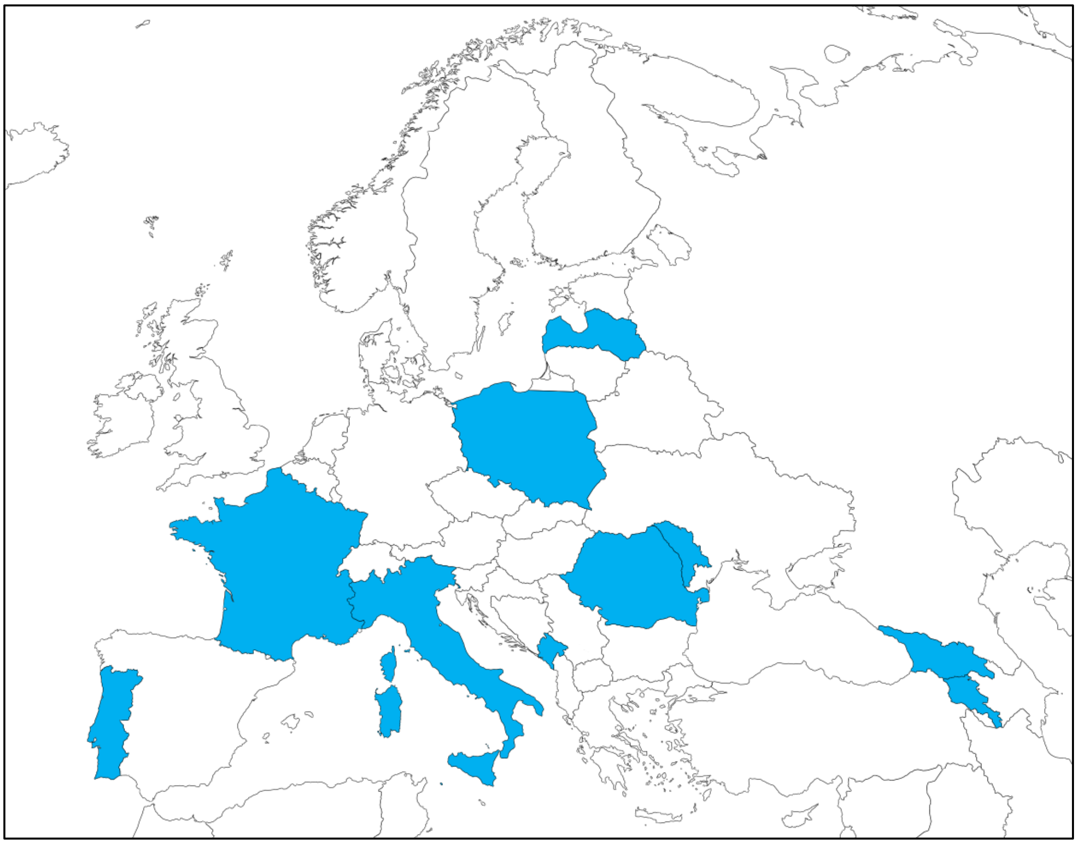
International Telecommunication Union



Compendium of Case Studies on Broadband Mapping Systems Across the EMERG and EaPeReg Regions

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Acronyms

AGCOM - Autorità di Regolazione per le Comunicazioni (Italy)
ANACOM - Portuguese Regulatory Authority for Communications
ANCOM - National Regulatory Authority for Electronic Communications and Information Technology (Romania)
ANRCETI - National Regulatory Agency for Electronic Communications and Information Technology (Moldova)
ARCEP - Autorité de Régulation des Communications Électroniques et des Postes (France)
BBmap - Broadband Mapping System in Italy
BCRD - Broadband Cost Reduction Directive
BEREC - Body of European Regulators for Electronic Communications
BNS - National Bureau of Statistics of the Republic of Moldova
ComCom - Georgian National Communications Commission
COTS - Commercial Off-The-Shelf
DAE - Digital Agenda for Europe
EaPeReg - Eastern Partnership Electronic Communications Regulators Network
EECC - European Electronic Communications Code
EKIP - Agency for Electronic Communications and Postal Services (Montenegro)
EMERG - European Mediterranean Regulators Group
ERCB - Regulatory Authority for Electronic Communication and Postal Services (Armenia)
ETL - Extract, Transform, Load
EU4Digital - European Union for Digital Networks Program
FttH - Fiber to the Home
GDPR - General Data Protection Regulation (EU)
GIA - Gigabit Infrastructure Act
GIS - Geographic Information System
HPE - Hewlett Packard Enterprise
ICT - Information and Communication Technology
INE - National Statistical Office (Portugal)
IPTV - Internet Protocol Television
ISPs - Internet Service Providers
ITU - International Telecommunication Union
LTEA - LTE Advanced (4G technology used in Armenia)
MoU - Memorandum of Understanding
MONSTAT - National Statistics Authority (Montenegro)
NRAs - National Regulatory Authorities
PIT - Single Information Point (Poland)
PostGIS - PostgreSQL Geographic Information System Extension
PPĢIS - Broadband Availability Geographical Information System (Latvia)
PSRC - Public Services Regulatory Commission (Armenia)
PUC - Public Utilities Commission (Latvia)
QGIS - Quantum Geographic Information System
REIF - Registry of Engineering Infrastructure Facilities (Moldova)
ROMES - Radio Frequency Measurement System (Romania)
SDGs - Sustainable Development Goals
SIDUSIS - System used for digital mapping in Poland

SIMBA - System for data analysis in Poland
SIP - Single Information Point
STISC - Information Technology & Cyber Security Service (Moldova)
UKE - Office of Electronic Communications (Poland)
UN - United Nations
VHCN - Very High Capacity Networks
inTELi - Telecommunications data system in Poland

Acknowledgments

The "Compendium of Case Studies on Broadband Mapping Systems across the EMERG and EaPeReg Regions" was developed by the ITU Office for Europe, in close collaboration with numerous stakeholders from EMERG and EaPeReg who have contributed their expertise and efforts to this comprehensive project.

This compendium was produced under the supervision of Mr. Jaroslaw Ponder, Head of the ITU Office for Europe. The project was closely coordinated by Mr. Elind Sulmina, Project Officer, ITU Office for Europe, and Dr. Michał Chojnowski, ITU Broadband Mapping system expert.

Special recognition is given to the key contributors from the participating countries of the series of workshops: Montenegro, Moldova, Poland, Armenia, Italy, Latvia, France, Georgia, Portugal, and Romania. Their detailed case studies and thorough analysis have provided a comprehensive understanding of the broadband mapping efforts and challenges in their respective regions.

Introduction and Purpose

The ITU has produced the **Compendium of Case Studies on Broadband Mapping Systems across the EMERG and EaPeReg Regions** to advance global knowledge in the field of broadband mapping systems. This document results from collaborative efforts following the joint declaration during the Global Symposium for Regulators 2023 (GSR23) between the ITU, EMERG and EaPeReg.

In the digital era, broadband infrastructure plays a critical role in shaping the socio-economic landscape of countries. Recognizing this, the ITU, alongside EMERG and EaPeReg, has initiated a series of workshops aimed at strengthening broadband infrastructure and services across Europe and beyond. These workshops align with ITU's aim of achieving the UN Sustainable Development Goals and facilitate the exchange of expertise and experiences among member countries and stakeholders, fostering a collaborative environment for digital transformation.

The compendium elaborates on the outcomes and learnings from the series of joint workshops. Furthermore, the compendium presents detailed case studies from Montenegro, Moldova, Poland, Armenia, Italy, Latvia, France, Georgia, Portugal, and Romania, highlighting good practices, challenges, current trends, and future outlook. This document serves as a critical resource for understanding and enhancing broadband mapping systems. It aims to aid policymakers, regulators, and industry stakeholders in gaining an in-depth understanding of the similarities, differences, challenges and opportunities that these two regional regulatory associations may have in common. The insights from these case studies are intended to promote harmonization of approaches and foster stronger cooperation among the regions, ultimately contributing to the advancement of global telecommunication infrastructure and services in the European continent and beyond.

Workshop Series and Contributions

The series of three workshops brought together regulatory authorities, industry representatives, and other relevant stakeholders to discuss and share good practices and challenges in broadband mapping. These workshops were instrumental in collecting case studies from various countries, which form the foundation of this compendium. Each workshop focused on specific countries and their approaches to broadband mapping: the first workshop in Montenegro presented case studies from Montenegro, Moldova, and Poland, offering insights into their strategies and methodologies in broadband mapping; the second online workshop featured case studies from Armenia, Italy, Latvia, and France, broadening the scope of the compendium with diverse European experiences; and the third workshop in Georgia included case studies from Georgia, Portugal, and Romania, adding further depth to the understanding of broadband infrastructure across the regions.

Methodology

The methodology for compiling this compendium involved a systematic approach to collecting and analyzing data from the participating countries. Each case study was developed through a combination of desk research, gathering of the presentations delivered during the workshops, email exchanges with the presenters, and analysis of any additional relevant documentation. The workshops facilitated direct exchanges of experiences and best practices, which were then documented and synthesized into the case studies. This approach ensured a comprehensive and nuanced understanding of the broadband mapping efforts in each country, highlighting both successes and challenges.

Strategic Collaboration Between ITU, EMERG, and EaPeReg

The strategic collaboration between ITU, EMERG, and EaPeReg is underpinned by respective bilateral memoranda of understanding and a trilateral joint declaration signed on June 5, 2023. This collaboration is aimed at expanding and enhancing global telecommunications and ICT. The joint declaration, endorsed by the Director of ITU's Telecommunication Development Bureau, the Commissioner of ComCom Georgia and EaPeReg Chair for 2023, and the Head of International Affairs Department, Ministry of Communications, Israel, and EMERG Co-Chair, marks a pivotal step towards cooperative efforts in the field of broadband infrastructure and services mapping. The declaration aligns with the ITU Development priority on 'Affordable connectivity' and the expected outcomes of the ITU Regional Initiative for Europe on 'Digital infrastructure development'.

The collaboration focuses on strengthening cooperation in mapping broadband infrastructure and services, facilitating knowledge sharing and best practices, and committing to joint workshops aimed at mapping broadband infrastructure and services. This initiative aligns with Resolution 139 (Rev. Bucharest, 2022), which aims to use telecommunications/ICT to bridge the digital divide and build an inclusive information society. The resolution acknowledges the necessity of enhancing affordability, availability, and investment in connectivity and relevant infrastructure, especially in developing countries, and recognizes the significant role of telecommunications/ICT in economic and social development.
The MoU between ITU and EaPeReg, signed on May 14, 2020, symbolizes a significant collaboration between a specialized agency of the United Nations and a pivotal regional network comprising NRAs for Electronic Communications Networks and Services in the Eastern Partnership countries. This partnership aims to harness the potential of ICT as a catalyst for sustainable development, aligning closely with the UN's SDGs. The ITU brings its extensive global outreach and resources to this partnership, while EaPeReg encompasses Armenia, Azerbaijan, Belarus, Georgia, Moldova, and Ukraine, holding a critical position in the regional telecommunications landscape.

Similarly, the MoU between ITU and EMERG, formalized at the Global Symposium for Regulators 2023, marks a pivotal development in the realm of electronic communications. This partnership fosters dynamic collaboration, focusing primarily on the development and regulation of electronic communications to navigate the evolving landscape of a sustainable digital future. The essence of the ITU-EMERG MoU lies in its commitment to joint initiatives and projects that resonate with the broader objective of global digital transformation. This strategic collaboration between ITU, EMERG, and EaPeReg represents a significant step towards enhancing the telecommunications sector. It underscores the necessity for international cooperation in tackling the complexities of the digital era, aiming to facilitate enhanced connectivity and foster sustainable digital growth. Through this collaborative endeavor, ITU, EMERG, and EaPeReg are setting a precedent for how global and regional entities can work together to achieve common goals in the ever-evolving world of electronic communications.

The Importance of Broadband Infrastructure and Services Mapping

Broadband infrastructure and services mapping involves systematically documenting and analyzing the availability and quality of broadband internet infrastructure and services within a specific area, often within a country. This comprehensive effort aims to create an accurate representation of the broadband landscape, including details such as coverage, speed, technology, and service providers. The key objectives of broadband mapping are to identify coverage gaps, inform policy and investment decisions, promote competition, facilitate infrastructure planning, improve consumer awareness, monitor progress, and support research and analysis. Ultimately, the goal is to create a comprehensive understanding of the state of broadband connectivity, leading to well-informed decision-making, targeted investments, and improved access to high-speed internet services for all.

The ITU Experience

The ITU has been instrumental in promoting the development of broadband infrastructure worldwide. Recognizing the transformative power of broadband connectivity, the ITU has implemented several initiatives to support the establishment and strengthening of national broadband mapping systems. In
2012, the ITU initiated the Interactive Transmission Maps project, a landmark effort aimed at mapping the global data highways. This project meticulously documents over 3,944,376 kilometers of backbone networks, incorporating data from more than 540 operators worldwide. The Interactive Transmission Maps provide comprehensive georeferenced data on national and international backbone transmission networks. These maps are essential tools for policymakers, regulators, and stakeholders, enabling them to visualize and analyze the global telecommunications infrastructure.

Building on the success of the Interactive Transmission Maps, the ITU expanded its focus to include broadband access networks. This expansion aims to address last-mile connectivity challenges and ensure that broadband services reach underserved and unserved areas. The new layer on the Interactive Transmission Maps now provides detailed information on the existence, type, and institutions responsible for broadband mapping systems targeting access networks. This initiative spans all six ITU regions, aiming to build a comprehensive repository of information accessible to all stakeholders and identify gaps in current practices.

To further support countries in developing effective broadband mapping systems, the ITU established the ITU Guidelines for Establishing Broadband Mapping Systems in 2022. These guidelines address the regulatory, technical, and project management barriers to successful broadband mapping. Drawing on best practices from around the world, particularly from Europe, these guidelines provide a framework for countries to follow. They outline minimum requirements and milestones for the implementation of broadband mapping systems, emphasizing the importance of georeferenced data in telecommunications policy.

On the regulatory aspects, the ITU's guidelines emphasize the need for a robust regulatory framework to support broadband mapping. This includes defining the legal mandates for data collection, ensuring data privacy and security, and establishing clear roles and responsibilities for different stakeholders. By aligning with international best practices, countries can create an enabling environment for effective broadband mapping. On the other hand, regarding technical requirements, the ITU's guidelines recommend the use of advanced geospatial technologies, such as GIS, to collect and analyze broadband data. The guidelines also emphasize the importance of interoperability and standardization to ensure that data from different sources can be integrated seamlessly, ensuring the accuracy and reliability of the data collected.

Finally, in terms of project management, successful broadband mapping requires effective coordination of the efforts of various stakeholders. The ITU's guidelines provide recommendations on project planning, stakeholder engagement, resource allocation, and sustainability. By following these recommendations, countries can ensure that their broadband mapping projects are well-managed and achieve their intended outcomes.

The EU Experience

The EU has developed a robust strategic and policy framework to support broadband mapping, reflecting a comprehensive and coordinated approach to digital development. Key strategies include the DAE and the Connectivity for a Competitive Digital Single Market. These strategies highlight the necessity of significant investments in broadband infrastructure and emphasize the reduction of deployment costs through collaborative efforts among member states. Central to the EU's approach are several pivotal regulations and directives. The EU Guidelines on State Aid for Broadband (2013) mandate a detailed mapping and analysis of coverage to facilitate the identification of underserved areas and ensure the efficient allocation of public funding. This directive ensures that resources are directed where they are most needed, fostering equitable access to broadband services. The BCRD (2014) promotes the joint use of existing physical infrastructure and the coordinated deployment of new infrastructure. This directive aims to reduce costs and improve efficiency in broadband deployment by mandating the establishment of a Single Information Point (SIP) to provide comprehensive data on existing infrastructure. The centralization of information through SIP helps streamline the deployment process and minimize redundancies. The EECC (2018) requires member states to conduct geographical surveys of network deployments and update this information regularly. The EECC empowers BEREC to set guidelines for these surveys, further enhancing the regulatory framework for broadband mapping. This ensures that mapping data remains current and accurate, supporting ongoing and future broadband development efforts.

The implementation of these regulations has had a significant impact on broadband mapping across the EU. Member states have developed comprehensive mapping systems that include data on both infrastructure and service availability. The EU's approach to broadband mapping is characterized by consistency and harmonization, with efforts to standardize practices across member states leading to greater uniformity in data collection and analysis. Transparency and public consultation are emphasized, ensuring that mapping efforts are inclusive and comprehensive. Public consultations and competitive selection processes play a key role in this inclusive approach. Investment in technology and infrastructure has been a cornerstone of the EU's strategy. The EU has invested in advanced mapping technologies and tools to improve the accuracy and reliability of broadband data. This includes the use of GIS technology and interactive maps to visualize broadband coverage and quality, providing valuable insights for policymakers, regulators, and stakeholders.

The European experience provides several valuable lessons and best practices for broadband mapping. A well-defined legal and regulatory framework is essential for successful broadband mapping. The EU's guidelines and directives offer clear mandates and responsibilities for member states, creating a solid foundation for mapping initiatives. Effective broadband mapping requires collaboration between regulators, operators, and other stakeholders. The EU's approach to stakeholder involvement has been key to its success, fostering a collaborative environment that enhances mapping efforts. Ensuring the accuracy and reliability of mapping data is crucial. The EU's emphasis on regular updates and data validation has helped maintain high standards of data quality. Sustainable mapping systems that can adapt to technological changes and evolving market conditions are vital. The EU's investment in scalable and adaptable mapping tools supports long-term sustainability, ensuring that broadband mapping efforts can continue to evolve and improve.

Conclusion

It appears evident that both ITU and the EU's experiences in broadband mapping underscore the importance of a comprehensive and holistic approach. ITU's efforts highlight the critical role of integrating regulatory, technical, and project management aspects. Through its guidelines, capacity- building initiatives, and knowledge-sharing platforms, ITU has significantly contributed to the development of effective broadband mapping systems in numerous countries, which are essential for achieving universal connectivity and fostering inclusive digital development. Similarly, the EU's approach, marked by strategic policies, robust regulations, and significant investments in technology and collaboration, offers a valuable model for other regions. By learning from the EU's experience, countries can develop broadband mapping systems that enhance digital infrastructure, improve service quality, and ensure equitable access to broadband services for all citizens.

Combining the insights from both ITU and the EU is crucial because it provides a comprehensive framework that can guide global efforts towards achieving universal and inclusive broadband connectivity. The ITU's global perspective and technical expertise, coupled with the EU's robust regulatory frameworks and advanced technological investments, offer a balanced and thorough approach to broadband mapping. This integrated approach ensures that countries can adopt best practices tailored to their unique contexts while striving towards a common goal of enhanced digital infrastructure and inclusive growth. The compendium, therefore, stands as a testament and framework of the intersection of the work between the ITU and the EU in the field of broadband mapping systems.

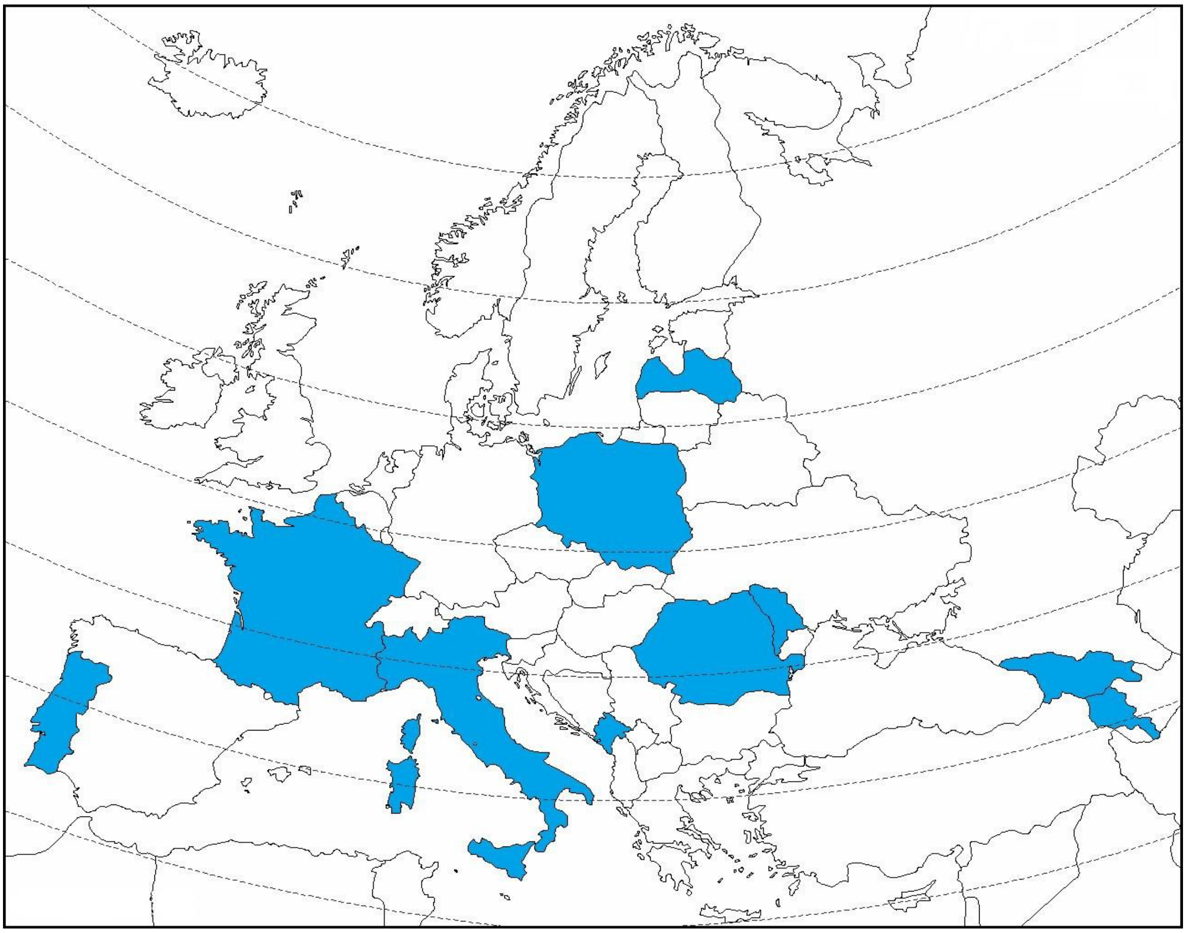


Figure 1. Map presenting countries, subject to case studies for 2023 Workshops

Case study 1: Montenegro

On September 28, 2023, EKIP presented Montenegro's broadband mapping system, with Dubravka Aleksić and Matija Tomčić as key speakers. The system plays a vital role in advancing Montenegro's digital infrastructure across 25 municipalities and 1,307 settlements. With a population of 620,029 over 13,883 km², the country has its capital in Podgorica and a historical capital in Cetinje.

EKIP leads the broadband mapping initiative, integrating national legislation, system architecture, diverse data sources, and advanced visualization tools to guide the nation's digital transformation. Central to this initiative is a solid legal framework based on laws such as the Law on Electronic Communications, the Rule Book on Data Delivery and Disclosure, and the Law on the Use of Infrastructure for High-Speed Electronic Communication Networks. These laws, aligned with the Digital Transformation Strategy (2022-2026), form the foundation for developing Montenegro's digital infrastructure.

The system is managed collaboratively with operators, planners, and national and local institutions. Data sources include operator-provided details about infrastructure (e.g., antenna poles, buildings, cables) and demographic information from national institutions. Data can be entered directly on the map or imported in bulk via shapefiles. The system is powered by QGIS, Geoportal, PostgreSQL/PostGIS, and Java applications, with HPE ProLiant servers handling storage and processing. Regular backups ensure data integrity.

One of the system's key features is its user-friendly interface, accessible to operators, planners, and institutions through public portals. It provides insights into geographical locations, ownership, broadband coverage, speeds, technologies, and the number of operators. The 100x100m grids display coverage data, offering transparency for both public and private stakeholders.

Challenges remain, particularly in reconciling discrepancies between database information and actual conditions. EKIP tackles these issues through rigorous data control, cross-referencing operator data with other agency systems. Future updates will enhance monitoring tools for broadband coverage and infrastructure development, as well as improve data control mechanisms.

In terms of coverage visualization, the system uses operator data on endpoint locations, displaying information by ownership, technology, and speed. Calculations are supported by data from operators, MONSTAT, and the Cadastre and State Property Administration, offering detailed insights into broadband coverage.

Overall, EKIP's presentation highlighted Montenegro's sophisticated approach to broadband mapping, demonstrating a commitment to evolving the country's digital infrastructure and setting an example for other nations.

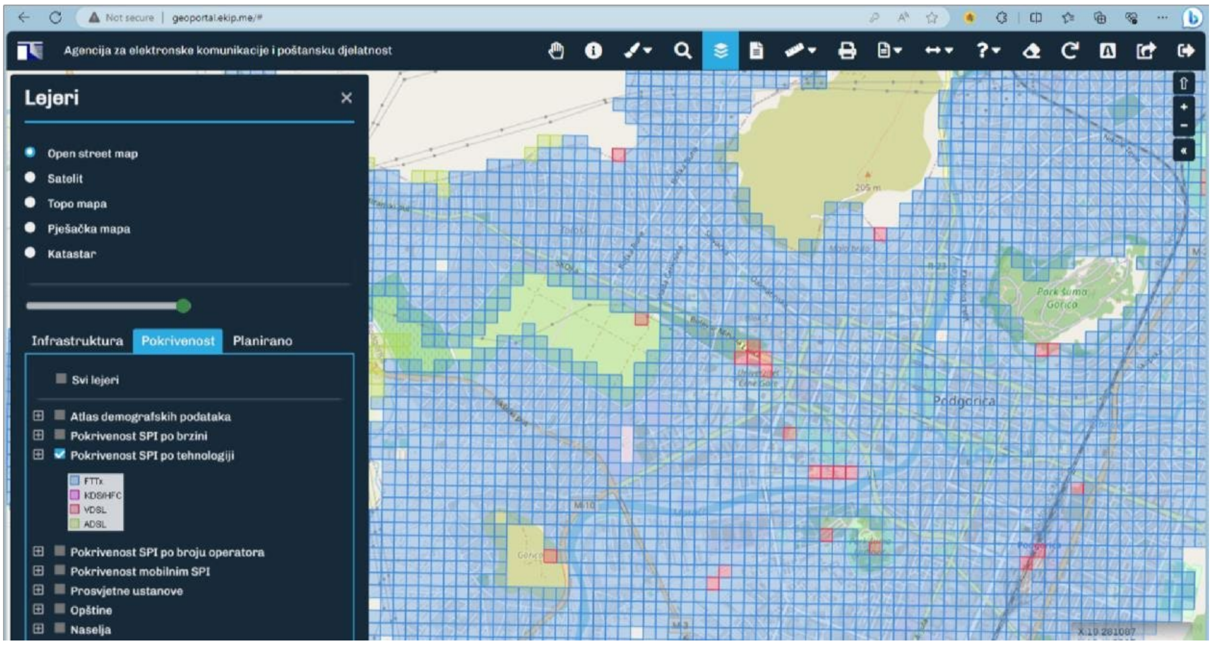


Figure 2. Montenegro's geoportal.ekip.me Broadband Coverage view by technologies

Aspect	Details
Legal Framework	Law on Electronic Communications, Rule Book on Data Delivery and Disclosure, Law on the Use of Infrastructure for High-Speed Electronic Communication Networks
Responsible Entities	EKIP
System Name	Broadband Mapping System
Main Objectives	Enhance digital infrastructure, identify coverage gaps, facilitate investments, reduce deployment costs
Data sources	Operator-provided information, national institutions (cadastre, settlements, statistical authorities)
Key Features	Comprehensive mapping of infrastructure (antenna poles, buildings, ducts, air cables), GIS technology, interactive maps, public access portals
Challenges	Data accuracy, consistency with real-world situations, technological updates
Future Steps	Enhanced Geoportal functionalities, improved data control tools, additional monitoring capabilities

Case study 2: Moldova

Vitalie Boboc, Head of the Electronic and Postal Communications Policy Directorate at the Ministry of Economic Development and Digitalization of the Republic of Moldova, presented the broadband mapping project on September 28, 2023. Moldova has made significant progress in strengthening its broadband infrastructure and services, focusing on reliable data, legislative frameworks, and stakeholder collaboration.

Moldova's broadband mapping is supported by a strong legal framework, including laws on access to properties, electronic communications, spatial data infrastructure, and the register of technical infrastructure objects. These laws align with European directives and ensure efficient, legal coordination of broadband initiatives.

The system, managed by various entities, includes contributions from ANRCETI, which has developed both road and fixed broadband coverage maps. Major telecom operators like Moldtelecom, Orange Moldova, and Moldcell have also provided coverage maps for their respective technologies. The Public Services Agency's implementation of the REIF consolidates spatial data to aid infrastructure management.

Moldova is actively aligning its data with EU directives, particularly Directive 2014/61/EU. The REIF focuses on engineering infrastructure, such as water, electric, and communication networks, and ensures compliance through monitoring, expert assessments, and recommendations.

Broadband coverage visualization is key to Moldova's digital infrastructure development, offering insights into service availability and quality across the country. The main objectives are identifying coverage gaps, assessing service quality, directing investment, preventing financing duplication, and ensuring regulatory compliance. The system also facilitates efficient use of funds and lowers network construction costs through coordination with existing infrastructure.

Stakeholder collaboration is essential to the success of Moldova's broadband mapping system. The Ministry of Economic Development and Digitalization, ANRCETI, network operators, local authorities, and institutions like STISC and the Public Services Agency work together to ensure data integration and the reliability of the mapping system.

While the mapping initiative has seen progress, implementation has been fragmented. Different entities, such as ANRCETI and telecom companies, provide separate coverage maps. However, Moldova's national spatial data infrastructure, through the REIF, plays a critical role in compiling comprehensive data. The methodology for calculating broadband coverage, based on data from operators and national institutions like BNS, offers a systematic view of broadband availability across the country.

Challenges in implementing broadband mapping have been analyzed by organizations such as EU4Digital and the World Bank. Their analyses have identified gaps in the legal framework and offered recommendations to better align Moldova’s system with EU standards. The collaboration between the Public Services Agency and STISC underscores the coordinated efforts necessary for successful mapping.

In conclusion, Vitalie Boboc’s presentation emphasized the importance of comprehensive and accurate broadband mapping for policy-making and infrastructure development in Moldova. Backed by a robust legal framework and collaborative engagement, Moldova is well-prepared to address coverage gaps, ensure efficient resource allocation, and improve its digital connectivity.

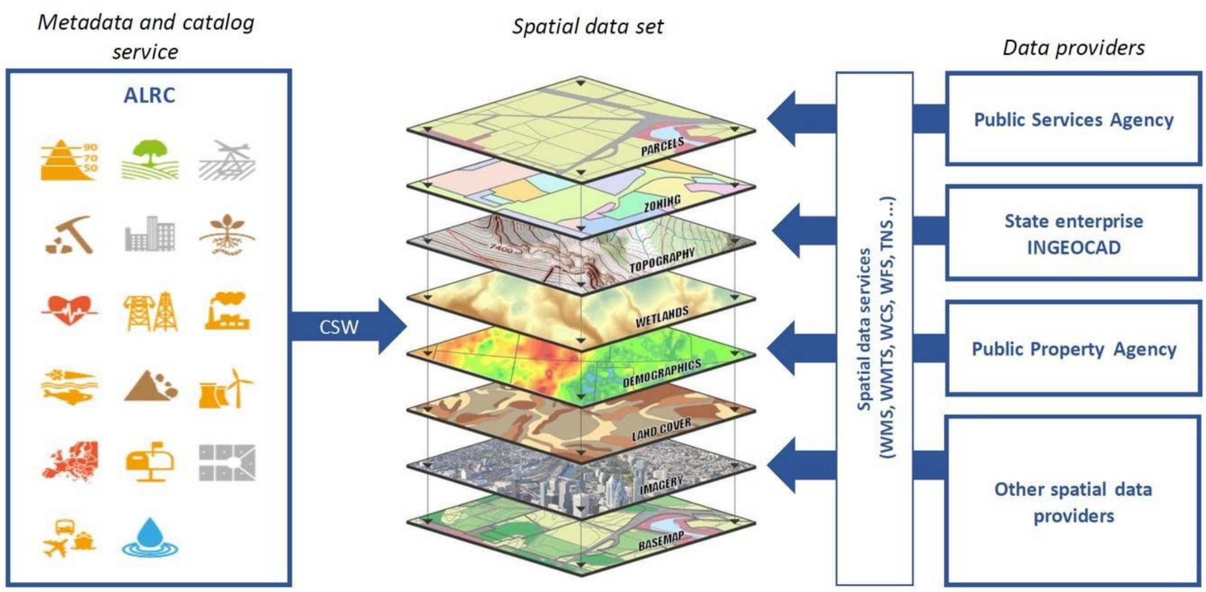


Figure 3. National Spatial Data Infrastructure of Moldova

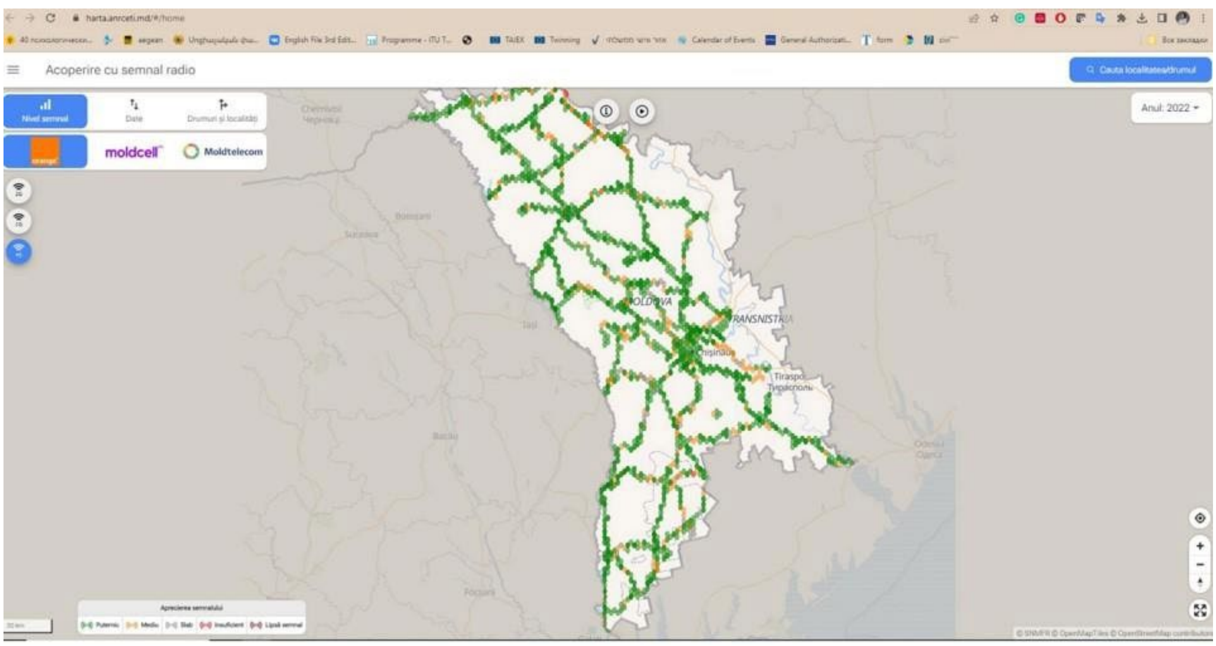


Figure 4. ANRCETI's Interactive Map of coverage and quality of mobile services on public roads (https://harta.anrceti.md/#/home)

Summary table for Moldova:

Aspect	Details
Legal Framework	Laws on access to properties, electronic communications, spatial data infrastructure, register of town-technical infrastructure objects
Responsible Entities	Electronic and Postal Communications Policy Directorate, Ministry of Economic Development and Digitalization, ANRCETI
System Name	Broadband mapping system
Main Objectives	Identify coverage gaps, suitable investment areas, avoid financial duplications, ensure efficient use of existing infrastructure
Data sources	Operator-provided information, national institutions (cadastre, settlements, statistical authorities)
Key Features	Interactive and statistical maps, detailed data on network coverage and technology, user-generated data
Challenges	Data accuracy, dynamic technological landscape, funding, and infrastructure deployment
Future Steps	Data validation mechanisms, public-private collaboration, regular updates, awareness campaigns, policy review

Case study 3: Poland

Michał Chojnowski, Ph.D., from the Office of the President of UKE, provided an in-depth overview of Poland's broadband infrastructure and services mapping. His presentation highlighted the complexity and sophistication of the country's approach, supported by a robust legal framework and advanced data platforms.

Poland's broadband mapping system centers around PIT, supplemented by complementary systems that gradually integrate or transfer data to PIT. This integrated approach is reinforced by key legislation, such as the Polish Act on Supporting the Development of Telecommunications Services and Networks, the Polish Telecommunications Law, and Directive 2014/61/EU, which aims to reduce the cost of high-speed electronic communications network deployment (BCRD). Additionally, the GIA, introduced by the European Commission in 2023, outlines steps to achieve Gigabit connectivity across the EU by 2030. As of January 1, 2023, regulatory changes mandate the President of UKE to prepare bi-annual inventories of telecommunications infrastructure, services, and colocation buildings, enhancing data granularity.

The PIT platform, accessible via https://pitmap.uke.gov.pl/, serves as a comprehensive tool for data analysis, report generation, and advanced searches. It includes data on telecommunications infrastructure, services, colocation buildings, and non-telecommunications infrastructure declarations. Other systems such as SIDUSIS, SIMBA, inTELi, and MapBook offer functionalities like internet availability checks, project management, and detailed data analysis, reflecting the multifaceted nature of Poland's broadband mapping initiatives.

Poland’s mobile network mapping focuses on detailed data collection from base station cells, including antenna location, cell characteristics, emission parameters, and band/channel specifics, in line with the Regulation of the Minister of Digital Affairs. The methodology for 4G/5G network throughput measurements emphasizes a reference grid, measurement locations, and both passive and active measurements to assess network capacity. The results, which include data tables, device specifications, and geographical coordinates, demonstrate Poland’s meticulous approach to understanding and improving network performance.

Broadband coverage visualization in Poland draws from various datasets, including information on foreign entities, nodes, flexibility points, cable line routes, base stations, mobile network ranges, and services at address points. Tools like PIT help address challenges related to infrastructure ownership and cable line routes, contributing to a clearer understanding of the broadband landscape. Continuous regulatory improvements and reporting mechanisms, alongside new tool development, further enhance Poland’s broadband coverage visualization efforts. The GIA supports Poland’s and the EU’s goal of achieving gigabit connectivity by 2030.

In summary, Michał Chojnowski’s presentation underscored the legal, technological, and methodological advancements in Poland’s broadband mapping system. The combination of a strong legal foundation, advanced platforms like PIT, and detailed measurement methodologies positions Poland as a leader in broadband mapping and network analysis. This comprehensive approach not only meets Poland’s immediate digital infrastructure needs but also contributes to broader EU objectives of enhanced digital connectivity.

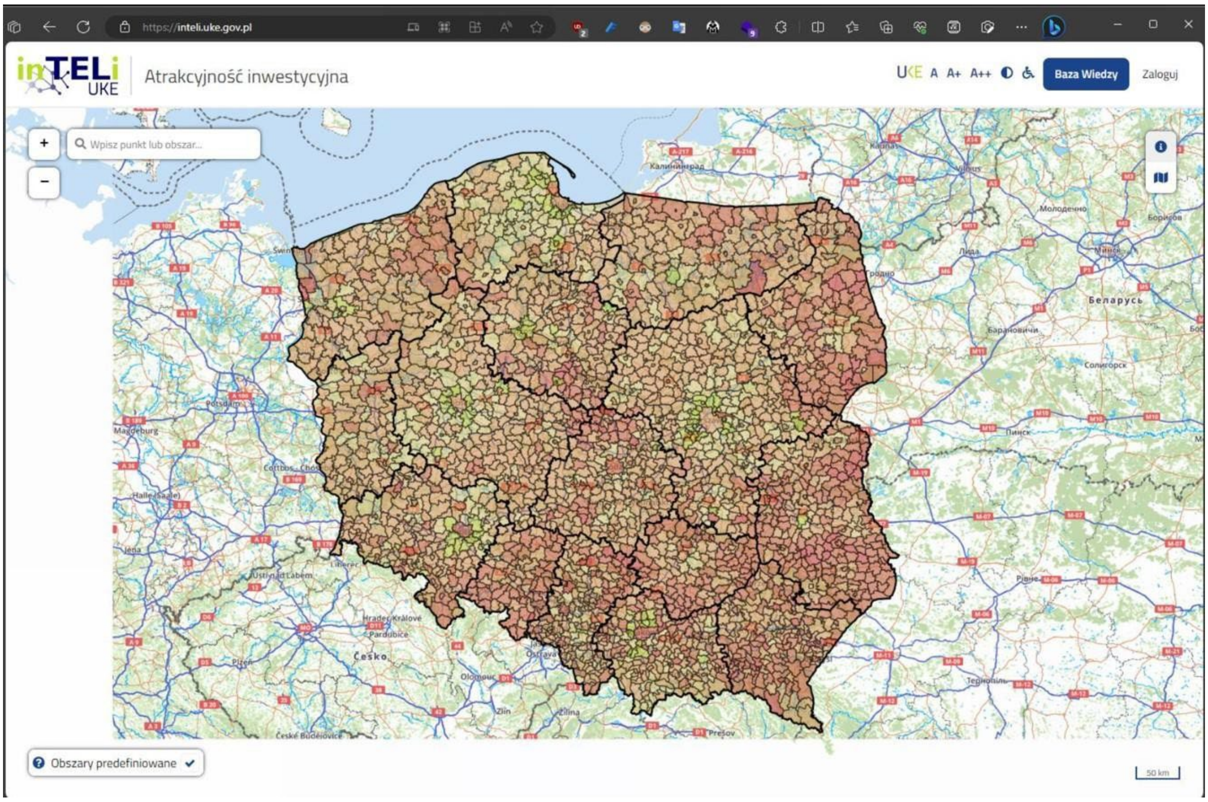


Figure 5. Thanks to mature registration systems operating in Poland, UKE provides map services presenting derivative

Summary table for Poland:

Aspect	Details
Legal Framework	Polish Act on Supporting the Development of Telecommunications Services and Networks, Polish Telecommunications Law, EECC, BCRD, GIA, EU Directives, BEREC Guidelines
Responsible Entities	UKE
System Name	PIT
Main Objectives	Data analysis, report generation, advanced search functionalities, enhanced data granularity
Data sources	Telecommunications infrastructure, services, colocation buildings, SIMBA, SIDUSIS, inTELi, MapBook
Key Features	Comprehensive platform, mobile networks mapping, 4G/5G network throughput measurements, user-friendly dashboards, detailed data tables
Challenges	Data sourcing, balancing mapping performance, maintaining reliable open data
Future Steps	Improved data validation, automated data gathering, enhanced data control tools, technological updates

Case study 4: Armenia

Zaruhi Stepanyan, Head of the International Cooperation Division at the PSRC of Armenia and Co-Chair of the IRB EWG (EaPeReg), presented the current state of broadband infrastructure in Armenia. Her presentation outlined Armenia's efforts to enhance the visibility and accessibility of high-speed internet services through comprehensive broadband mapping systems.

Armenia's legal framework for broadband mapping is primarily governed by the Electronic Communications Law, with oversight from ERCB. This framework emphasizes the role of accurate broadband mapping in informing policy decisions and bridging the digital divide.

The broadband mapping system in Armenia utilizes GIS technology, data from ISPs, and user-generated data to collect and analyze broadband infrastructure information. GIS technology spatially represents broadband infrastructure, enabling detailed planning and analysis. Data from ISPs includes network coverage, technology types, and service speeds, while user-generated data, collected through surveys, provides valuable insights into end-user experiences. The system's interactive maps visualize broadband availability across the country, covering technologies such as DSL, cable, fiber-optic, and wireless, aiding stakeholders in assessing service quality and coverage.

Despite progress, Armenia faces challenges in ensuring data accuracy, particularly from ISPs, where discrepancies between reported coverage and actual service quality can reduce the effectiveness of broadband maps. The rapid evolution of broadband technologies and financial limitations also make it difficult to keep the maps updated, especially in regions with challenging terrain that hinder infrastructure deployment.

To address these challenges, several strategies are recommended. Implementing stricter data validation mechanisms can improve the reliability of the mapping system. Enhanced collaboration between the government, private sector, and local communities can help overcome funding challenges and speed up infrastructure development. A framework for regularly updating the broadband mapping system will ensure it keeps pace with new technologies. Public awareness campaigns can encourage user-generated data contributions, fostering community involvement in improving broadband services. Periodic reviews of regulatory frameworks can ensure alignment with technological advancements and evolving connectivity needs.

Armenia has been regulating its telecommunications sector since 2006 under the RA Law on Electronic Communications, with the PSRC overseeing implementation. Mobile network coverage has grown from limited availability in 2006 to 100% public mobile network coverage today, featuring widespread 3G and 4G+ (LTEA) technologies. Strategic moves such as the introduction of a third operator in 2008 and radio frequency band auctions have played key roles in expanding network coverage, including the deployment of LTE ADVANCE/4G+ and plans for 5G.

Fixed network coverage has also seen significant progress. From over 200 settlements lacking fixed telephony access in 2006, today all settlements are covered by fixed telephony and broadband internet services, supported by both wired and wireless technologies. This expansion is driven by competitive development, fiber-optic backbone network construction by major operators, and the entry of new communication operators into the regions. Licensing obligations for incumbent operators and major telecom companies have increased the capacity of fixed broadband networks and the number of broadband subscribers.

In summary, Zaruhi Stepanyan's presentation showcased Armenia's strategic and comprehensive approach to broadband infrastructure development. Through regulatory reforms, strategic partnerships, and targeted initiatives, Armenia has achieved significant improvements in both mobile and fixed network coverage, contributing to the country's digital advancement and alignment with broader regional goals.

Summary table for Armenia

Aspect	Details
Legal Framework	Electronic Communications Law, regulations by ERCB
Responsible Entities	PSRC
System Name	Broadband Mapping System
Main Objectives	Enhance visibility and accessibility of high-speed internet, inform policy decisions, bridge the digital divide
Data sources	GIS technology, data from ISPs, user-generated data
Key Features	Interactive maps, detailed analysis of network coverage, technology types, service speeds
Challenges	Data accuracy, dynamic technological landscape, funding and infrastructure deployment
Future Steps	Data validation mechanisms, public-private collaboration, regular updates, awareness campaigns, policy review

Case study 5: Italy

Italy's broadband mapping efforts were presented by AGCOM, through their BBmap initiative, which provides a comprehensive and detailed view of the country's broadband infrastructure. The BBmap serves not only as a tool for end-users to understand their connectivity options but also as a vital resource for policymakers and telecommunications companies to track progress, make informed decisions, and drive strategic planning.

Italy has developed a robust legal framework for broadband mapping, underpinned by the Italian Communications Code and enforced by AGCOM. These regulations obligate ISPs to report accurate data, which AGCOM uses to ensure compliance and support Italy's digital connectivity goals.

The broadband mapping system is built on a sophisticated architecture, leveraging GIS technology. This enables the spatial representation of broadband infrastructure, facilitating detailed analysis and planning. Data is gathered from ISPs, including network coverage, technology types, and service speeds, while user-generated data, collected through surveys, adds real-world insights into broadband experiences. This multifaceted approach ensures a comprehensive and accurate portrayal of broadband coverage across the country.

Interactive maps, a key feature of Italy's broadband mapping system, visually represent broadband availability across regions, showcasing various technologies like DSL, cable, fiber-optic, and wireless. These maps assist policymakers and provide transparency for the public to assess broadband quality and availability.

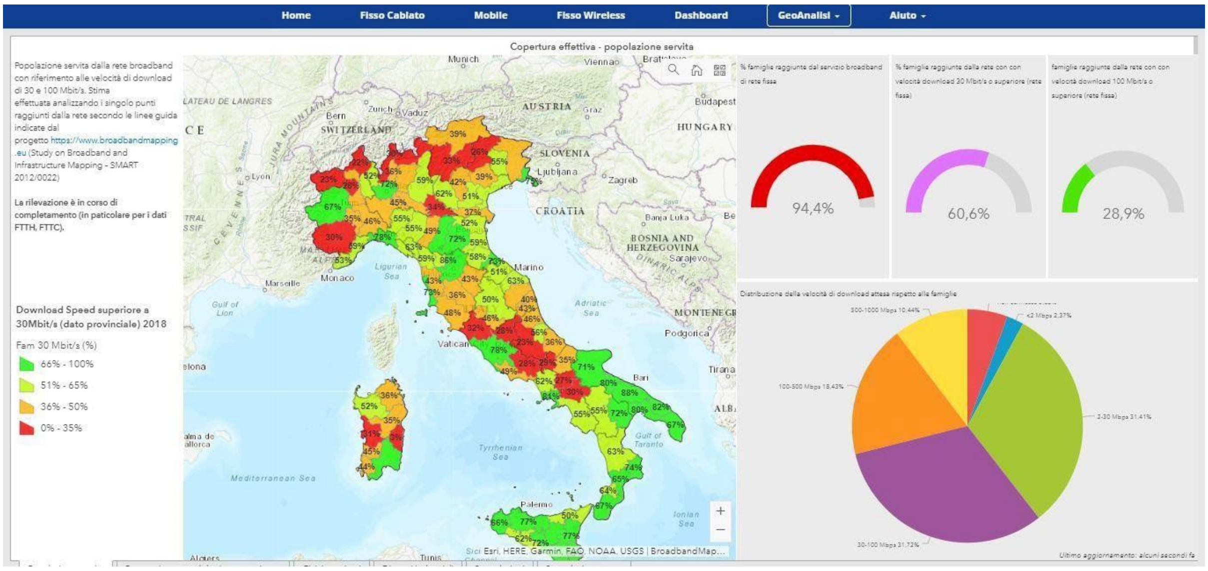
Despite significant advancements, Italy faces challenges in maintaining the accuracy of ISP-reported data and ensuring that the mapping system reflects the latest infrastructure developments and technological upgrades. Additionally, Italy's diverse geography complicates broadband deployment in some regions, affecting mapping accuracy and service availability.

To address these challenges, several strategies are recommended. Strengthening data validation mechanisms will improve accuracy, while establishing a framework for regular updates will ensure that new technologies and infrastructure developments are promptly incorporated. Public awareness campaigns can encourage community participation in contributing user-generated data. Additionally, fostering collaboration between government, private sector, and local communities can help overcome funding challenges and expedite broadband infrastructure deployment. Regular reviews of regulatory frameworks are necessary to keep pace with evolving connectivity needs.

Italy's BBmap initiative is crucial for achieving national broadband objectives and meeting European Digital Agenda targets. The map provides granular data on broadband services and infrastructure availability, serving as a repository of data that informs policy-making and strategic planning. BBmap's dashboard feature tracks national broadband plan progress and supports the formulation of incentive policies tailored to specific regional needs.

BBmap's high-resolution GIS analysis allows for detailed tracking of fixed network variability across Italy, ensuring that local connectivity levels are accurately reflected. The technical rigor of the mapping process ensures that data on speed and technology deployment is precise, providing stakeholders with the information necessary to bridge digital divides and enhance connectivity across the nation.

In summary, Italy's approach to broadband mapping through BBmap emphasizes technical precision and comprehensive data utilization. The initiative serves both public and private sectors by providing the tools necessary for informed decision-making and contributing to the creation of a digitally inclusive society.



Figures 6 and 7 show how the Italian broadband mapping system is very mature and allows for both granular and general data analyses, merging the information on local and national level.

Summary table for Italy:

Aspect	Details
Legal Framework	Italian Communications Code, regulatory oversight by AGCOM, EECC, BCRD, GIA, EU Directives, BEREC Guidelines
Responsible Entities	AGCOM
System Name	BBmap
Main Objectives	Provide detailed broadband service information, enhance digital infrastructure, support strategic planning and policy-making
Data sources	Contributions from ISPs, user-generated data, GIS technology
Key Features	Interactive maps, high-resolution GIS analysis, public access portals, comprehensive data on broadband technologies and speeds
Challenges	Data accuracy, continuous updates, geographic diversity
Future Steps	Enhanced data validation, regular system updates, public engagement, strengthened public-private collaboration, periodic regulatory reviews

Case study 6: Latvia

Rinalds Ritmanis, Head of the Radio Frequency Planning Division at the Electronic Communications Office of Latvia, presented Latvia's broadband mapping progress during the Second ITU-EMERG-EaPeReg Joint Workshop on Strengthening Broadband Infrastructure and Services. His presentation highlighted Latvia's commitment to digital transformation through its PPĢIS.

Latvia's broadband mapping initiative is driven by European directives, particularly Directive (EU) 2018/1972, and national legislation, including the Electronic Communications Act of Latvia. This legal framework empowers the Ministry of Transport to develop a GIS system for broadband availability. The PUC plays a crucial role in conducting surveys of electronic communications networks, ensuring alignment with European and national digital goals.

Latvia's mapping system uses sophisticated GIS technology to visualize broadband coverage, enabling detailed analysis and planning. The system integrates data from various sources, including ISPs, government agencies, and user-generated inputs. ISPs provide key information on network coverage, technology types, and service speeds, while user-generated feedback offers insights into the real-world performance of broadband services.

Interactive maps are central to Latvia's broadband mapping, showcasing coverage across regions and highlighting different broadband technologies such as DSL, cable, fiber-optic, and wireless. These maps help policymakers identify areas that need intervention and provide the public with a clear understanding of local broadband availability.

Despite its advancements, Latvia faces challenges in ensuring the accuracy of ISP-reported data, with discrepancies sometimes occurring between reported and actual service quality. The evolving nature of broadband technologies necessitates continuous updates to the mapping system to reflect new developments. Additionally, Latvia's diverse geography presents challenges for broadband deployment in certain regions, affecting mapping accuracy.

To address these issues, several strategies are recommended. First, implementing robust data validation mechanisms will improve data reliability. Establishing a framework for regular updates to the mapping system will ensure it keeps pace with new technologies. Encouraging public participation through awareness campaigns can enhance community involvement in broadband services. Strengthening collaboration between government entities, the private sector, and local communities is essential for addressing funding challenges and accelerating infrastructure deployment. Regular updates to the regulatory framework will ensure that it remains aligned with technological advancements and evolving needs.

Latvia's broadband mapping system, PPĢIS, features public access for viewing broadband availability and restricted access for detailed analytics and data input. The system integrates data from mobile and fixed operators and state authorities, ensuring a comprehensive representation of broadband availability. Visualization tools allow users to filter broadband data by coverage type (3G, 4G, 5G) and fixed technologies (xDSL, coaxial, optics).

Challenges related to data accuracy and harmonization persist, including difficulties with vector format data and incomplete information on addresses and coordinates. Automating data gathering processes could improve efficiency but presents technical challenges.

To enhance broadband mapping, Latvia should focus on automating data collection, improving data validation, strengthening collaboration with data providers, and conducting public awareness campaigns. Regular updates to the system will ensure it reflects the latest technologies and infrastructure developments.

In conclusion, Latvia's broadband mapping efforts demonstrate a strong commitment to digital transformation. By addressing challenges and adopting forward-looking strategies, Latvia will continue to bridge the digital divide and meet European connectivity goals.

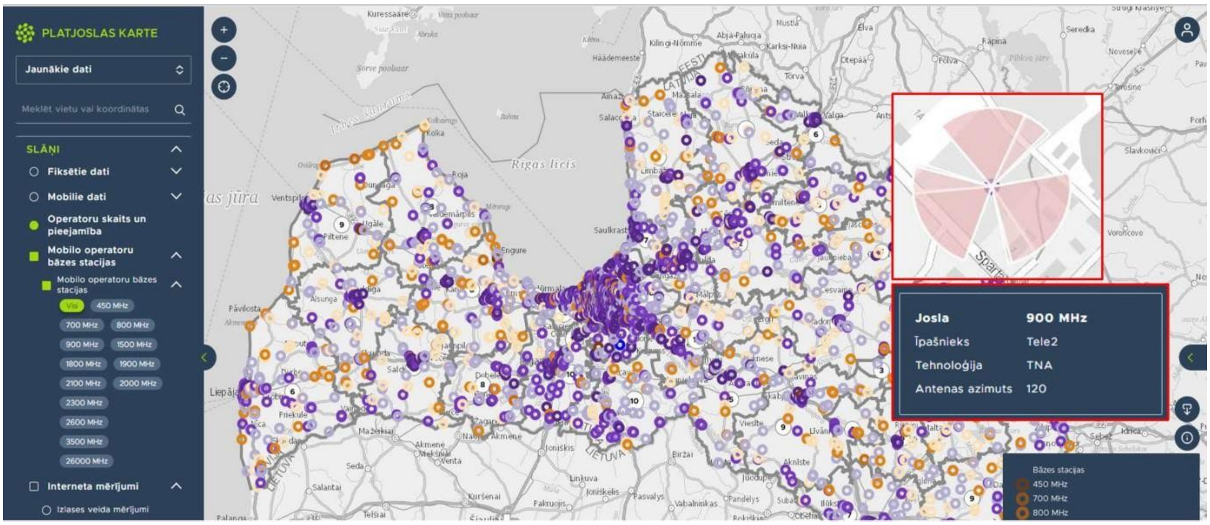


Figure 8. Example analysis and visualisation of mobile networks stations and their parameters in Latvia.

Summary table for Latvia:

Aspect	**Details**
Legal Framework	Electronic Communications Act of Latvia, EECC, BCRD, GIA, EU Directives, BEREC Guidelines
Responsible Entities	Ministry of Transport, Electronic Communications Office, PUC
System Name	PPĢIS
Main Objectives	Advance digital transformation, consolidate broadband data, publicize broadband availability, identify unserved areas, comply with European gigabit society goals by 2025
Data Sources	Contributions from ISPs, state authorities, geographical surveys, GIS technology
Key Features	Interactive map, address-level speed map, statistical coverage by administrative strata, detailed analytics, identification of white, grey, and black areas
Challenges	Data accuracy, harmonizing data formats, establishing automated data gathering
Future Steps	Automated data gathering, enhanced data validation, strengthened collaboration with data providers, public awareness campaigns, regular system updates

Case study 7: France

In November 2023, ARCEP presented a comprehensive broadband mapping initiative that underscores France's strategic commitment to digital transformation. This initiative highlights the country's ambitious goals, including full broadband coverage by the end of 2022, establishing FttH as the primary broadband technology by 2025, and phasing out the historical copper network by 2030. France's approach prioritizes user-oriented data, focusing on premises eligibility over infrastructure specifics, ensuring the mapping system is practical and accessible.

France’s broadband mapping system leverages advanced architecture and integrates interactive and statistical maps to provide a detailed view of broadband coverage. Using sophisticated ETL operations with tools like Airflow and PostGIS, the system maintains accuracy and reliability. Data is collected from various sources, including ISPs, administrative borders, premises details, and addresses, resulting in a comprehensive depiction of broadband availability.

The visualization of broadband coverage is facilitated through maconnexioninternet.fr, an interactive map at the address level that empowers users with information on service providers, eligible technologies, and theoretical internet speeds. Aggregated statistics by administrative areas help local authorities make informed decisions about digital strategies. This user-centric system provides a clear view of the best-available services across the country and supports transparency in the broadband market.

Despite these successes, the initiative faces challenges. Ensuring data reliability, automating manual processes, and balancing system performance with storage efficiency are key issues. France is addressing these challenges by implementing automated data gathering processes, enhancing data validation mechanisms, fostering collaboration with data providers, and conducting public awareness campaigns. Additionally, regular updates to the mapping system will incorporate new technologies and infrastructure developments, reflecting a proactive approach to maintaining leadership in digital connectivity.

The broadband mapping initiative operates within a robust legal framework, reflecting France’s commitment to achieving European connectivity goals. The framework aligns with national ambitions, such as full broadband coverage and the transition to FttH, and emphasizes premises eligibility to meet practical needs.

ARCEP’s system integrates interactive maps that provide detailed information at both address and administrative levels. The data is processed through ETL operations to ensure accuracy and includes contributions from operators, administrative borders, and premises details. This holistic approach provides a comprehensive view of broadband availability across the country.

At maconnexioninternet.fr, the interactive map allows users to view eligibility details for broadband services, available ISPs, and maximum theoretical internet speeds at the address level. Aggregated coverage data, displayed by administrative areas, aids local authorities in planning their digital strategies, ensuring that users and stakeholders can make informed decisions based on reliable data.

ARCEP continues to identify and address challenges such as data reliability, evolving technologies, and the need for automating processes. Future steps include enhancing data validation, automating data collection, and regularly updating the mapping system to reflect technological advancements. Strengthening collaboration with data providers and conducting public awareness campaigns are also key strategies.

France’s broadband mapping initiative is a forward-thinking approach to digital connectivity. The robust legal framework, sophisticated system architecture, and user-centric visualization tools reflect a commitment to transparency and accessibility. ARCEP’s proactive stance in addressing challenges ensures France will continue to lead in the digital connectivity landscape, empowering users with data-driven insights and fostering innovation in the broadband market.

In conclusion, France’s broadband mapping initiative, led by ARCEP, exemplifies a sophisticated and user-centric approach to digital infrastructure planning. The system’s comprehensive architecture, detailed visualizations, and proactive strategies make it a model for digital connectivity, positioning France at the forefront of innovation in the European digital landscape.

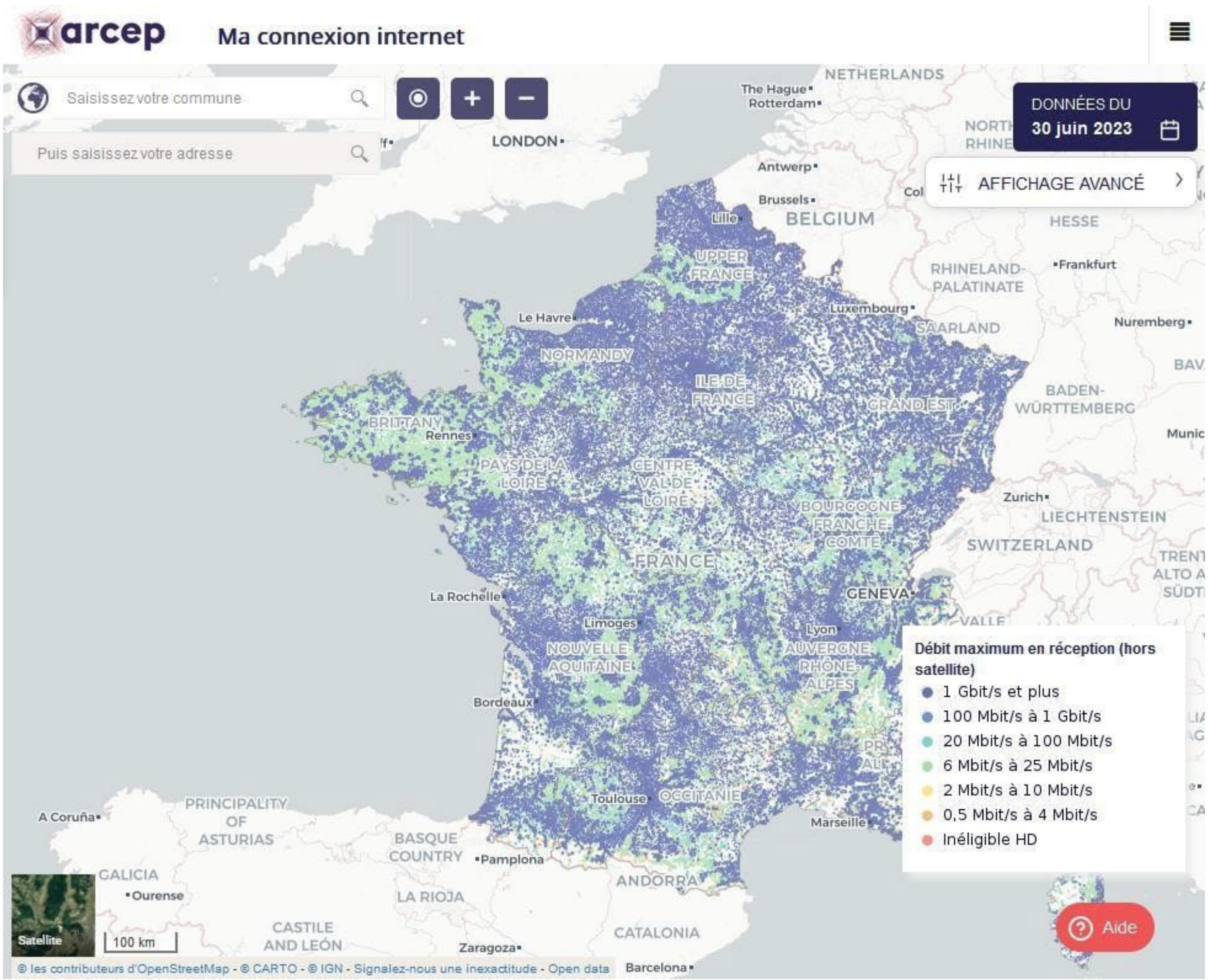


Figure 9. Example view of Arcep interactive service visualising available throughput.

Summary table for France:

Aspect	Details
Legal Framework	Electronic Communications Act of France, national targets for full broadband coverage by 2022, FttH by 2025, and copper phase-out by 2030, EECC, BCRD, GIA, EU Directives, BEREC Guidelines
Responsible Entities	ARCEP
System Name	maconnexioninternet.fr
Main Objectives	Advance digital transformation, achieve full broadband coverage, generalize FttH technology, phase out copper network, focus on user-oriented data
Data Sources	Operator data, administrative borders, premises details, addresses, governmental sources, publicly available data, mapping and geospatial technologies
Key Features	Interactive map, address-level speed map, statistical coverage by administrative strata, detailed analytics, identification of white, grey, and black areas
Challenges	Data accuracy, data formats, automatic data gathering
Future Steps	Automated data gathering, enhanced data validation, strengthened collaboration, public awareness campaigns, technological upgrades

Case study 8: Georgia

The telecommunications industry in Georgia has grown significantly in recent years, driven by the increased penetration of fiber optic and mobile internet services. With a population of over 3.7 million, the telecom sector has expanded steadily, fueled by advancements in mobile, fixed broadband, and IPTV services. Revenue from telecommunications has risen, with major contributions from mobile communications and fixed broadband.

Historically, ComCom has utilized digital mapping systems for regulatory compliance, infrastructure planning, and public service delivery. These legacy systems have been foundational in developing more advanced broadband mapping initiatives. Alongside telecommunications, Georgia has engaged in several GIS projects aimed at enhancing spatial data management, urban planning, and environmental monitoring. These projects have fostered GIS expertise within the country.

ComCom's broadband mapping efforts stem from Georgia's commitment to the EU-Georgia Association Agreement. Legislative milestones, such as the Law of Georgia on Sharing Telecommunication Infrastructure and Universal Service Regulation, have established a framework for these initiatives, emphasizing infrastructure sharing and data transparency.

As of November 2023, Georgia is in the process of developing a comprehensive broadband mapping system to meet regulatory demands and improve decision-making. A key development includes the adoption of the Infrastructure Sharing Law in June 2023, facilitating the creation of a SIP to centralize broadband infrastructure data. ComCom also aims to build a Universal GIS Platform to integrate multiple data layers, including broadband coverage and infrastructure from ComCom and public registries.

International collaborations, such as the Log-In Georgia project financed by the World Bank and European Investment Bank, support the development of the SIP for Infrastructure Sharing and the broadband map, ensuring alignment with global best practices. However, challenges remain, including finding experienced GIS developers, collecting high-quality data from telecom operators, and fostering cooperation with state agencies.

Broadband mapping in Georgia faces several ongoing challenges. Ensuring data accuracy, particularly in rural and underserved areas, is a persistent issue due to discrepancies in reporting. Securing adequate funding for ongoing data collection, system maintenance, and infrastructure investments is essential for long-term success. Additionally, improving collaboration between government agencies, ISPs, and community organizations is critical for enhancing data sharing and coordination.

To address these challenges, several future steps are recommended. Implementing robust data validation mechanisms, such as field surveys and independent audits, will help verify the accuracy and completeness of broadband coverage data. By adopting collaborative, data-driven approaches, Georgia can strengthen its broadband mapping systems and accelerate efforts to bridge the digital divide, ensuring reliable, high-speed internet access for all residents.

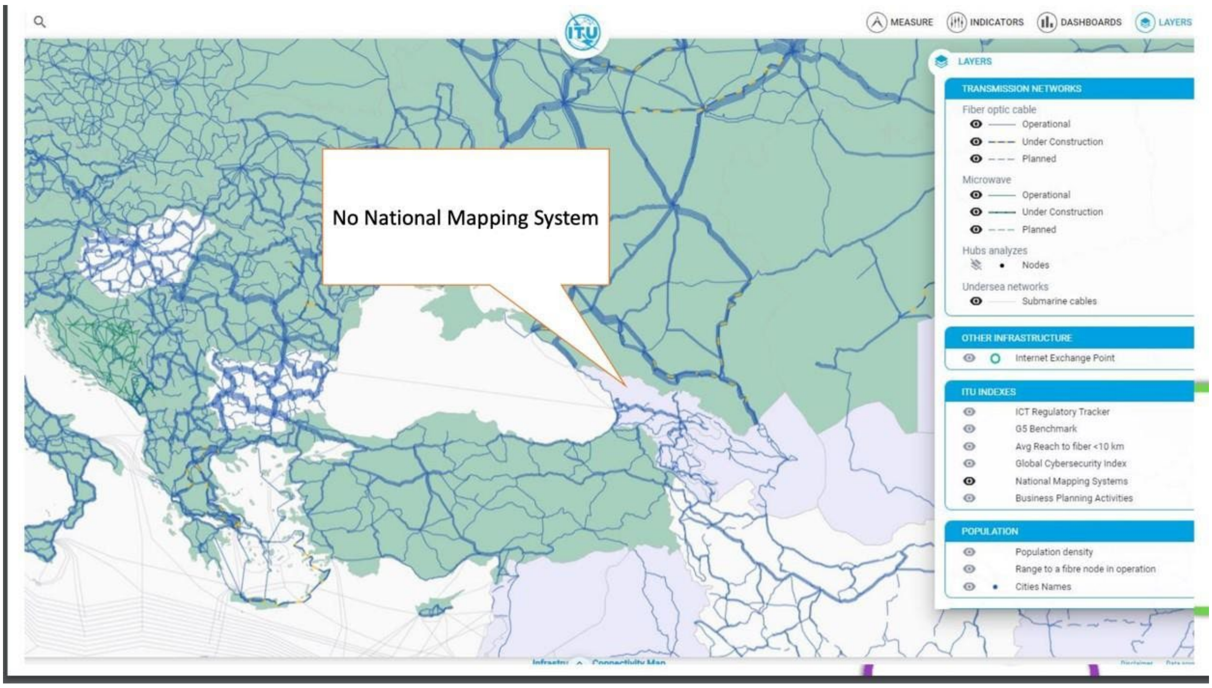


Figure 10. Slide from ComCom's presentation displaying Georgia on the ITU Broadband Map

Summary table for Georgia:

Aspect	Details
Legal Framework	Infrastructure Sharing Law (2023)[1]; ComCom Digital Map Resolution (2020)[2]
Responsible Entities	ComCom
System Name	Universal GIS Platform comprising of Single Information Point and Broadband (Digital) Map (under development)
Main objectives	Centralize broadband telecom and utility infrastructure data, publicize broadband availability, identify unserved areas, comply with EU Association Agreement
Data Sources	ISPs, Utility companies, National geospatial data, crowdsourced data
Key features	Multi-tiered architecture, interactive maps, integration of passive and active infrastructure data, international collaboration for development
Challenges	Data accuracy, identifying experienced GIS developers, quality data collection from telecom operators, stakeholder collaboration
Future Steps	With internal resources ComCom has developed a pilot version of the SIP. It is working on procedures for automated data gathering, enhanced data validation, community engagement, regular system updates. ComCom is finalizing procedures for announcement of the tender for GIS platform for SIP and Broadband (Digital) Map, supported by World Bank and European Investment Bank.

[1] Infrastructure Sharing Law of Georgia: https://matsne.gov.ge/en/document/view/5810383?publication=0
[2] ComCom Digital Map resolution (in Georgian): https://www.matsne.gov.ge/ka/document/view/4861607?publication=0

Case study 9: Portugal

Portugal has established a robust legal framework to support the development and implementation of broadband mapping systems. The National Broadband Plan, aligned with EU directives such as the DAE and the EECC, guides the deployment of high-speed internet infrastructure throughout the country. ANACOM plays a central role in regulating the telecommunications sector, setting requirements for broadband providers to report coverage data and ensuring compliance with the EECC.

Under Article 22 of the EECC, member states are required to develop broadband mapping systems to assess broadband service coverage and availability. Portugal fulfills this requirement through Decree-Law nr 40/2022, which implements an information platform for citizens, businesses, and government entities to access broadband coverage data. The BEREC Guidelines provide additional guidance to NRAs like ANACOM on consistent application of geographical surveys, ensuring accurate and standardized broadband mapping.

Portugal's broadband mapping system collects data on both fixed and mobile broadband coverage, including technologies used, network properties, and speed metrics at the address level. The system covers fixed networks (broadband, voice, and narrowband), mobile networks (broadband, voice, SMS, and MMS), transport and access networks, submarine cables, and satellite coverage. INE provides a unique address database with geographic coordinates for approximately 3.5 million residential buildings, which is regularly updated to ensure granularity and accuracy. ANACOM collaborates with operators to integrate their data with the INE database, requiring detailed information on network coverage for each building.

The system utilizes GIS technology and geoprocessing techniques to effectively integrate and visualize data from different sources, including ISPs, government agencies, and crowdsourcing platforms. Crowdsourced data allows citizens to report their broadband experiences, enhancing the accuracy of broadband mapping. Data from various sources is integrated into a centralized database, which is visualized through interactive maps and dashboards. This enables policymakers, regulators, and stakeholders to assess coverage gaps and prioritize investments.

Interactive maps offer users intuitive tools to explore broadband coverage at different geographic scales, from national overviews to detailed regional maps. Users can zoom in on specific areas to view broadband availability, speeds, and technologies. Color-coded layers indicate different levels of service availability, helping users distinguish between areas with high-speed access, underserved regions, and areas with no coverage. Performance metrics such as download/upload speeds, latency, and reliability indicators help users assess service quality and identify areas for improvement.

Despite progress, Portugal's broadband mapping efforts face challenges, including inconsistencies in operator data, discrepancies in address databases, and difficulties in aligning operator data with the INE database. ANACOM has addressed these challenges by utilizing the INE georeferenced building database, which provides accurate georeferencing and facilitates data integration. A unique ID per building and standardized data formats help ensure data sharing and interoperability among stakeholders.

Portugal's commitment to a Gigabit Society by 2025 is reflected in its broadband mapping efforts. Adherence to the EECC, particularly Article 22, and the enactment of Decree-Law nr 40/2022 demonstrate the country's commitment to providing comprehensive broadband information. The mapping system includes dual-speed metrics—maximum achievable speeds and expected speeds during peak times—providing a realistic portrayal of service levels for consumers and enhancing transparency.

Challenges such as the lack of universally available data across all operators and the absence of a unified address database remain. However, Portugal has mitigated these challenges by collaborating with INE to use a georeferenced database equipped with unique IDs for over 3.5 million residential buildings. This ensures data integrity and facilitates data sharing with operators. Integration of operator data with the INE database uses GIS tools and Python scripts to map coverage at an address level, even in cases where discrepancies exist in operator data.

The mapping system provides a comprehensive view of fixed broadband coverage, including details on technology used, network ownership, and available speeds. It highlights areas lacking VHCN—known as “white areas”—aiding in the strategic planning of network expansions. The GEO.ANACOM public portal extends this effort by offering various layers of information, covering spectrum management, mobile and satellite services, market statistics, and general infrastructure data.

In conclusion, Portugal’s broadband mapping initiative is a significant step toward achieving the European Union’s vision for a Gigabit Society by 2025. By addressing current challenges and leveraging advanced geospatial tools, Portugal is ensuring that its broadband infrastructure remains transparent, efficient, and future-proof, providing high-speed internet access across the country.

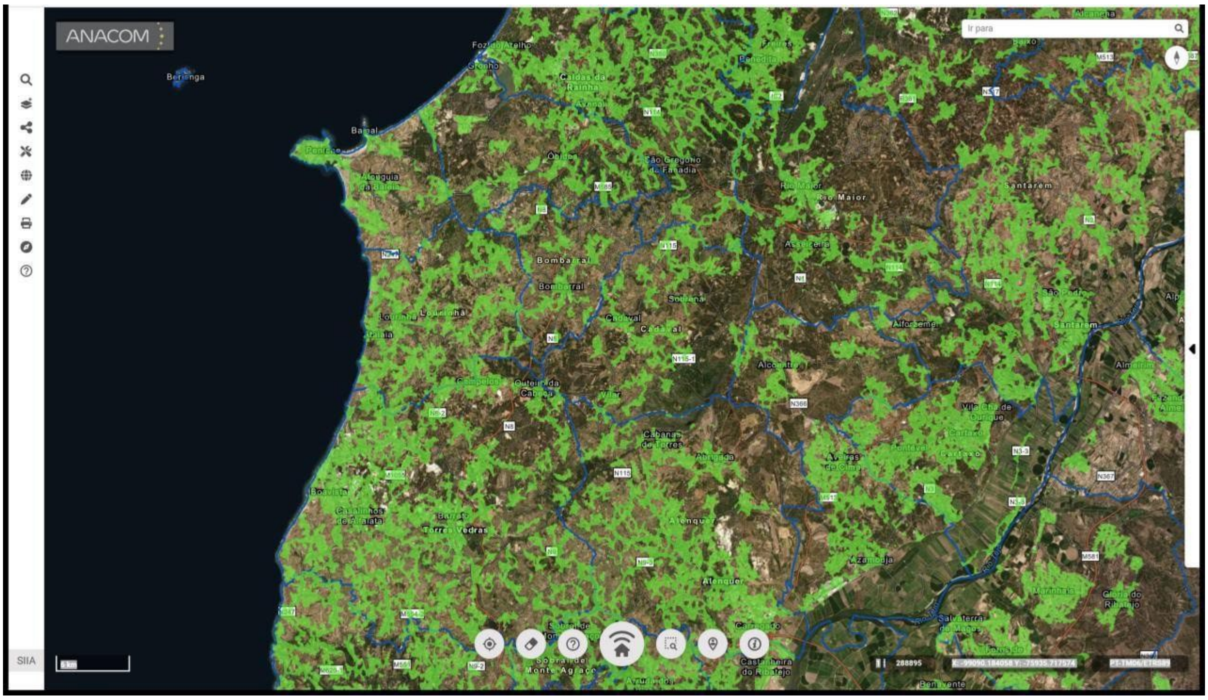


Figure 11. Example view of fiber optical broadband services availability in GEO.ANACOM

Summary table for Portugal:

Aspect	Details
Legal Framework	National Broadband Plan, Decree-Law nr 40/2022, EECC, BCRD, GIA, EU Directives, BEREC Guidelines
Responsible Entities	ANACOM
System Name	GEO.ANACOM
Main objectives	Inform citizens, businesses, and state entities, align with European gigabit society goals, provide comprehensive broadband coverage data
Data Sources	ISPs, government agencies, crowdsourcing platforms, INE georeferenced Database
Key features	Granular data collection at the address level, integration with INE database, interactive maps, performance metrics visualization
Challenges	Data availability across operators, address database inconsistencies, data integration challenges

Future Steps	Enhance data validation, public-private partnerships, community engagement, adapt to emerging technologies

Case study 10: Romania

In Romania, broadband mapping operates within the legal framework established by ANCOM. The foundation for this framework is rooted in EU directives, such as the EECC, which promotes efficient and transparent broadband infrastructure deployment across member states. National legislation, including the Electronic Communications Law, supports the regulation, mapping, monitoring, and reporting of broadband coverage across Romania.

Romania's mobile communication regulations cover frequency bands from 800 MHz to 2600 MHz, allocated for technologies like 2G, 3G, and 4G. Following the 2012 spectrum auction, ANCOM imposed strict coverage obligations on mobile operators, particularly in "white areas" (regions lacking coverage). Operators were required to provide at least 98% population coverage with voice services and data speeds of 2 Mbps with a 95% probability of indoor reception for 60% of the population. ANCOM closely monitors compliance through extensive measurement campaigns.

Romania's broadband mapping system utilizes a robust architecture designed to collect, process, and visualize broadband infrastructure and coverage data. Data is sourced from ISPs, government agencies, and crowdsourcing platforms. GIS play a critical role in visualizing broadband coverage, integrating spatial and other datasets to create detailed maps. ISP reports, regulatory filings, national surveys, and geolocation data from consumer devices form the backbone of Romania's broadband coverage information. Crowdsourced data, gathered through user feedback and speed tests, further enriches the system's accuracy.

ANCOM has conducted regular measurement campaigns since 2018 to evaluate coverage for 2G, 3G, and 4G technologies. These campaigns involved assessing roads in localities, FTP downloads in fixed locations, and coverage along national and county roads. The analysis, powered by ROMES software and a PostgreSQL database system, provides valuable insights into the coverage evolution of major operators like Orange, Digi, Vodafone, and Telekom.

Broadband coverage visualization is a vital tool for policymakers, regulators, and consumers, providing interactive maps at national and local levels. These maps, often color-coded, distinguish between various broadband types, such as fiber-optic, cable, DSL, and wireless, and display performance metrics like download/upload speeds and service reliability. These tools help users assess the quality of internet service and enable stakeholders to track coverage improvements over time, facilitating targeted interventions.

ANCOM has outlined ambitious plans to further enhance mobile coverage measurement. These include introducing quality FTP upload/download measurements, expanding 5G coverage assessments, and developing an independent geocoding database. ANCOM also aims to update existing coverage maps and refine propagation models, potentially incorporating AI technologies to improve accuracy.

Despite advancements, challenges remain, particularly in rural and remote areas where infrastructure may be limited or underreported. Ensuring data accuracy and completeness in these regions requires robust data sharing and collaboration among stakeholders, including ISPs, government agencies, and community organizations. Closing the digital divide between urban and rural areas is a priority for Romania's broadband policy.

To address these challenges, Romania plans to invest in underserved areas through public-private partnerships and incentive programs to encourage broadband deployment in remote communities. Emerging technologies such as 5G, satellite internet, and smart infrastructure will be critical to expanding broadband access and improving connectivity speeds. Policymakers are committed to supporting research and innovation in broadband technology to meet evolving consumer demands.

Romania's approach to broadband mapping involves a systematic collection and analysis of mobile coverage data. The mapping process incorporates comprehensive frequency band measurements across all relevant spectrums, ensuring accurate assessments of network coverage. These efforts stem from the coverage obligations imposed by the 2012 auction, which aimed to significantly improve coverage in underserved areas and establish benchmarks for population coverage with voice and data services.

Romania's diverse geography plays a pivotal role in mapping, with coverage percentages analyzed in relation to specific landforms to identify regions requiring infrastructure development. ANCOM's rigorous measurement campaigns, utilizing PostgreSQL with PostGIS for geospatial analysis, ensure accurate evaluations of coverage against licensing conditions. Public dissemination of coverage maps through www.aisemnal.ro allows end-users and stakeholders to access up-to-date coverage data for 2G, 3G, and 4G technologies, fostering transparency and informed decision-making.

Looking ahead, Romania plans to adopt new methodologies for 5G coverage measurements and enhance data service quality assessments. Developing a comprehensive geocoding database will further improve the accuracy of coverage maps, with the potential application of AI technologies to refine propagation models. Romania's forward-looking approach in broadband mapping is data-driven, technologically advanced, and positioned to keep pace with the evolving landscape of telecommunications.

In conclusion, Romania's journey in broadband mapping is marked by a commitment to data accuracy, technological innovation, and regulatory rigor. This approach not only addresses the country's current connectivity needs but also prepares it for future telecommunications advancements, ensuring Romania remains at the forefront of digital connectivity.

Summary table for Romania:

Aspect	Details
Legal Framework	Electronic Communications Law, EECC, BCRD, GIA, EU Directives, BEREC Guidelines
Responsible Entities	ANCOM
System Name	Not specified
Main objectives	Comprehensive broadband coverage, adherence to EU directives, informed regulatory decisions
Data Sources	ISPs, government agencies, crowdsourcing platforms, national surveys, geolocation data from consumer devices
Key features	Interactive maps, color-coded layers, performance metrics, trend analysis
Challenges	Data accuracy and completeness, data sharing and collaboration, bridging digital divide, embracing emerging technologies
Future Steps	Enhanced data validation, public-private partnerships, community engagement, adapting to new technologies

Good Practices in Broadband Mapping

As described extensively in this report, broadband mapping is crucial for understanding and improving digital connectivity. The following best practices identified throughout the three ITU-EMERG-EaPeReg joint workshops highlight the critical elements for developing effective and comprehensive broadband mapping systems. These practices are drawn from the experiences and lessons learned across various countries.

The thorough analysis and practical guidance on prerequisites, project setup, architectural, and technical design of National Broadband Mapping Systems are provided in the "ITU Guidelines on Establishing or Strengthening National Broadband Mapping Systems (2022)." For particular elements highlighted below, targeted references are provided so that readers can take guidance and advice to draw solutions suiting their needs in regard to implementing broadband networks and services mapping systems, regardless of the stage they may be in. The Guidelines provide a full scope for both the establishment and strengthening of national broadband mapping systems. If a reader is preparing a feasibility study for project evaluation and approval, including financial support, the Guidelines can be followed for each element provided in particular chapters and paragraphs. They answer questions based on the reader's particular circumstances and provide a path and advice to produce comprehensive documentation for their project. For example, starting with Table 1 of the Guidelines, one can clearly state the type of mapping solution to undertake.

Readers can be advised on strategies, policies, and the regulatory environment if their goal is to shape an enabling legal environment for introducing broadband mapping solutions, following project setup, technical requirements, and project management. However, if the feasibility study concerns an already established legal framework, one can focus on Chapter 3: Project Setup and Technical Requirements for Broadband Mapping.

On the other hand, if tendering is anticipated, the variants given in the Guidelines, such as GIS platform selection or COTS vs. Open-Source software use or on-premises vs. cloud solutions, can be left for the contractor to consider when filing their offer. In many cases, the answers and variants given in the Guidelines will be naturally followed, considering already presented cases. Take, for example, Georgia, which is building a broadband mapping system and already has a civil infrastructure mapping system with cadastral data available. They should use those already available resources. This is the optimal way, as indicated in the Guidelines and hereby within this Compendium.

Address Database

A reliable address database is fundamental to accurate broadband mapping. It should include precise geographical coordinates for each address, ensuring comprehensive coverage. Using a common database, sourced from official administrative database, e.g. cadastre or civil infrastructure system is greatly advised as it ensures consistency in the data while allowing to improve the accuracy of reference data.

Criteria	**Importance**	**Implementation example**
Geographical Precision	High	**Using GIS data from cadastral systems** Chapter 2.3.3 of the ITU Guidelines provides an introduction and explanation of the BEREC guidelines based on the EECC act. In Chapter 3.1.1, readers are provided with a comprehensive scope of datasets, including infrastructure mapping, service mapping, investment mapping, and demand mapping. This chapter also details the specific data types and properties to include in such records.

Data Consistency	High	**Standardized format for address data**
		If it is advisable to use an existing address database, the address data will be determined by that existing artifact. Otherwise, the given address should be stored as both: postcode, place name, street name, street number, extension (such as entrance or building number), and geocoded coordinates. As stated in Chapter 3.1.1 of the ITU Guidelines, under the section "Data formats," the standard and recommended form of addressing and geolocation format is vector form. Chapter 3.1.1 also provides guidelines and best practices on data conversion and data quality checks.
Update Frequency	High	**Regular updates from municipal records regarding reference data, such as the address database** For subject data, a standard starting interval of yearly updates can be followed. Alternatively, European Commission and BEREC guidelines (see Chapter 2.2.3 of the ITU Guidelines) recommend shortening the intervals, aiming for constant updates with snapshot data taken at given periods for verification and audit purposes. If following the Guidelines for a feasibility study, this issue is addressed in the third checklist of Minimum Technical Requirements in Chapter 3.3 of the ITU Guidelines.

Policy and Regulatory Framework

Establishing a clear policy and regulatory framework is critical. This framework should define the specific objectives of the broadband mapping initiative, such as identifying coverage gaps, informing policy decisions, and guiding infrastructure investments. It should also clearly delineate the roles and responsibilities of all stakeholders involved, including government agencies, regulatory bodies, telecommunication operators, and local authorities. Legislative support is essential to ensure that broadband mapping initiatives are backed by strong legal mandates requiring data sharing and compliance from all stakeholders.

If the reader is interested in shaping the legal and legislative framework to enable or foster an environment for broadband mapping systems, Chapter 2 of the ITU Guidelines, [Strategies, Policies, and Regulatory Environment for Broadband Mapping], should be of interest.

Key Elements of a Policy and Regulatory Framework

Framework Element	Description	Example
Objectives	Define specific goals e.g., identifying coverage gaps)	EU Digital Agenda See Checklist 1 (Chapter 2.4) of the ITU Guidelines
Roles and responsibilities	Clear delineation among government agencies, operators, etc.	Romanian Electronic Communications Law See Checklist 2 (Chapter 3.3 of the ITU Guidelines) - establishment of a project governance
Legal Mandates	Legislative support for data sharing and compliance	European Electronic Communications Code

See Chapter 5 of the ITU Guidelines [Conclusion] and follow the "First checklist – Policy and Regulatory Checklist".

Collaboration and Partnerships

Fostering collaboration among government agencies, regulatory bodies, telecommunication operators, and other relevant stakeholders is key to enhancing the accuracy and comprehensiveness of broadband mapping efforts. Public-private partnerships significantly contribute to these efforts. Such collaborations enable the pooling of resources, expertise, and data, leading to more accurate and comprehensive mapping outcomes.

These particular recommendations are given in Chapter 3.1.2 of the ITU Guidelines, which underline collaboration and partnerships as essential elements. This chapter emphasizes the importance of structured and thoughtful proceedings involving information sharing, consultation, involvement, and collaboration.

Stakeholder Collaboration Model

Stakeholder Group	Role in Broadband Mapping	Example Initiatives
Government Agencies	Policy-making, funding, and oversight	EU Digital Agenda
Regulatory Bodies	Data collection standards, compliance enforcement	ANACOM in Portugal
Telecommunication Operators	Data provision, infrastructure deployment	Public-private partnerships in Italy
Community Organizations	Crowdsourced data collection, public awareness	Local initiatives in Georgia

Within the stakeholder's collaboration model, it's worth considering the context of Checklist 2 in Chapter 3.3 of the ITU Guidelines. This will culminate in the elaboration of a "Second Checklist," which is presented and explained in Chapter 5 of the ITU Guidelines.

Data Collection and Standardization

Developing standardized methodologies for collecting broadband-related data is crucial. These methodologies should cover various parameters such as speed, technology, and coverage, ensuring consistency in data collection across different regions. Standardization facilitates comparability and reliability of the data, which is vital for informed decision-making and policy formulation.

Checklist 3 in Chapter 3.3 of the ITU Guidelines points out the standards regarding data collection. Additionally, the exact data structures and formats are advised in Chapter 3.1.1.

Data Parameter	**Description**	**Standardization Example**
Speed	Measurement of download and upload speeds	Decree-Law nr 40/2022 (Portugal)
Technology Type	Types of broadband technology (e.g., fiber, DSL, cable)	ITU Standards
Coverage	Geographic extent of broadband service	GIS-based mapping
Data Source	Origin of data (e.g., ISP reports, surveys, crowdsourcing)	Integration of ISP crowdsourced data: An example is the regulation on the inventory of telecommunications infrastructure and services issued on December 19, 2022. This regulation provides the exact data structure and data types that ISPs must report to the NRA every 6 months. Appendix 2 specifies the catalog of standards and technologies for both fixed and radio data transfer and infrastructure provision techniques.

Legal and Privacy Considerations

Addressing legal and privacy considerations associated with broadband data is another important aspect. Establish protocols to protect sensitive information and comply with data protection regulations. Ensuring that data privacy is maintained while collecting and using broadband data builds trust among stakeholders and encourages greater participation and data sharing.

Privacy and Data Protection Protocols

Privacy Concern	**Mitigation Strategy**	**Example Protocols**
Data Sensitivity	Anonymization and aggregation of personal data	GDPR compliance in the EU
Access Control	Restricted access to sensitive data	Role-based access controls
Data Protection	Encryption and secure storage of data	ISO/IEC 27001 standards

Visualization of Broadband Coverage

Broadband coverage visualization serves as a vital tool for policymakers, regulators, and consumers to assess the availability and quality of internet connectivity across different regions. Interactive maps and performance metrics are key components of effective visualization.

Interactive maps allow users to explore broadband coverage at various geographic scales, from national-level overviews to detailed street-level data. These maps often incorporate color-coded layers to distinguish between areas with different types of broadband access, such as fiber-optic, cable, DSL, and wireless. Performance metrics displayed on these maps may include download and upload speeds, latency, and service reliability. This information helps users evaluate the quality of internet service in their area and make informed decisions about choosing ISPs.

Visualization Technique	Description	Example Features
Interactive Maps	Web-based maps that allow users to explore broadband coverage at various geographic scales.	Zoomable maps, address level detail Fixed-wireless services: https://agcom.maps.arcgis.com/apps/MapSeries/index.html?appid=bd6a4b303dcc491188d1b7584927ce58 Mobile network data transfer services: https://agcom.maps.arcgis.com/apps/MapSeries/index.html?appid=d880343c6929433e8f9f0f3e67a1ed8f
Color-Coded Layers	Layers on maps color-coded to indicate different levels of service availability and performance.	Distinguishes fiber, DSL, wireless https://geo.anacom.pt/publico/home
Performance Metrics	Displays metrics such as download/upload speeds, latency, and reliability indicators.	Speed test results, latency measures Broadband coverage and service quality: https://maps.agcom.it/agcomapps/BBmap_6.4.2/
Heatmaps	Visual representation of broadband speed or signal strength variations across areas.	High-density areas, coverage gaps Mobile services quality map with both crowdsourced and NRA measured data: https://monreseaumobile.arcep.fr/
Trend Analysis Tools	Features for analyzing temporal trends in coverage and performance data.	Year-over-year comparisons Example of comparison-enabled feature: https://cartefibre.arcep.fr/index.html?lng=6.988105275215503&lat=48.613357454476585&zoom=11.594625088154315&mode=normal&legende=true&filter=true&trimestre=2024T1 Image below
Public Access Portals	Websites or applications providing open access to broadband coverage data.	User-friendly interface, public access Example: https://maps.agcom.it/
Geospatial Analysis Tools	Utilizes GIS technology to map broadband availability, speeds, and technology types.	Detailed geospatial https://maps.agcom.it/

Dashboards	Aggregated displays of various broadband performance metrics and coverage data.	Charts, graphs, summary statistics https://maps.agcom.it/ -> Reportistica
3D Mapping	Advanced visualization showing terrain, building heights, and broadband infrastructure in 3D.	Realistic, interactive 3D models Romania: https://www.aisemnal.ro/home (image below)

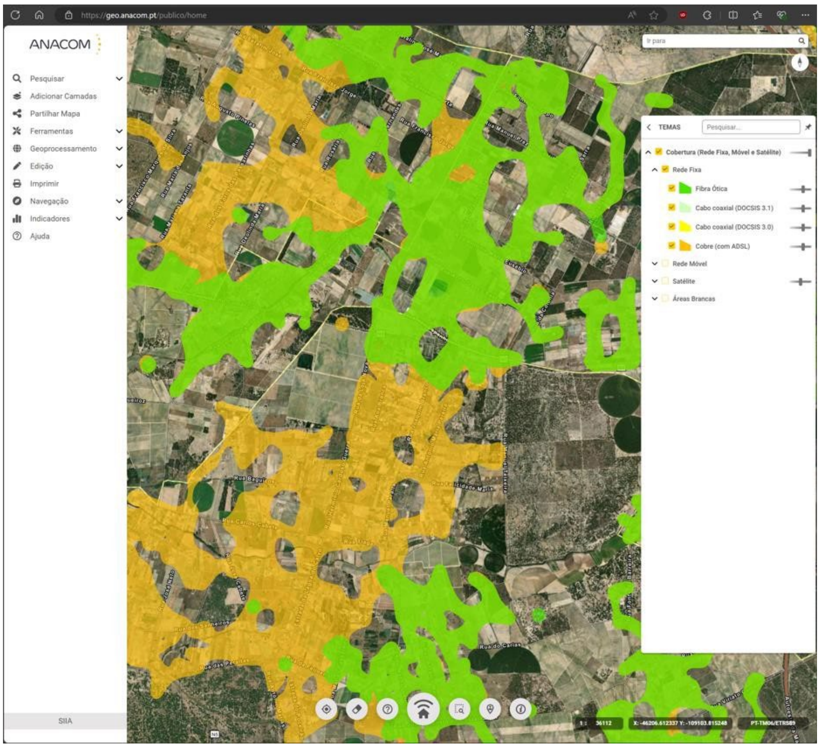
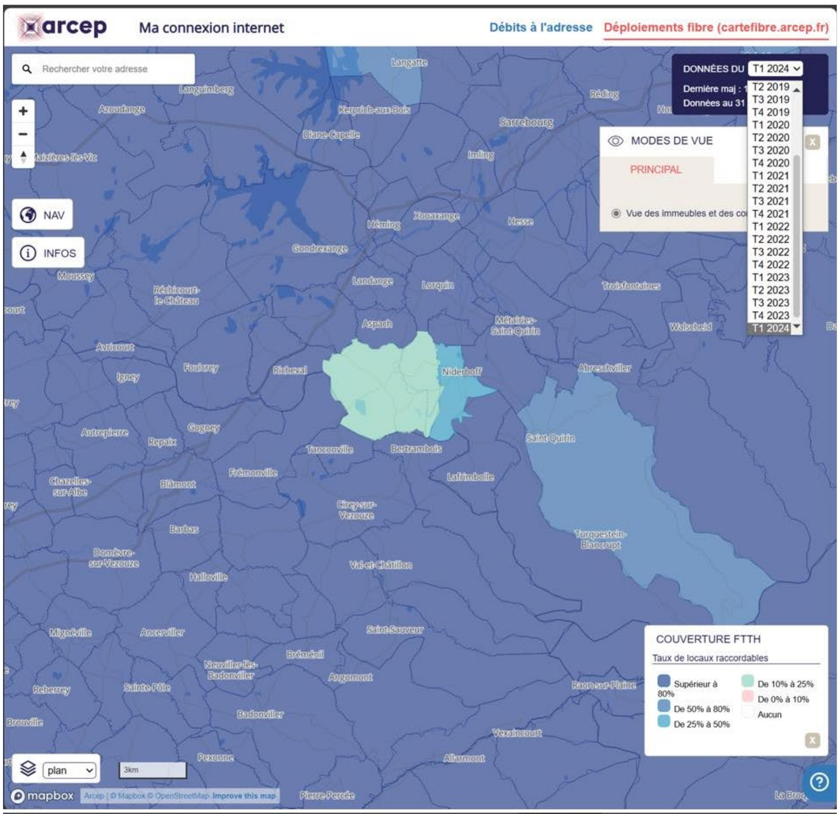


Figure 12. Example: https://geo.anacom.pt/publico/home



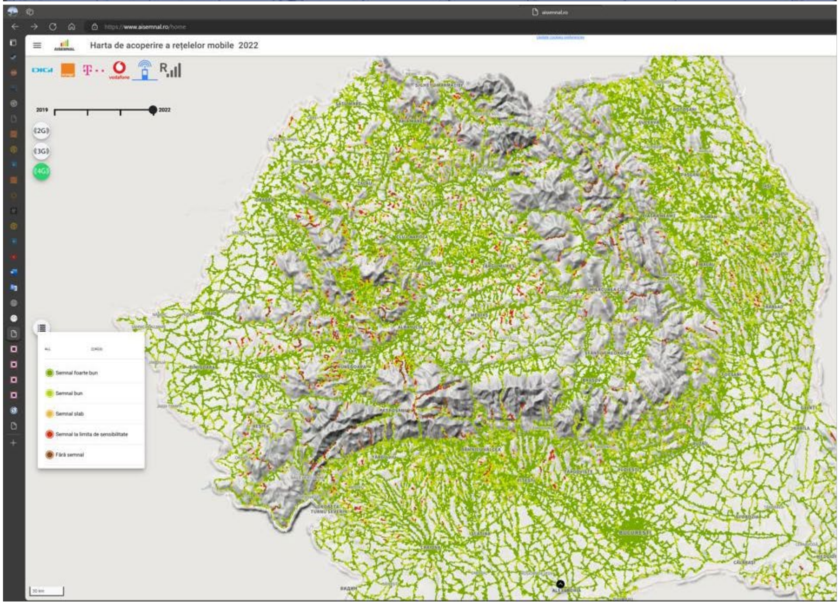


Figure 13 and 14. Example of time-comparison enabled FTTH mapping: https://cartefibre.arcep.fr/index.html?lng=6.988105275215503&lat=48.613357454476585&zoom=11.594625088154315&mode=normal&legende=true&filter=true&trimestre=2024T1

Figure 15. Dashboards example: https://maps.agcom.it/ -> Reportistica

Common Challenges Found in the EMERG and EaPeReg Regions

Despite the successful implementation of broadband mapping systems in many countries, significant challenges persist. These challenges range from data accuracy and availability to regulatory frameworks and technological complexities. A detailed examination of these challenges, supported by case studies, reveals common obstacles and potential solutions. One of the primary challenges is ensuring the accuracy and availability of broadband coverage data from ISPs and other sources. Data collection processes need to be thorough and regularly updated to reflect the dynamic nature of broadband infrastructure. Inconsistencies between databases and real-world situations are common, as seen in Montenegro, where EKIP addresses these issues through meticulous data control and cross- referencing information from various sources. Similarly, Portugal's use of a georeferenced database provided by the National Statistical Office (INE) helps maintain data accuracy.

Establishing and maintaining a robust geospatial data infrastructure is crucial for accurately mapping broadband coverage. This includes integrating geolocation data, census data, and infrastructure data into a unified system that supports mapping and analysis. Portugal's integration of operator data with the INE database is a notable example of overcoming data integration challenges. Disparities in broadband infrastructure between urban and rural areas present significant challenges. Ensuring accurate mapping in both urban and rural areas is crucial for providing a comprehensive view of broadband availability and addressing digital divides. Romania's efforts to map both urban and rural areas highlight the ongoing struggle to bridge these gaps. Inconsistent or unclear regulatory frameworks can hinder data collection from ISPs and coordination between regulatory bodies. Harmonizing regulations and ensuring legal clarity can facilitate the development of accurate broadband maps. Romania's regulatory framework, provided by the Electronic Communications Law, supports broadband mapping and monitoring efforts. The absence of standardized methodologies for mapping broadband can lead to discrepancies in data interpretation. Establishing industry standards and best practices can contribute to more uniform and comparable mapping efforts. The BEREC guidelines are an example of efforts to standardize broadband mapping methodologies across Europe. Balancing the need for detailed broadband mapping with privacy and security considerations is essential. Protecting user data while providing meaningful insights poses a challenge. Portugal addresses these concerns with Decree-Law nr 40/2022, ensuring data protection while offering comprehensive broadband coverage information.

Some countries face a shortage of technical expertise and skilled professionals who can design, implement, and maintain sophisticated broadband mapping systems. Building local capacity and expertise is crucial for sustained success. Georgia's challenge in finding experienced GIS developers underscores the need for technical expertise in broadband mapping initiatives. Developing and maintaining a robust broadband mapping system requires financial resources and human capital. Some countries face budgetary constraints or lack the necessary resources to invest in comprehensive mapping initiatives. International cooperation and programs, such as ITU guidelines on broadband mapping systems, can help facilitate resource assessment and provide financial support. Engaging with local communities and raising awareness about the importance of broadband mapping can be challenging. Without active participation from end-users, gathering crowdsourced data and ensuring the accuracy of mapping efforts can be difficult. Italy's emphasis on community involvement and public awareness campaigns highlights the importance of engaging local communities. Integrating various technologies, including GIS, APIs, and data analytics tools, can be complex. Ensuring seamless interoperability and data exchange between different systems is crucial for an effective broadband mapping infrastructure. Portugal's advanced GIS tools and Python scripts demonstrate successful technology integration.

Promoting interoperability and standardization across various data sources, mapping platforms, and stakeholder organizations is essential for ensuring consistency and reliability in broadband mapping efforts. Achieving consensus on data formats, metadata standards, and quality assurance processes can be challenging but necessary for a cohesive broadband mapping system. Ensuring the sustainability of broadband mapping systems requires long-term planning, institutional support, and ongoing investment in technology, human resources, and capacity building. Developing strategies for maintaining and updating mapping data over time is essential for keeping pace with evolving broadband infrastructure and user needs.

Addressing these challenges requires a coordinated and multi-faceted approach, involving collaboration among governments, regulatory bodies, industry stakeholders, and civil society organizations. By overcoming these challenges, countries can develop comprehensive and reliable broadband mapping systems that support informed decision-making, promote digital inclusion, and drive economic development.

Table: Key Challenges in Broadband Mapping

Challenge	Description
Data Accuracy and Availability	Ensuring accurate and up-to-date data from ISPs and other sources.
Geospatial Data Infrastructure	Integrating geolocation, census, and infrastructure data into a unified system.
Infrastructure Disparities	Addressing differences in broadband infrastructure between urban and rural areas.
Regulatory Frameworks	Harmonizing regulations and ensuring legal clarity for data collection.
Lack of Standardization	Establishing industry standards for consistent data interpretation.
Privacy and Security	Balancing detailed mapping needs with user data protection.
Technical Expertise	Building local capacity and expertise in mapping systems.
Funding and Resources	Securing financial and human resources for mapping initiatives.
Community Engagement	Engaging local communities in data collection efforts.
Technology Integration	Ensuring seamless interoperability and data exchange between different systems.
Interoperability	Promoting standardization across data sources and platforms.

Sustainability	Ensuring long-term support and investment in mapping systems.

Step-by-Step Technical Guide: Setting Up a National Broadband Mapping System

Step 1: Project Initiation and Planning

- **Legal Compliance and Governance:** Verify that the mapping initiative complies with existing laws on data collection, privacy, and cybersecurity. Establish a project governance structure by defining roles and responsibilities, appointing a project leader with appropriate authority, and setting up a stakeholder engagement process with regular meetings and clear reporting mechanisms. Implement risk and change management processes to handle potential challenges effectively.
- **Cost Efficiency and Roadmap Development:** Leverage existing national mapping systems (e.g., cadastral maps, utility grids, INSPIRE geoportal if applicable) to reduce implementation and maintenance costs. Consider the concept of a Single Information Point (SIP) to centralize reporting and presentation of service availability. Create a detailed roadmap outlining the project's scope, objectives, milestones, deliverables, and resource allocation. Plan for knowledge transfer and maintain comprehensive documentation to ensure sustainable system maintenance.

Step 2: Defining Scope, Functionalities, and Technical Requirements

- **Scope Definition:** Determine the focus of the mapping exercise by deciding whether to map infrastructure, services, or both; include fixed and/or mobile networks; and consider existing infrastructure, ongoing projects, and planned investments. This will guide the data sets to collect from telecom operators and public authorities.
- **Functionalities Specification:** Define the minimum functionalities required, such as enabling data submission through forms and bulk imports, providing data reporting and aggregation tools, implementing GIS-based visualization with appropriate scales and coordinate systems (e.g., ETRS89), allowing searching and filtering capabilities, and enabling data export for further analysis.
- **Technical Requirements and IT Resources:** Choose between on-premises servers or cloud environments based on available resources and scalability needs. Utilize technologies like PostgreSQL with PostGIS extensions for spatial data management. Implement open-source GIS software solutions provided by the Open Source Geospatial Foundation (OSGeo), such as GeoServer, QGIS, and PostGIS. Ensure compliance with open technical standards recommended by the Open Geospatial Consortium (OGC), such as Web Map Service (WMS) and Web Feature Service (WFS), to facilitate interoperability and avoid proprietary limitations. Define accessibility and availability requirements, following guidelines like the Web Content Accessibility Guidelines (WCAG) to make the system user-friendly and setting realistic system uptime expectations considering budget constraints.

Step 3: Data Acquisition and Integration

- **Data Collection from Various Sources:** Collaborate with telecom operators to gather data on network connection points, coverage maps, and expansion plans. Collect cadastral data, population density, and public infrastructure records from public authorities. Include data from utility providers for potential infrastructure sharing opportunities.
- **Centralized Reporting and Integration:** Establish a centralized system, such as a Single Information Point (SIP), for data submission and access, ensuring compliance with legal and technical standards.

Integrate with existing state registers and mapping authorities to avoid data duplication and leverage existing data sets for enhanced accuracy.

Step 4: GIS Implementation and Spatial Visualization

- **GIS Software Deployment:** Implement GIS software solutions like GeoServer for managing and serving geospatial data via WMS or WFS, QGIS for desktop analysis, and QField for mobile field surveys. Use PostGIS extensions with PostgreSQL databases to handle spatial data effectively.
- **Map Configuration and Visualization:** Configure map layers to display telecom infrastructure (fiber networks, mobile towers), population data (density maps, urban/rural classifications), utilities, and coverage gaps. Utilize web mapping libraries like OpenLayers or Leaflet for frontend development, ensuring that maps are interactive and user-friendly. Implement Web Processing Services (WPS) to enable advanced functionalities such as querying the database, filtering data, and setting boundaries to reduce the browser's load by displaying only the required data.

Step 5: Data Management and Validation

- **Geographical Segmentation and Classification:** Segment the country based on population density and infrastructure availability in accordance with EU directives or ITU guidelines, using automated scripts (e.g., Python, SQL) to classify areas efficiently following these standards. Generate detailed coverage maps to visualize the availability of different network technologies across regions.
- **Data Submission and Validation from Operators:** Work closely with telecom operators to obtain accurate data on network capacities and expansion plans. Implement strict data formats and validation checks to ensure data accuracy and consistency, utilizing tools like GeoServer for data processing and QGIS for data analysis. Maintain accountability by keeping records of data submissions and changes for transparency and auditing purposes.

Step 6: System Deployment and Stakeholder Access

- **Data Enhancement:** Utilize remote sensing methods, such as drones or satellite imagery, when appropriate, and integrate collected data to enhance the mapping system's accuracy.
- **Web GIS Viewer Development:** Develop a web-based GIS viewer that provides stakeholders with tools to view, analyze, and export data. Implement role-based access controls to ensure security and appropriate permissions. Use GeoServer for processing and rendering geographic data, and integrate with web mapping libraries like OpenLayers or Leaflet for an interactive user interface. The viewer can be developed using environments like Microsoft Visual Studio with ASP.NET MVC. Implement Web Processing Services (WPS) to enable advanced functionalities such as querying the database and filtering data.

Step 7: Maintenance, Security, and Continuous Improvement

- **System Maintenance and Optimization:** Perform regular maintenance by keeping operating systems, GIS software, and databases updated, and ensure daily backups with system redundancy to prevent data loss. Optimize data processing to handle large datasets efficiently and automate tasks like data imports and synchronization using scripts (e.g., Python scripts).
- **Security and Data Protection:** Implement robust security measures, including data encryption for data in transit and at rest, and access controls to ensure only authorized personnel can access or modify data. Adhere to national regulations regarding data sharing and privacy, and conduct regular security audits to identify and address vulnerabilities. Follow security best practices and standards from organizations like the Open Web Application Security Project (OWASP) and the

Center for Internet Security (CIS). Engage with national Computer Security Incident Response Teams (CSIRT) for guidance and compliance with RFC2350 expectations.

- **Training and Capacity Building:** Provide comprehensive training for staff on system usage, data input, retrieval, and maintenance procedures; while countless trainings are offered, we at ITU specifically recommend two courses from the ITU Academy—**"Introduction to Broadband Mapping"** and **"Advanced Broadband Mapping"**—after which staff should receive specific training tailored to your system. Utilize QGIS and GeoServer training materials to enhance technical skills. Develop user manuals and documentation to facilitate effective system use and knowledge transfer from external experts to internal teams.
- **Continuous Improvement and Future Updates:** Regularly update the system by incorporating new data sources and technological advancements, such as 5G networks or IoT data. Periodically review the system to ensure it meets evolving stakeholder needs and design it with flexibility to integrate future technologies. Engage with the Open Source Geospatial Foundation (OSGeo) community for updates on software improvements and best practices.

For a summary of this technical guide in table format, please refer to Annex 3, and for key software tools and download links, see Annex 4.

Conclusion and Future Outlook

This compendium on broadband mapping systems across various countries served as a comprehensive resource, capturing the diverse experiences, challenges, and innovations in the field. The detailed case studies from Montenegro, Moldova, Poland, Armenia, Italy, Latvia, Georgia, Portugal, and Romania highlighted the strides made in digital connectivity and the persistent hurdles that still needed to be addressed. Each section of the compendium provided valuable insights into the complex task of accurately mapping broadband infrastructure and coverage.

The **Introduction and Background** sections established the importance of broadband mapping, detailing its role in identifying coverage gaps, informing policy decisions, and facilitating investments in infrastructure. It underscored the need for accurate data and robust legal frameworks to support these efforts.

The **Case Studies** delved into specific country experiences, offering a granular view of their broadband mapping initiatives. Each case study discussed the legal background, system architecture, data sources, visualization tools, challenges faced, and future steps. For instance, Montenegro's case emphasized meticulous data control and future enhancements to the Geoportal. Moldova focused on integrating various data sources and improving data accuracy, while Poland utilized a comprehensive Single Information Point (PIT) for data integration. Armenia leveraged extensive legal frameworks and stakeholder collaboration, and Italy implemented user-centric mapping with advanced GIS technologies. Latvia centralized data through the Broadband Availability Geographical Information System (PPĢIS). Georgia developed a universal GIS platform with international support, and Portugal emphasized transparency and public access through GEO.ANACOM. Romania highlighted rigorous measurement campaigns and public coverage maps.

The **Challenges** section identified common challenges, such as data accuracy, infrastructure disparities, regulatory inconsistencies, and technical expertise shortages. It stressed the need for robust geospatial data infrastructures, standardized methodologies, and enhanced stakeholder collaboration. Despite the successful implementation of broadband mapping systems in many countries, challenges persisted, such as inconsistencies between the database and real-world situations. EKIP addressed these issues through meticulous data control, cross-referencing information received from operators with other agency systems. Future steps included enhancing the Geoportal with additional functionalities for monitoring broadband coverage and infrastructure development, along with improvements to data control tools. Thus, a common catalogue of challenges included obtaining accurate and up-to-date data on broadband coverage, speeds, and service availability. Ensuring the availability and accuracy of broadband coverage data from internet service providers (ISPs) and other sources remained a significant challenge, especially in countries where ISPs might be reluctant to share detailed coverage information due to competition concerns. Establishing and maintaining a robust geospatial data infrastructure was crucial for accurately mapping broadband coverage. This included integrating geolocation data, census data, and infrastructure data into a unified system that supported mapping and analysis.

The **Good Practices** section offered recommendations for addressing these challenges. These included establishing clear regulatory frameworks, fostering public-private partnerships, standardizing data collection, ensuring privacy, and raising community awareness. These practices aimed to improve data accuracy, enhance collaboration, and promote sustainable mapping efforts. The use of an address database from cadastre and developing standardized methodologies for collecting broadband-related data, including parameters such as speed, technology, and coverage, ensured consistency in data collection across different regions.

Throughout the compendium, the emphasis was on leveraging innovative technologies and collaborative efforts to create comprehensive and reliable broadband maps. The integration of Geographic Information System (GIS) technologies, crowdsourced data, and automated data collection methods proved effective in enhancing data accuracy and visualization.

The compendium not only served as a repository of knowledge but also as a call to action for continued collaboration and innovation. Despite significant progress, the journey toward comprehensive and accurate broadband mapping was ongoing. The common challenges of data accuracy, infrastructure disparities, and regulatory frameworks required concerted efforts and shared solutions.

The joint workshops organized by ITU, EMERG, and EaPeReg had proven invaluable for sharing best practices and innovative solutions. It is auspicable that for 2024, such engagement would continue by extending these workshops to include more countries from the EMERG and EaPeReg regions, to facilitate deeper understanding and collaboration. These workshops could help countries collectively enhance their mapping capabilities, overcome shared challenges, and accelerate the deployment of high-speed broadband infrastructure.

The invitation is open to all member countries to participate in future workshops and contribute to this ongoing effort. Through continued collaboration, shared learning, and mutual support, countries could achieve the collective goal of comprehensive and accurate broadband mapping. This would ensure that all citizens had access to reliable, high-speed internet connectivity, fostering digital inclusion and driving economic development.

In conclusion, the compendium is a testament to the power of collaborative efforts in achieving digital connectivity. By embracing innovation, fostering partnerships, and committing to a shared vision, we could pave the way for a digitally inclusive future. Let us continue this journey together, exploring new frontiers and creating lasting impacts through our collective efforts.

Annex 1 – Parameter Table

CATEGORY	DESCRIPTION	EXAMPLE/DETAILS
	INFORMATION TO BE COLLECTED	
Type (Level i)	Nodes, lines, services	• Nodes: Central Office, Data Center • Lines: Fiber Optic Cable, Copper Cable • Services: Internet, VoIP
Attributes (Level ii)	Master description, additional info about infrastructure existence or broadband service availability	• Node: Operational Status, Capacity • Line: Length, Installation Date • Service: Bandwidth, Latency
Values/Terms (Level iii)	Defined values or terms for second-level attributes	• Node Status: Active, Inactive • Line Material: Fiber, Copper • Service Type: Internet, VoIP
Address Database	Reliable address database including geographical coordinates for each address	• Sourced from official administrative databases like cadastre or civil infrastructure systems
Criteria	Importance	Implementation Example
Geographical Precision	High	Using GIS data from cadastral systems • Address: 123 Main St, Springfield, • Longitude: 40.7128, • Latitude: -74.0060
Data Consistency	High	Standardized format for address data Format: • CSV, • XML
Update Frequency	High	Regular updates from municipal records, yearly updates, or as per European Commission and BEREC guidelines Update Interval: Annually, Quarterly

Policy and Regulatory Framework	**Details**	**Example**
Objectives	Define specific goals like identifying coverage gaps	EU Digital Agenda Objective: Identify underserved areas for broadband expansion
Roles and Responsibilities	Clear delineation among government agencies, operators, etc.	Romanian Electronic Communications Law Roles: Government sets policy, ISPs provide data
Legal Mandates	Legislative support for data sharing and compliance	European Electronic Communications Code Mandate: ISPs must share network data with regulatory body
Collaboration and Partnerships		
Government Agencies Regulatory Bodies Regulatory Bodies	Policy-making, funding, and oversight Data collection standards, compliance enforcement	EU Digital Agenda Agency: Ministry of Digital Transformation ANACOM in Portugal Body: National Regulatory Authority (NRA)
Telecommunication Operators	Data provision, infrastructure deployment	Public-private partnerships in Italy Operator: Telecom Italia
Community Organizations	Crowdsourced data collection, public awareness	Local initiatives in Georgia Organization: Georgia Broadband Alliance
Data Collection and Standardization	**Details**	**Example**
Speed	Measurement of download and upload speeds	Section 3.1 of BEREC's Net Neutrality Regulatory Assessment Methodology

Technology Type	Types of broadband technology (e.g., fiber, DSL, cable)	ITU Standards Technology: Fiber Optic, DSL, Cable
Coverage	Geographic extent of broadband service	GIS-based mapping Coverage Area: 10 km radius
Data Source	Origin of data (e.g., ISP reports, surveys, crowdsourcing)	Polish Regulation on telecom infrastructure and service inventory Source: ISP self-reports, User surveys
Infrastructure Mapping Systems		
Technical Parameters for Nodes	**Details**	**Example**
Node Address	- Province - Commune - Unique identifier - Town name - Street name - Building number	Province: Lombardy Commune: Milan Identifier: 12345 Town: Milan Street: Via Roma Building: 10
Coordinates	- Geographical coordinates: longitude and latitude in the WGS-84 coordinate system with an accuracy of 1 m	Longitude: 9.1900, Latitude: 45.4642
Building Type	- Office - Residential - Industrial - Service - Public - Sacred object - Power grid - Tower - Mast - Container - Pole - Cable well	Type: Office Type: Residential
Sharing Surface Area	Yes/No	Yes
Layers of Node	- Backbone - Distribution - Access	Layer: Backbone
Transmission Medium	- Fiber Optic - Coax	Medium: Fiber Optic

	- Copper - Radio	
Technology	- Ethernet - Fast Ethernet - Gigabit Ethernet - GPON - EPON - DWDM - CWDM - SDH - PDH - (EURO)DOCSIS - VDSL - ADSL - HDSL - POTS/ISDN - Radio link - WiFi - WiMAX	Technology: GPON Technology: VDSL
Maximum Bandwidth	- For download and upload	Download: 1 Gbps, Upload: 500 Mbps
Number of Interfaces		24
Source of Funding	- Commercial - State aid	Funding: Commercial
Power Supply	- Type of power supply - Backup power options	Power Supply: AC, Backup: Battery
Environmental Conditions	- Operating temperature range - Humidity levels	Temperature: -10°C to 50°C, Humidity: 10% to 90%
Security Features	- Physical security measures - Network security protocols	Security: CCTV, Access Control
Maintenance Requirements	- Regular maintenance schedules - Fault tolerance features	Maintenance: Quarterly
Technical Parameters for Lines	**Details**	**Example**
Coordinates	- Geographical coordinates: longitude and latitude in the WGS-84 coordinate system with an accuracy of 1 m	Longitude: 9.1910, Latitude: 45.4650
Layer of Cable	- Backbone - Distribution - Access	Layer: Distribution

Type of Line	- Fiber Optic - Coax - Copper - Radio	Type: Fiber Optic
Fibers	- Fibers of the optical cable	Fibers: 24
Source of Funding	- Commercial - State aid	Funding: State Aid
Length of Line	- Total length in meters/kilometers	Length: 2 km
Installation Date	- Date of installation	Installation: 2023-01-15
Expected Lifespan	- Estimated operational lifespan	Lifespan: 20 years
Technical Parameters for Mobile Towers	**Details**	**Example**
Coordinates	- Geographical coordinates: longitude and latitude in the WGS-84 coordinate system with an accuracy of 1 m	Longitude: 9.1920, Latitude: 45.4660
GSM Cell Technology	- 2G - 3G - 4G - 5G	Technology: 4G
GSM Cell Identifier	- Unique identifier of the corresponding GSM cell	Identifier: GSM123
Tower Height	- Height of the tower in meters	Height: 50 m
Coverage Area	- Radius of coverage area in meters/kilometers	Radius: 10 km
Frequency Bands	- Frequency bands supported	Bands: 700 MHz, 1800 MHz, 2600 MHz
Capacity	- Maximum number of connections supported	Capacity: 1000 users
Service Mapping Systems		
Datasets for Service Mapping	**Details**	**Example**
Building Address	- Province - Commune - Unique identifier - Town name	Province: Lombardy Commune: Milan Identifier: 67890 Town: Milan

	- Street name - Building number	Street: Via Verdi Building: 15
Coordinates	- Geographical coordinates: longitude and latitude in the WGS-84 coordinate system with an accuracy of 1 m	Longitude: 9.1930, Latitude: 45.4670
Medium	- Fiber Optic - Coax - Copper - Radio	Medium: Coax
Access Network Technology	- Ethernet - Fast Ethernet - Gigabit Ethernet - GPON - EPON - DWDM - CWDM - SDH - PDH - (EURO)DOCSIS - VDSL - ADSL - HDSL - POTS/ISDN - Radio link - WiFi - WiMAX	Technology: DOCSIS 3.1
Possible Services	- Fixed Internet access - Fixed line POTS and ISDN - VoIP telephony - IPTV or DTV	Services: Fixed Internet, IPTV
Maximum Bandwidth	- Download and upload bandwidths	Download: 500 Mbps, Upload: 50 Mbps
Provided Services	- Fixed Internet access - Fixed line POTS and ISDN - VoIP tele	

Annex 2 – Links to National Broadband Mapping Portals by Country

Country	**Link to broadband map**
Montenegro	geoportal.ekip.me
Moldova	harta.anrceti.md
Poland	pitmap.uke.gov.pl
Armenia	
Italy	geo.agcom.it
Latvia	ppgisin.platjoslaskarte.lv
France	maconnexioninternet.arcep.fr
Georgia	
Portugal	geo.anacom.pt
Romania	aisemnal.ro

Annex 3 – Technical Workflow and Tools for Setting Up a National Broadband Mapping System

Step	Key Actions	Technologies and Software
1. Project Initiation and Planning	- Verify legal compliance (data collection, privacy, cybersecurity).- Establish project governance (roles, leader, stakeholder engagement).- Develop roadmap (scope, objectives, milestones, resources).- Leverage existing systems (cadastral maps, utility grids, **INSPIRE geoportal**, **Single Information Point (SIP)**).	
2. Define Scope and Requirements	- Decide mapping focus (infrastructure, services, fixed/mobile networks, investment stages).- Define functionalities (data submission, reporting, GIS visualization with **ETRS89**, search/filter, data export).- Determine technical requirements (on-premises/cloud, accessibility, availability).- Utilize open standards and software.	- **PostgreSQL** with **PostGIS**.- **GeoServer**, **QGIS**, **QField** (from **OSGeo**).- Follow **OGC** standards (**WMS**, **WFS**).- Adhere to **WCAG** guidelines.
3. Data Acquisition and Integration	- Collect data from telecom operators (network points, coverage, plans).- Gather data from public authorities (cadastral, population, infrastructure).- Include utility data for infrastructure sharing.- Centralize data submission and access (**SIP**).- Integrate with state registers and mapping authorities.	- Collaborate with operators and authorities.- Use centralized system (**SIP**).
4. GIS Implementation and Visualization	- Deploy GIS software: **GeoServer** (**WMS**, **WFS**), **QGIS** (desktop), **QField** (mobile).- Configure map layers (infrastructure, population, utilities, coverage gaps).- Develop interactive maps using **OpenLayers** or **Leaflet**.- Implement **Web Processing Services (WPS)** for advanced functionalities.	- **GeoServer**, **QGIS**, **QField**.- **PostgreSQL**, **PostGIS**.- **OpenLayers** or **Leaflet**.- **WPS**.
5. Data Management and Validation	- Segment country based on population and infrastructure (per **EU directives/ITU guidelines**).- Use automated scripts (**Python**, **SQL**) for classification.- Generate coverage maps of network technologies.- Obtain accurate data from operators; implement strict data formats and validation checks.- Maintain records for accountability and auditing.	- **Python**, **SQL** scripts.- **GeoServer**, **QGIS** for data processing and analysis.
6. System Deployment and Access	- Enhance data with remote sensing (drones, satellite imagery).- Develop web GIS viewer with role-based access.- Use **GeoServer** for data processing.- Integrate maps using **OpenLayers** or **Leaflet**.- Optionally, develop viewer using **Microsoft Visual Studio** with **ASP.NET**	- **GeoServer**.- **OpenLayers** or **Leaflet**.- **Microsoft Visual Studio**, **ASP.NET MVC** (optional).- **WPS**.

	MVC.- Implement **WPS** for advanced querying and filtering.	
7. Maintenance, Security, Improvement	- Perform regular maintenance; update software and databases; ensure backups.- Optimize data processing; automate tasks with **Python** scripts.- Implement security measures (encryption, access control).- Follow best practices from **OWASP**, **CIS**; consult **CSIRT**.- Provide training: recommend **ITU Academy** courses "**Introduction to Broadband Mapping**" and "**Advanced Broadband Mapping**"; utilize **QGIS** and **GeoServer** materials; develop user manuals.- Regularly update system with new data and technologies (**5G**, **IoT**); engage with **OSGeo** community.	- **Python** scripts.- Security standards: **OWASP**, **CIS**, **CSIRT**.- **ITU Academy** courses.- **QGIS**, **GeoServer** training materials.- Engage with **OSGeo**.

Annex 4 – Key Software Tools for Broadband Mapping System Setup

Software Tool	Description	Download Link
GeoServer	An open-source server for sharing geospatial data.	Download GeoServer
QGIS	A free and open-source desktop GIS application.	Download QGIS
QField	A mobile GIS app based on QGIS for field data collection.	Get QField
PostgreSQL	An open-source relational database management system.	Download PostgreSQL
PostGIS	A spatial database extender for PostgreSQL.	Install PostGIS
OpenLayers	An open-source JavaScript library for displaying map data in web browsers.	Visit OpenLayers
Leaflet	A lightweight open-source JavaScript library for interactive maps.	Visit Leaflet
Python	A programming language used for scripting and automation.	Download Python
Microsoft Visual Studio	An integrated development environment (IDE) for application development.	Download Visual Studio
ASP.NET MVC	A web application framework for building dynamic websites.	Download ASP.NET MVC
Web Processing Service (WPS)	An OGC standard for publishing geospatial processes.	Learn about WPS