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Article

A Multi-Source Quality of Service Validation Framework for Evidence-Based Broadband Regulation in the Philippines

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Abstract: Being able to rely on a robust broadband network is crucial for digital inclusion, public service, economic engagement, and evidence-based telecommunications regulation. In developing countries and archipelagic settings, however, traditional broadband monitoring relies on operator-submitted reports, limited datasets of speed tests, or localized engineering survey.In developing countries and archipelagic settings, however, the traditional method for broadband monitoring, in terms of providing evidence for regulatory planning, is based on operator-submitted reports or limited speed test datasets or isolated engineering surveys. This study introduces a multi-source broadband validation and mapping system known as National Telecommunications Commission Quality of Service (NTC-QoS) Framework designed to aid the country's nationwide assessment of the performance of the telecommunications and broadband service providers in the Philippines. The framework includes validation of FTTH, wireless broadband measurements, radio spectrum analysis, cell site validation, inventories of NAPs, speed-tests, Geographic Information Systems, and a cloud-based QoS Portal. The design and development research approach was used, including standardized field validation and spatial processing, database integration, and regulatory analytics based on dashboards. The results of the completed implementation yielded 5,719 FTTH barangays, 5,349 wireless barangays, 439,120 mapped NAP points, 11,721 validated cell sites and 3,509 recorded 5G observations. The QOS Portal allows users to do interactive filtering and analysis according to the provider, radio technology, signal strength, infrastructure layer or administrative level (national, regional, city/municipality, barangay). The results show that the framework is more spatially resolved and robustly independently validated than conventional broadband monitoring approaches. The system proposed provides a scalable model for evidence-based telecommunications regulation, identification of connectivity gaps, infrastructure planning and continual broadband QoS monitoring in the Philippines.
Keywords: Broadband Quality of Service; telecommunications regulation; GIS broadband mapping; field validation; Philippines

1. Introduction

Broadband connectivity has been turned into a tool for communication and has become an indispensable means of achieving economic, public service, educational, healthcare, disaster and technological innovation. In today's context, inclusive digital transformation and a fair access to digital opportunities has become a prerequisite to having high-quality broadband infrastructure. Thus, governments have focused their efforts from availability to reliability, affordability, and accessibility of these services, along with the ability to handle data-intensive applications. According to the International Telecommunication Union (ITU, 2025), almost 75% of the world's population is connected to the Internet, although approximately 2.2 billion people have yet to benefit from this connectivity, and difficulties in access to and quality of broadband services exist between urban and rural areas. The conditions make clear that connectivity is not enough, quality and consistency are now key variables to measure digital inclusion.

Quality of Service (QoS) has been traditionally perceived as the overall characteristics of a service, which affect its ability to satisfy a user's needs (International Telecommunication Union, 2008; International Telecommunication Union, 2001), and there are four perspectives on communications quality: required, offered, achieved, and perceived. Previous broadband research looked at QoS in a piecemeal fashion. Technical research on broadband packet switching, congestion control, routing, scheduling, and end-to-end QoS guarantees was directed towards improving the QoS of information systems (Chen & Lee, 2000; Leung, 2002; Lorenz & Orda, 2002; Orda, 1999), and adaptive research on information system was applied to model the QoS of information systems in multi-channel environments (Marchetti et al., 2004). Other studies focused on adoption, user behavior and institutional factors, demonstrating that none of the above factors alone necessarily ensures that the broadband will be used meaningfully (Choudrie & Lee, 2004; Sangjo et al., 2003; Venkatesh & Brown, 2001). Enabulele and Ghinea (2006) also suggested that the quality of broadband must be multi-faceted, comprising of besides technical QoS, reliability, pricing, security, policy, customer service and perception.

As far as measurements, the key ones for QoS are download speed, upload speed, latency, jitter, packet loss and availability. Budiman and Wicaksono (2016) measured mobile Internet QoS; Budiman et al. (2017) measured the mobile broadband quality using active testing and demonstrated that the measured results can be lower than expected values. Research on QoS and Quality of Experience (QoE) for 4G LTE also delineate the differences between network measures and usability and reliability perceived by users (Broadband Forum, 2006; Malisuwan et al., 2016). Some other studies on the past multimedia applications revealed discrepancies between the quality of the network and the perception of the users (Ghinea et al., 1999). These studies all provide evidence that broadband regulation that links technical performance and user experience with governance is required. This has been completed and expanded over the past few years with broadband measurement data from crowdsourcing, mobile broadband measurement data and geospatial analytics. The results should, however, not be taken at face value as they may differ between the different areas of the map, subscription tiers, devices, server choice, sampling bias, and test method (Paul et al., 2022a; MacMillan et al., 2023). Measuring and demographic information can be used together to advance a study of Internet quality inequities, which needs to be contextualised (Paul et al., 2022b). To ensure that samples are representative and avoid bias in estimates, mobile benchmarking studies rely on sampling and stratification (Tripkovic et al., 2023); user-side monitoring and QoE monitoring can be used to identify bottlenecks and service degradation (Fida et al., 2023; Al-Azzeh et al., 2022). The use of spatial modeling, regional clustering and GIS (Geographic Information System) in the cloud also enhances interpretation of broadband data. Spatial modeling can convert individual latency observations into meaningful insights for a region for policy-making purposes, as demonstrated by Sharma et al. (2024). Alamri (2024) showed that cloud GIS and crowdsourcing can play an important role in spatial data analytics, and Samulowska (2021) presented the importance of quality assurance to minimize the bias and errors in volunteered geographic data. These should include latency and packet loss as well as speed – it should be broadband monitoring, not speed monitoring (Burger et al., 2023). The results from these studies provide support for multi-metric, spatially validated and quality-controlled monitoring for regulation.

These developments have not led to a paradigm shift in the existing studies, and they mostly consist of localized measurements, consumer surveys, technical QoS analysis or crowdsourced speed tests, or single network performance evaluation. In the Philippines, operator-reported data, Ookla Speedtest, or local surveys are used, but they only capture a part of the picture of the quality of service. While national indicators are helpful for reporting macro-level service gaps, they are not enough to pinpoint localized service gaps at the city, municipality and barangay level, especially in geographically isolated and disadvantaged areas (GIDAs) (Serafica, 2023). This study introduces a new solution to this gap – the NTC-QoS Framework – that combines FTTH validation, wireless broadband assessment, spectrum measurements, GIS, reference datasets, and cloud-based dashboards in a barangay-level decision-support platform that helps guide evidence-based telecommunications regulation.

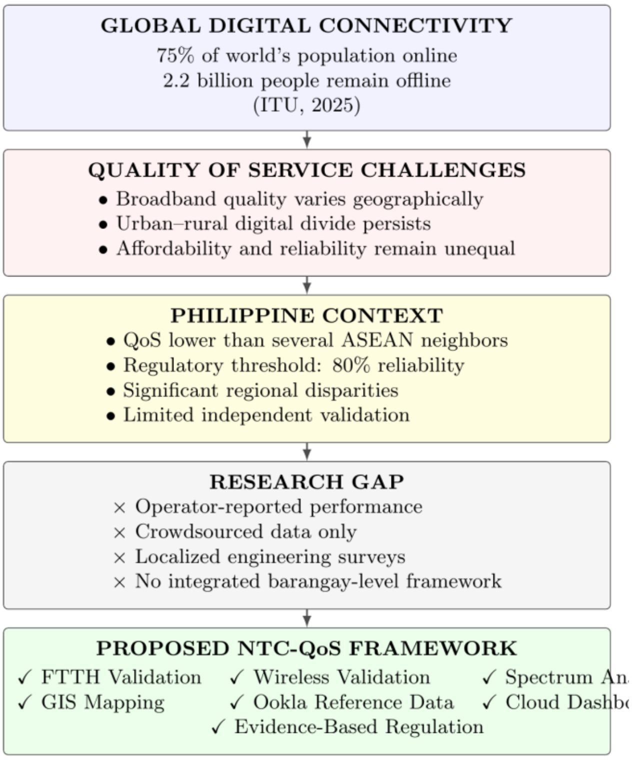

Figure 1. Global and Philippine digital connectivity challenges driving the development of the NTC-QoS Framework

2. Materials and Methods

2.1 Research Design

The National Telecommunications Commission Quality of Service (NTC-QoS) Framework for nationwide broadband performance monitoring was developed and evaluated by using Design and Development research (DDR) approach. The research was a systems engineering process, validated in the field, accompanied by a Geographic Information Systems (GIS) and telecommunications performance assessment in order to create an integrated framework for evidence based regulatory decision making. The proposed framework differ from the traditional QoS studies, which are mainly based on isolated measurements of speed or data provided by operators in the form of statistics, by bringing together various independent data sources into a unified regulatory information system. It was created to enable monitoring of the wired fiber-to-the-home (FTTH) and wireless broadband services, as well as geospatial visualization and regulatory analytics via a cloud-based dashboard.

2.2 Study Area

The first application of the NTC-QoS Framework took place in 5 pilot regions which span a wide range of geographical, socio-economic and telecommunications contexts in the Philippines. The pilot implementation included both highly urbanized cities as well as geographically isolated municipalities with the aim of checking the framework's applicability to different broadband deployments. As of the implementation the validation activities have been finished in 78 cities and municipalities, and 18 local government units are going through field validation. About 5273 barangay survey was conducted using coordinated field activities by NTC Regional Offices and USTP field engineers. The pilot implementation is the basis for the rollout of the project to about 20,000 barangays in Phase II.

2.3 Overall NTC-QoS Framework

The proposed framework is comprised of six interrelated elements: field data acquisition, reference performance data collection, broadband validation, GIS processing, cloud-based data management and decision-support dashboarding. The NTC-QoS Framework is a multi-source validation system, allowing the use of complementary field, reference, spectrum, and geospatial data for independent validation of broadband quality, in contrast to broadband monitoring systems, which rely mostly on a single data source. The overall methodological procedure of the system is shown in Figure 2.

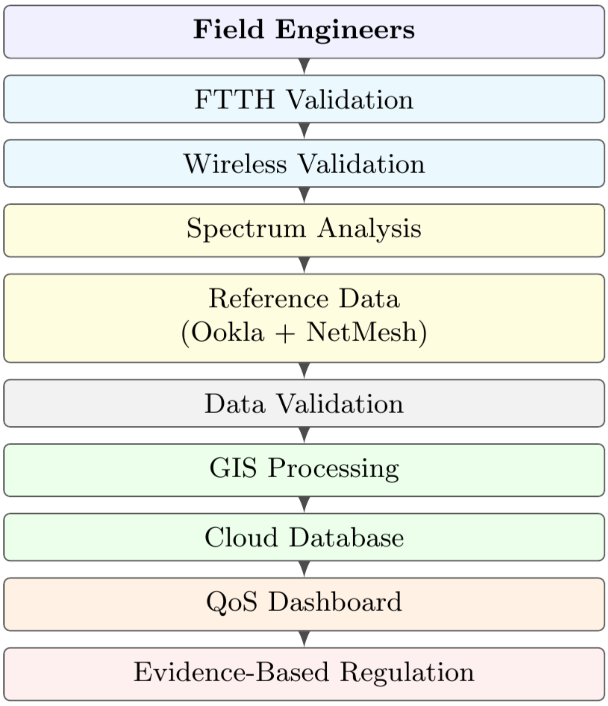

Figure 2. Overall methodological framework of the NTC-QoS system

2.4 Data Sources

The proposed framework has incorporated multiple independent data sources. The primary field measurements were taken by experienced field engineers with the aid of standard survey questionnaires established by the National Telecommunications Commission. Field teams collected geographic coordinates, administrative location, Internet service provider, broadband technology, the availability of FTTH, characteristics of the wireless signal, and measurements of network performance at each of the validation points. The sites for validation were geotagged for spatial analysis and GIS visualization.

In addition to field data, the framework also included data from independent sources for broadband performance, such as Ookla Speedtest reference data and NetMesh broadband performance measurements from commercial and crowdsourced sources. These datasets were not used as replacements for field validation work, but as independent reference data sets to compare, cross check and detect anomalies. Wireless broadband validation also comprised radio spectrum measurement with professional spectrum analyzers to check the utilization of frequencies, signal strength, spectrum occupancy and characteristics of interference. This process allowed for independent verification of wireless broadband deployment conditions other than traditional speed tests.

2.5 Broadband Validation Procedure

The validation process was carried out as per a standard procedure, which was applied in all the participating regions. NTC Region Offices identified target barangays and validation sites. Secondly, trained field engineers were sent across to perform field evaluations of the broadband. Thirdly, availability information and service information were gathered related to FTTH. Fourth, wireless broadband conditions were measured via the spectrum and the quality of signals was evaluated. Fifth, field measurements were compared with reference data sets available. Lastly, validated records were submitted in the centralized NTC-QoS Portal. Quality checking was done on each validation record before they were added to the national database.

2.6 Geographic Information System Processing

GIS techniques were used to process all the validated records. The broadband measurements were translated into a spatial feature and included geographical features, service provider information, broadband technology, validation status and performance indicators. Spatial processing allowed mapping the coverage of the broadband, identifying areas not served or underserved, and providing municipality-level summaries, visualization at barangay-level and regional comparisons. The GIS can be used in addition to the traditional tabular broadband report to help regulators identify gaps in broadband services by using interactive maps and information.

2.7 Cloud-Based Dashboard Architecture

A national information system in the cloud was created to facilitate information management across the country. It is comprised of a mobile data collection interface, a RESTful API services, central database, a GIS server and a web dashboard. The dashboard offers visualization of validated barangays, FTTH deployment, wireless broadband status, Internet service providers, regional achievements, and the progress of validation. Only users authorized by the NTC Central Office and Regional Offices can get access to the dashboard for monitoring, reporting and decision support.

2.8 Sampling Design and Site Selection

The barangay sample and validation sites were selected using stratified purposive sampling design. The primary stratum in each pilot region was treated as each pilot region and cities, municipalities and barangays were nested geographic units. Variation in settlement type, broadband availability, level of population density, accessibility, and reported connectivity gaps were stressed in site selection. Let R be the set of pilot regions, M_r the set of municipalities or cities in region r and B_{rm} the set of barangays in municipality m. The following number of barangays were assigned for per validation in each region:

$$n_r = \left\lceil \frac{N w_r}{\sum_{r \in R} w_r} \right\rceil \quad (1)$$

where N is the total target number of validation barangays and w_r is a regional priority weight based on population, geographic isolation, broadband deployment status, and regulatory priority. Within each selected municipality, barangay candidates were ranked using a composite priority score:

$$S_b = \alpha P_b + \beta G_b + \gamma U_b + \delta C_b \quad (2)$$

where P_b represents population or demand potential, G_b represents geographic isolation, U_b represents underserved or unserved status, C_b represents complaint or regulatory concern indicators, and α, β, γ, and δ are adjustable regulatory weights. Barangays with higher S_b values were prioritized while maintaining representation across urban, peri-urban, rural, and geographically isolated areas.

2.9 QoS Metrics and Measurement Indicators

The framework included service-level and radio-level metrics to fully represent the performance of broadband services. The QoS indicators which were offered for both fixed and mobile broadband included download speed, upload speed, latency, jitter and packet loss. The received signal strength indicator (RSSI), reference signal received power (RSRP), reference signal received quality (RSRQ), and signal-to-interference-plus-noise ratio (SINR) were among the wireless signal quality indicators. These metrics are chosen due to the fact that the mere speed is not enough to define user experience or network reliability. For instance, in real-time applications like videoconferencing and telemedicine, packet loss is a sign of service instability, and latency and jitter are issues. RSSI, RSRP, RSRQ and SINR are indicators of radio coverage and quality of the radio signals and are engineering level evidence of interference.

Table 1. QoS and wireless indicators used in the NTC-QoS Framework

Category	Metric	Purpose
Throughput	Download and upload speed	Measures data transfer capacity for fixed and wireless broadband services.
Delay	Latency and jitter	Evaluates responsiveness and variation in delay for real-time applications.
Reliability	Packet loss	Indicates dropped packets, instability, and potential congestion.
Radio signal	RSSI and RSRP	Measures received signal strength and cellular reference signal power.

Category	Metric	Purpose
Radio quality	RSRQ and SINR	Evaluates signal quality, interference, and usable radio conditions.

2.10 Measurement Hardware and Field Instruments

To ensure consistency across regions, calibration of measurement instruments and standardisation of mobile devices were used to validate field data. Wireless and spectrum measurements were developed for professional grade spectrum analyzers or comparable instruments approved by the NTC that can measure frequency utilization and signal levels and report on interference conditions. The mobile broadband testing was done on one of the standard smartphones or test devices with active subscription from the target Internet service providers. The Geolocation was recorded by using GPS-Devices, and before sending it to the portal the Coordinates were verified at the validation-site. For some cases, the exact device models differed by region and deployment, device type, calibration of the instruments, operating band, device identifier, and the GPS accuracy was captured as metadata in the validation form. This metadata facilitated a later quality control and traceability of field measurements.

2.11 System Architecture

The NTC-QoS platform was realized as a cloud-based regulatory information system built up with interoperable service layers. It features a mobile field collection interface, authentication service, RESTful API gateway, validation/reconciliation service, centralized relational database, GIS server, object storage for supporting files, analytics service and web-based dashboard. It provides a modular structure that enables field record, reference data and geospatial layers to be ingested separately and then matched via a shared validation process.

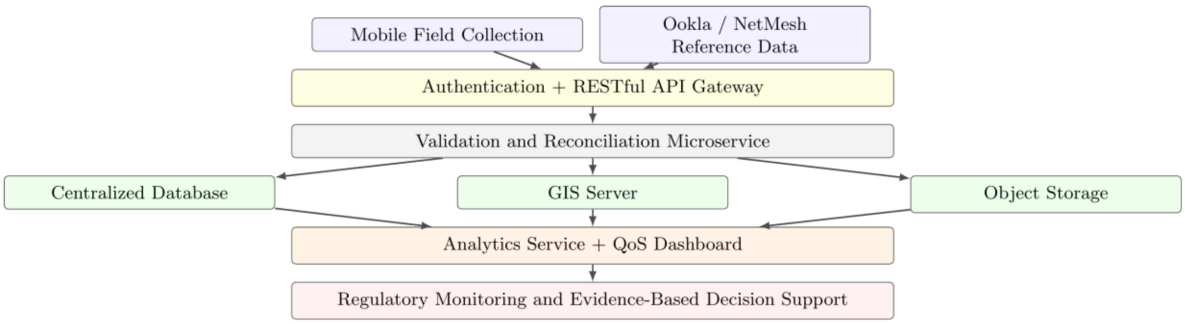

Figure 3. Cloud-based system architecture of the NTC-QoS platform

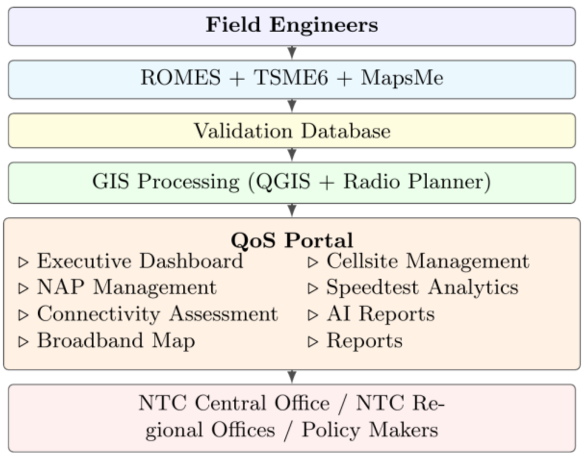

Figure 4. Field-to-portal system architecture supporting regulatory decision-making

2.12 Data Fusion and Validation Algorithm

The records from Field, Ookla and NetMesh were processed by a spatial and temporal reconciliation process. The main source of validation was field measurements and reference datasets were used for comparison and anomaly detection. Records were matched if they were within a spatial buffer and measurement time window. A validation flag was set as the consensus of the data sources, the completeness of relevant data elements and the consistency of the QoS indicators.

Algorithm 1. Multi-source QoS data validation

```
Input: Field records F, Ookla records O, NetMesh records N
Output: Validated QoS records V

for each field record f in F do
   verify required fields, GPS coordinates, timestamp, and device metadata
   find Ookla records O_f within spatial buffer d and time window t
   find NetMesh records N_f within spatial buffer d and time window t
   compute QoS differences between f, O_f, and N_f
   if required fields are complete and QoS values are within thresholds then
      assign status = "validated"
   else if reference data disagree or values exceed thresholds then
      assign status = "for review"
   else if no reference data are available but field record is complete then
      assign status = "field validated"
   else
      assign status = "rejected or incomplete"
   end if
   store record, validation status, source metadata, and GIS geometry in V
end for
return V
```

2.13 Data Analysis

Descriptive statistical analysis was used to present the findings of accomplishments in the implementation and outputs of the validation process. Performance indicators are number of validated barangays, validated cities and municipalities, validation of FTTH, validation of wireless, regional achievement, deployment of engineers, and distribution of broadband coverage. Spatial analysis was also conducted for visualization of geographic distribution of broadband services and to identify underserved communities that need more regulatory attention.

2.14 Framework Evaluation

The proposed framework was tested by the operational indicators and not only by lab experiments. The assessment was based on factors such as barangay validation, geographic coverage, data integration capability, dashboard capability, support for regulatory decision making, and capability to deploy nationwide. The framework was deemed to be operationally successful if it was possible to combine validated broadband data from various independent providers into one single dashboard that could be used for planning, monitoring and formulating policies.

3. Results and Discussion

3.1 Development and Completion of the NTC-QoS Framework

The project's main outcome is the creation and completion of the NTC Nationwide Quality of Service (QoS) Mapping and Assessment Project, known as the NTC Nationwide Quality of Service Mapping and Assessment of Performance of Telecommunications and Broadband Providers. The project was accomplished through the University of Science and Technology of Southern Philippines (UPSP) under the contract of National Telecommunications Commission (NTC) with a budget of Php 30,000,000.00. The implementation period started on 23rd December 2024 and ended on 22nd December 2025, the Terminal Report was submitted on 19th February 2026.

The final NTC-QoS Framework provided accurate data on telecommunications and broadband coverage and performance at the barangay level. The framework combines a cell site tower validation with a wireless technology and spectrum band validation for 2G/3G/4G/5G services, repeated broadband network speed testing, FTTH (fiber to the premise) and fiber optic network mapping, GIS (geo-referencing) visualization and a Broadband Map Website, which is being developed with the participation of local operators. These datasets are combined into a cloud-based regulatory information system that can be used to help plan, monitor, report on, and inform broadband policy with evidence, as illustrated in Figure 3.

3.2 NTC Quality of Service Portal and Multi-Layer GIS Interface

The NTC Quality of Service (QoS) Portal is the prime digital solution created as part of the NTC Nationwide QoS Mapping and Assessment Project. The portal, created by USTP for the NTC, brings together the broadband validation data from all over the country to a single GIS-based decision support platform. The system translates thousands of field observations into interactive maps, dashboards, technical reports and regulatory intelligence which allow evidence-based telecommunications planning and policy-making.

The portal features wireless broadband validation, FTTH mapping, Network Access Point (NAP) inventories, cell site validation, radio network coverage analysis, speed test measurements, and spectrum utilization data to give regulators a big-picture, nationwide perspective of telecommunications infrastructure and broadband performance. The NTC QoS Portal utilizes platforms like ROMES, the TSME6 Multiband Scanner, Radio Planner, and geospatial databases, and combines them with actual field validation and engineering measurements to capture validated measurements. This holistic approach allows the Commission to monitor compliance to regulatory standards, assess QoS, identify infrastructure deployment gaps and monitor the overall connectivity of infrastructure.

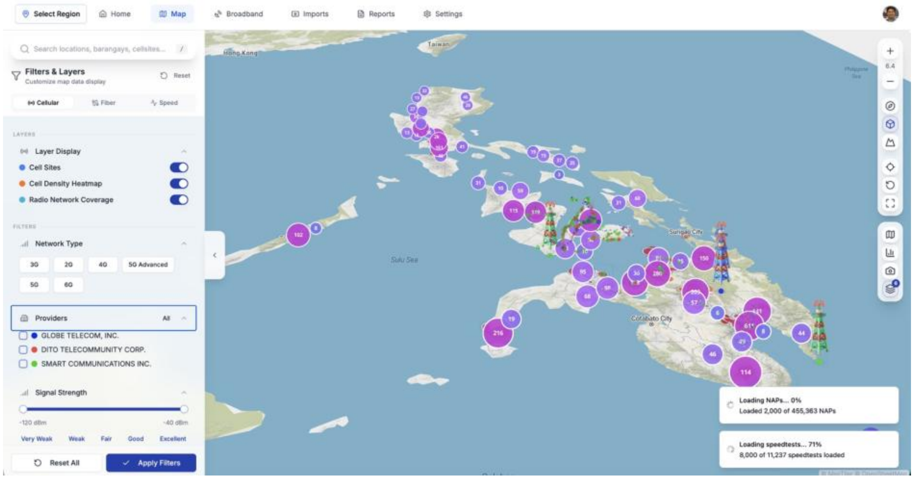

Figure 5. Nationwide visualization of the NTC QoS Portal integrating FTTH NAPs, validated cell sites, broadband performance records, and wireless validation datasets within a single GIS environment

A national visualization of the NTC QoS Portal is provided in Figure 5, which integrates over 455,000 FTTH NAPs, 11,700 cell site validations, 11,000 broadband performance records and 5,300 wireless validation datasets in a single GIS environment. This interactive filtering by provider, radio technology (from 2G to 5G), signal strength and infrastructure layers allows for complete broadband availability, network density and telecommunications performance analysis at local, national, regional and city/barangay levels for regulatory monitoring and planning.

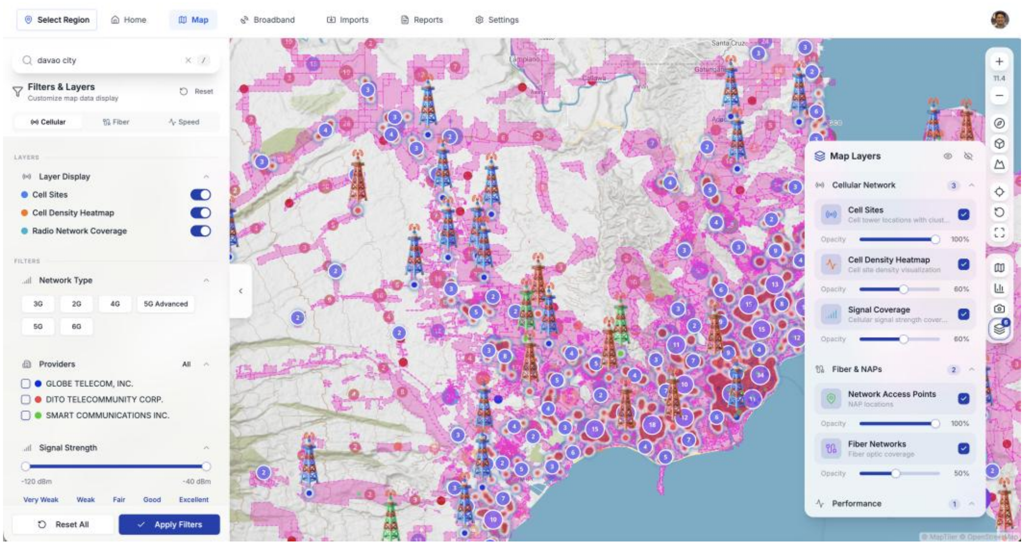

Figure 6. Interactive multi-layer GIS interface of the NTC QoS Portal for Davao City

The NTC QoS Portal interface (Figure 6) is an interactive multi-layer GIS, which allows multiple telecommunications datasets to be integrated and displayed in one operational environment. The example is based in the city of Davao, illustrating how regulators could use the GIS and the different layers to be configured to analyse the telecommunications infrastructure, broadband deployment and network performance of the city. The portal enables dynamic visualization of cell site location, cell density heat map, radio network coverage, FTTH NAPs, fiber network infrastructure and broadband performance indicators. The controls controlling each layer are independent of the others and can be turned on, off, and modulated by transparency controls to explore the relationships between service availability, network infrastructure and measured QoS.

There are advanced filtering options to analyze based on the telecommunications provider, such as Globe Telecom, Smart Communications, DITO Telecommunity, and others, mobile technology generation (2G, 3G, 4G, 5G, etc.), and signal strength thresholds. This capability can be used for provider performance comparisons and to identify under-served, over-served or poor-performing provider service areas. The QoS Portal differs from traditional broadband maps by combining validated field survey data with information about the infrastructure, GIS analysis, broadband performance and network coverage and is built into a single, cloud-based platform, making it a total regulatory decision support platform. With its multi-layer architecture, the platform can continue to be updated as new field validation information becomes available, keeping the platform as an authoritative source of validated telecommunications information for nationwide QoS monitoring.

It offers all the modules needed to run a network: a national geospatial broadband map, executive dashboard and regional KPI monitoring, cell site management, NAP management, broadband speed test analytics, connectivity assessment and reporting, AI-assisted report generation, bulk data import and integration, user and access management, and system administration. As a whole, these modules empower the NTC to keep track of the telecommunications infrastructure in real time, and also generate reports that can be used by the NTC for regulatory planning, infrastructure investments, consumer protection, and broadband development initiatives.

Table 2. Major Broadband Map Website capabilities

Capability	Access Role	Functional Features
National geospatial map	Public/Internal	NAPs, cell sites, speed test data, nationwide heatmaps, provider filters, and validation layers.
User and access management	SuperAdmin	Users, roles, permissions, user regions, and municipalities.
Executive dashboard	Regional Admin	Regional KPI tracking, mapped NAPs/cell sites, average speed tests, connectivity evaluation, and ISP ranking.
Cellsite and NAP management	Regional Admin	Cellsite/NAP lists, coordinates, infrastructure details, regional maps, layer controls, and map-based entry.
Speedtest analytics	Regional Admin	Record creation/editing, map view, exports, performance trends, latency analysis, and speed comparison charts.
Bulk data integration	Regional Admin	File uploads, infrastructure files, downloadable templates, and standardized imports.
Connectivity reporting	Regional Admin	Wired/wireless reports, connectivity gap analysis, barangay filtering, and Excel/PDF export.
AI report generation	Regional Admin	Automated insight extraction, assessment synthesis, and AI-generated summaries.
System settings	SuperAdmin	Providers, services, generations, technologies, frequency allocation, and barangay coverage management.

3.3 Nationwide Broadband Validation Coverage

A key achievement of the project was the completion of activities to map and validate barangays across the target cities and municipalities. The project results were summarized in Table 3, which met the minimum of 4,981 barangays as stipulated in the TOR for both the FTTH and wireless validation categories. A total of 5,719 barangays were validated for FTTH coverage while 5,349 barangays were validated for wireless coverage. The project also finished the validation of the cities and municipalities by large city categories such as Top 10 Next Wave Cities, Top 10 Emerging Cities, highly urbanized cities and nearby cities and/or municipalities.

Table 3. Mapping and broadband validation accomplishments by target category

Indicator	TOR Target	FTTH Validated	Wireless Validated
Total barangays covered	4,981	5,719	5,349
Barangays in Top 10 Next Wave Cities	438	438	432
Barangays in Top 10 Emerging Cities	652	632	633
Barangays in HUCs except Iligan City	300	300	300
Nearby cities/municipalities barangays	1,000	1,812	1,513

These results demonstrate the operational feasibility of implementing high-resolution broadband monitoring at the barangay level. Compared with conventional reports that rely on regional or provincial averages, barangay-level validation enables regulators to identify localized service gaps and prioritize interventions more precisely.

3.4 Data Collection, Wireless Validation, and Performance Database

The project involved implementation of a workflow from the field to the database to GIS, which included mapping applications, navigation tools, NTC equipment and database integration. Wireless validation was performed with NTC products and equipment, including the ROMES, the TSME6 Rohde & Schwarz multiband scanner, and the integration of GIS and Radio Planner for visualization, radio coverage analysis and post-processing. These tools were used for technology type identification, power and center frequency analysis, signal parameter extraction and propagation mapping.

A centralized database was created to process all the validated field observations, cell site parameters, technology and band information, speed test results, and FTTH NAP points. The following table (Table 4) highlights the key datasets generated from the project. The database contains 11,721 validated cell site towers, 5,349 wireless data technology band for FTTH NAP points that have been post-processed validated and 439,120 FTTH NAP points. Towers that were discovered in the field but not mentioned in reference lists were documented but were not fully cross-referenced because the acquisition lists for sources were not available.

Table 4. Systematic data collection and database outputs

Dataset	Records Count	Key Fields	Validation Status
Cell site towers validated	11,721	Tower ID/name, coordinates, provider, notes	Validated
Towers found outside reference list	Not cross-referenceable	Coordinates, evidence reference, remarks	Not validated
Speed test records	No records	Provider, three trials, average, timestamp, location	No records
Technology band wireless data	5,349 barangays	2G/3G/4G/5G and band observations	Post-processing under validation
FTTH NAP points	439,120	NAP coordinates, provider/ISP, barangay	Validated

3.5 QoS Evaluation and Provider Performance

The project created evaluation and summary documents of the QoS, based on UPDs and common reporting formats, for cities, municipalities and providers. Performance for Internet speed was calculated based on repeated test per test point (three test per provider) and averaged results (where records were available). For NTC Region 10, averages of providers' download and upload performance were different. Table 5 shows that SMART achieved the highest average download speed of 28.6 Mbps, GLOBE 12.0 Mbps and DITO 7.4 Mbps. SMART also had the fastest average upload speed of 9.1 Mbps followed by GLOBE at 8.6 Mbps and DITO at 2.8 Mbps.

Table 5. Average provider speed performance based on NTC Region 10 ranking statistics

Provider	Avg Download (Mbps)	Avg Upload (Mbps)
GLOBE	12.0	8.6
SMART	28.6	9.1
DITO	7.4	2.8

In Region X, 917 speed tests were performed and the mean download speed was 33.35 Mbps and the mean upload speed was 11.94 Mbps. A total number of 3,509 5G availability cases were also identified across the surveyed regions, showing a significant presence of the next generation network coverage. The results demonstrate the possibility of applying the framework for provider level comparison and regional QoS assessment.

3.6 Connectivity Classification and GIS-Based Broadband Mapping

One of the significant outputs of the project is the classification of barangay sites into served, underserved and unserved categories. Summary of Barangay Locations with Strong and Reliable Connectivity: 3,452 Barangay Locations (50%) had strong and reliable connectivity that met the provider's service standards. A total of 2,875 or 42% of the barangay locations were identified to be ‘underserved', either because they were out of range or because connectivity was intermittent or weak. Lastly, 512 barangay locations or 8 per cent were identified as unserved because no signal could be detected, specifically in remote rural areas and in dense forests.

Table 6. Barangay-level connectivity classification based on validated data

Classification	Share / Count	Interpretation
Served	50% (3,452)	Strong and reliable connectivity meeting provider service standards, concentrated in cities identified as centers of excellence.
Underserved	42% (2,875)	Intermittent connectivity or low signal strength, commonly in suburban margins or urban outskirts.
Unserved	8% (512)	No detectable signal, predominantly in remote rural zones and dense forested regions.

GIS-based broadband coverage maps were generated for wired and wireless services, based on key parameters including technology, frequency band, provider, and location. The Broadband Map Website supports filtering and analytics for interpretation, report download and infrastructure updates. This GIS-based approach can enhance situational awareness by enabling NTC Central and Regional Offices to understand service gaps by using the interactive spatial layer instead of a static tabular summary.

3.7 Comparative Analysis with Existing Broadband Monitoring Approaches

There are a number of benefits of the NTC-QoS Framework over traditional methods of broadband monitoring. Platforms for crowdsourcing speed tests can give good performance indicators, but can have some methodologically biased and non-uniform spatial participation. Operators submit reports which are essential for compliance documents, but need verification. Local engineering surveys offer high accuracy measurements, but are limited to a specific region. The NTC-QoS Framework overcomes these limitations by bringing field validation, FTTH mapping, wireless validation, spectrum analysis, GIS processing, reference datasets and decision support via dashboard together in the same regulatory ecosystem.

Table 7. Comparison of broadband monitoring approaches

Feature	Crowdsourced Platforms	Operator Reports	NTC-QoS Framework
Independent field validation	✗	✗	✓
FTTH validation	Limited	Limited	✓
Wireless validation	Limited	✓	✓
Spectrum analysis	✗	✗	✓
GIS integration	Limited	Limited	✓
Barangay-level monitoring	✗	✗	✓
Cloud regulatory dashboard	Limited	Limited	✓
Decision support	Limited	Moderate	High

3.8 Implementation Challenges and Mitigation Measures

There were a number of issues with the implementation of the project. Some field validation schedules were delayed due to the weather conditions; some access to critical and restricted areas were limited to selected barangays and limitations in regional reference data also impacted on wireless validation. The manual digitization and radio coverage post-processing were also time consuming and technically laborious. A few adjustments to the schedules in the field, prioritization of accessible areas, processing the wired validation first to facilitate unidentified cell site provider tagging, a new and improved method of structuring the Excel data for subsequent importation into Radio Planner and frequent review by NTC personnel to ensure that the outputs of the processing matched the rubrics found on the CMTS, were all advised to overcome these issues. The implementation of these mitigation measures enabled the project to get to the end of the validation process, streamline manual workload, speed up post processing and enhance the workflow for the connectivity assessment.

3.9 Implications for Regulation and Digital Governance

The results demonstrate the capability of the proposed framework for not only the traditional broadband speed test but also to generate validated datasets, GIS based coverage outputs, technical reports and a functional Broadband Map Website. The following outputs will serve as an evidence base to develop an understanding of the gaps in services, improve planning for digital infrastructure and inform regulatory action. The framework also empowers future periodic validation cycles, addition of new municipalities and growth corridors, institutionalized reporting of suspected illegal stations, common definitions of QoS KPIs and continuous enhancement of data governance, user roles and security of the system.

4. Conclusion

This study introduced the multi-source broadband validation and mapping framework, the National Telecommunications Commission Quality of Service (NTC-QoS) Framework, which helps in evidence-based telecommunications regulation in the Philippines. The proposed framework, in contrast to traditional broadband monitoring methods based on operator-reported data, crowdsourced speed-test sites, or self-reported engineering surveys, combines field-validation of Fiber-to-the-Home (FTTH) network service offerings, wireless broadband measurement sites and data collection, radio spectrum analysis, validated cell site inventories and information, Network Access Point (NAP) mapping, Geographic Information Systems (GIS) and a cloud-based regulatory information system into a one-stop national broadband monitoring platform. The framework facilitates multiple independent data sources to be integrated, allowing for higher level confidence in validating broadband infrastructure and Quality of Service (QoS) indicators and to support interactive visualization and regulatory analytics at national, regional, city, municipality and barangay levels.

The implementation provided evidence of the feasibility of the nationwide broadband validation using standard methodologies in the field. The completed system resulted to validated datasets of 5,719 FTTH barangays, 5,349 wireless validation barangays, 439,120 mapped Network Access Points, 11,721 validated cellular sites and 3,509 recorded 5G observations. The outputs meet or far exceed the minimum contractual requirements and demonstrate the strength of the framework to provide high resolution spatial evidence for identified served, underserved, and unserved communities. These datasets are then further turned into interactive GIS layers, regulatory dashboards, regulatory infrastructure inventories, infrastructure connectivity, and automated reporting tools that offer a far greater level of regulatory situational awareness than traditional static reporting methods.

The proposed framework adds a decision support model that is scalable towards independent verification of telecommunication infrastructure and broadband performance from a regulatory point of view. Using engineering measurements, spatial analytics, and centralised information management, regulators can gain insight into where there is a localized deficiency in connectivity, track provider quality, prioritise investment in broadband infrastructure, assess national broadband policies, and help drive digital inclusion with objective and validated evidence. The framework also provides a repeatable methodology that can be institutionalised for periodic national assessments of QoS to enable a continuous monitoring process, instead of evaluation exercises.

However, there are a few drawbacks to these contributions. Post-processing and reconciliation of some wireless validation records are still ongoing and implementation regions differed in the availability of speed tests. Likewise, access to certain areas was limited due to their geographical isolation and security concerns, which also affected full field coverage in specific barangays. Also, the framework uses several independent datasets, but more integration with real-time network telemetry, crowdsourced measurements, and automated spectrum monitoring would improve the temporal resolution and operational responsiveness.

To expand the framework to a fully functional nationwide Broadband observatory for all Philippine barangays, future work is recommended. Continuous automatic data acquisition, incorporation of both fixed and mobile crowdsourced measurements, automated identification of anomalies with the aid of AI, predictive modelling of the broadband quality, prioritisation of infrastructure investment, monitoring of the trends in broadband performance over time. The platform could also feature future performance metrics for 5G Advanced and 6G technology, satellite broadband testing, Internet of Things (IoT) connectivity testing and machine learning tools to automatically identify underserved communities in future versions. All these developments contribute to the NTC-QoS Framework becoming a viable basis for data-driven policy making in telecom, national digital infrastructure planning, and even evidence-based broadband governance in the Philippines.

Author Contributions

Conceptualization, A.M.; methodology, A.M.; software development and system design, A.M.; validation, A.M., and the NTC-QoS field validation team; investigation, A.M.; resources, A.M.; data curation, A.M.; writing—original draft preparation, A.M.; writing—review and editing, A.M.; visualization, A.M.; supervision, A.M.; project administration, A.M.; funding coordination, A.M. The author has read and approved the published version of the manuscript.

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Data Availability Statement

The datasets generated and analyzed during the study are maintained in the NTC-QoS Portal and project database. Access to the full datasets is restricted due to regulatory, infrastructure, and data governance considerations. Aggregated results, figures, and summary statistics are included in this article. Additional data may be made available from the corresponding author upon reasonable request and subject to approval by the National Telecommunications Commission.

Conflicts of Interest

The author has no competing financial interests and no personal relationships that could be construed to bias the results of this work reported in this paper. The funder was present during the project implementation, but was not involved in the preparation, interpretation, or decision to submit this manuscript for publication.

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References

1. Broadband Forum. (2006). Triple-play services quality of experience requirements. Broadband Forum Technical Report.
2. Budiman, E., & Wicaksono, O. (2016). Measuring quality of service for mobile internet services. 2016 2nd International Conference on Science in Information Technology (ICSITech), 300–305. https://doi.org/10.1109/ICSITech.2016.7852652
3. Budiman, E., Moeis, D., & Soekarta, R. (2017). Broadband Quality of Service Experience: Measuring mobile networks from consumer perceived. 2017 3rd International Conference on Science in Information Technology (ICSITech), 423–428.
4. Chen, Y., & Lee, S. Y. (2000). Bounded tag fair queuing for broadband packet switching networks. Computer Communications, 23(1), 45–61.
5. Choudrie, J., & Lee, H. (2004). Broadband development in South Korea: Institutional and cultural factors. European Journal of Information Systems, 13(2), 103–114.
6. Enabulele, E. A., & Ghinea, G. (2006). Broadband quality regulation: Perspectives from UK users. IEEE Broadband Networking Conference.
7. Ghinea, G., Thomas, J. P., & Fish, R. S. (1999). Multimedia, network protocol and users: Bridging the gap. Proceedings of the Seventh ACM International Conference on Multimedia, 473–476.
8. International Telecommunication Union. (2001). ITU-T Recommendation G.1000: Communications quality of service: A framework and definitions.
9. International Telecommunication Union. (2008). ITU-T Recommendation E.800: Definitions of terms related to quality of service.
10. Leung, K. K. (2002). Load-dependent service queues with application to congestion control in broadband networks. Performance Evaluation, 50(1), 27–39.
11. Lorenz, D. H., & Orda, A. (2002). Optimal partition of QoS requirements on unicast paths and multicast trees. IEEE/ACM Transactions on Networking, 10(1), 102–114.
12. Malisuwan, S., Milindavanij, D., & Kaewphanuekrungsi, W. (2016). Quality of service (QoS) and quality of experience (QoE) of the 4G LTE perspective. International Journal of Future Computer and Communication, 5(3), 158–162.
13. Marchetti, C., Pernici, B., & Plebani, P. (2004). Quality of service: A quality model for multichannel adaptive information. Proceedings of the 13th International World Wide Web Conference on Alternate Track Papers & Posters, 48–54.
14. Orda, A. (1999). Routing with end-to-end QoS guarantees in broadband networks. IEEE/ACM Transactions on Networking, 7(3), 365–374.
15. Sangjo, O., Joongho, A., & Beomsoo, K. (2003). Adoption of broadband Internet in Korea: The role of experience in building attitudes. Journal of Information Technology, 18(4), 267–280.
16. Venkatesh, V., & Brown, S. A. (2001). A longitudinal investigation of personal computers in home: Adoption determinants and emerging challenges. MIS Quarterly, 25(1), 71–102.
17. Alamri, S. (2024). The geospatial crowd: Emerging trends and challenges in spatial data analytics and crowdsourcing. ISPRS International Journal of Geo-Information, 13(6), 168.
18. Al-Azzeh, J. S., et al. (2022). Method for QoE monitoring and increasing in cellular communication networks. EURASIP Journal on Wireless Communications and Networking, 2022, Article 83.
19. Burger, E. W., et al. (2023). Measuring Broadband America: A retrospective on origins, achievements, and challenges. Proceedings of the ACM SIGCOMM Workshop on Network-Application Integration.
20. Chen, Y. P., Oughton, E. J., Zagdanski, J., Jia, M. M., & Tyler, P. (2023). Crowdsourced data indicates broadband has a positive impact on local business creation. arXiv. https://arxiv.org/abs/2308.14734
21. Department of Information and Communications Technology. (2025). National Digital Connectivity Plan. https://cms-cdn.e.gov.ph/DICT/pdf/LATEST%20PUBLICATION%20NDCP_bda86f60-7dd4-4cf9-be58-c25275508074.pdf
22. Fida, M. R., et al. (2023). Bottleneck identification in cloudified mobile networks using user-side performance monitoring. IEEE Access, 11, 103000–103014.
23. International Telecommunication Union. (2025). Measuring digital development: Facts and Figures 2025. https://www.itu.int/en/ITU-D/Statistics/pages/facts/default.aspx
24. MacMillan, K., et al. (2023). A comparative analysis of Ookla Speedtest and NDT7. Proceedings of the ACM on Measurement and Analysis of Computing Systems, 7(1).
25. Organisation for Economic Co-operation and Development. (2022). Broadband statistics. https://www.oecd.org/en/topics/sub-issues/broadband-statistics.html
26. Paul, U., et al. (2022a). The importance of contextualization of crowdsourced Internet measurement data. Proceedings of ACM Internet Measurement Conference 2022.
27. Paul, U., et al. (2022b). Characterizing Internet access and quality inequities in California. Proceedings of ACM COMPASS 2022.

28. Samulowska, M. (2021). Crowdsourcing without data bias: Building a quality assurance system for volunteered geographic data. ISPRS International Journal of Geo-Information, 10(2), 46.
29. Serafica, R. B. (2023). Making broadband universal: A review of Philippine policies and strategies. Philippine Institute for Development Studies. https://pidswebs.pids.gov.ph/CDN/document/pidsdps2331.pdf
30. Sharma, T., et al. (2024). Beyond data points: Regionalizing crowdsourced latency measurements. Proceedings of the ACM on Measurement and Analysis of Computing Systems.
31. Tripkovic, S., et al. (2023). Unbiased benchmarking in mobile networks: The role of sampling and stratification. IEEE Access, 11, 60235–60248.