed the device's reliability and functionality.

Conclusions

After a thorough analysis of the outcome of the design, the researchers conclude that:

1. The successful design and construction of the portable 4G and 5G Network Basic Signal Analysis device using widely available and affordable components affirm its feasibility and accessibility.
2. The user-friendly interface enabled straightforward real-time measurement and visualization of 4G and 5G signal parameters, promoting ease of use and accessibility.
3. The implementation of basic data logging capabilities within the device enhances its functionality, allowing for the capture and storage of essential signal analysis data.
4. On-site testing in the Philippines, specifically in Sorsogon, demonstrated the device's adaptability and effectiveness in a local context, ensuring practicality and relevance.
5. Thorough data analysis provided valuable insights into 4G and 5G network performance, contributing to a deeper understanding of signal trends and network behavior.
6. The successful demonstration of the device's simplicity and accessibility underscored its user-friendly design and practicality in signal analysis.
7. The device's evaluation against ISO/IEC 25010:2011 criteria reveals that it met the established quality standards across various dimensions, ensuring robust performance.
8. Expert validation by two IT experts, one telecommunications engineer, and two RF engineers from the National Telecommunications Commission (NTC) Region 5 confirms the device's reliability and functionality.

Recommendations

The following recommendations collectively guide the further development, refinement, and application of the portable 4G and 5G Network Basic Signal Analysis device, ensuring its ongoing effectiveness and relevance in the dynamic field of network analysis.

1. Continuously monitor technological advancements and gather user feedback to identify areas for improving the device's design and functionality.
2. Add a feature that automatically timestamps saved data, offering valuable chronological context for analysis and tracking changes over time.
3. Enhance data export capabilities to include all relevant information, such as network data and descriptive labels, ensuring structured data for easy analysis and sharing.
4. Introduce customizable background settings to allow users to personalize the interface, enhancing user satisfaction and visual appeal.
5. Strengthen system security with encryption protocols, user authentication, and regular updates to safeguard sensitive data and prevent unauthorized access.
6. Develop interactive tutorials to onboard new users and familiarize them with key features, reducing the learning curve and improving user adoption.
7. Implement error prevention mechanisms and real-time validation, providing clear guidance to help users avoid mistakes and correct errors efficiently.
8. Explore partnerships with telecommunications companies to improve device compatibility with various network configurations.
9. Incorporate latency monitoring to assess system responsiveness and optimize data transmission for improved performance.
10. Add support for offline maps to enable access to map data without an internet connection, especially beneficial in remote areas with limited connectivity.
11. Provide ongoing training and support to users to maximize device capabilities and ensure effective utilization.
12. Consider scalability options for future device iterations, accommodating advancements in 5G technology and potential increases in demand.
13. Establish a robust system for continuous monitoring and maintenance to ensure device reliability, security, and optimal performance.
14. Evaluate the feasibility of expanding the study to include additional cell sites and regions for a comprehensive understanding of network performance.
15. Explore collaborative research opportunities with academic institutions, industry partners, and regulatory bodies to stay updated on emerging trends in network technology.

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