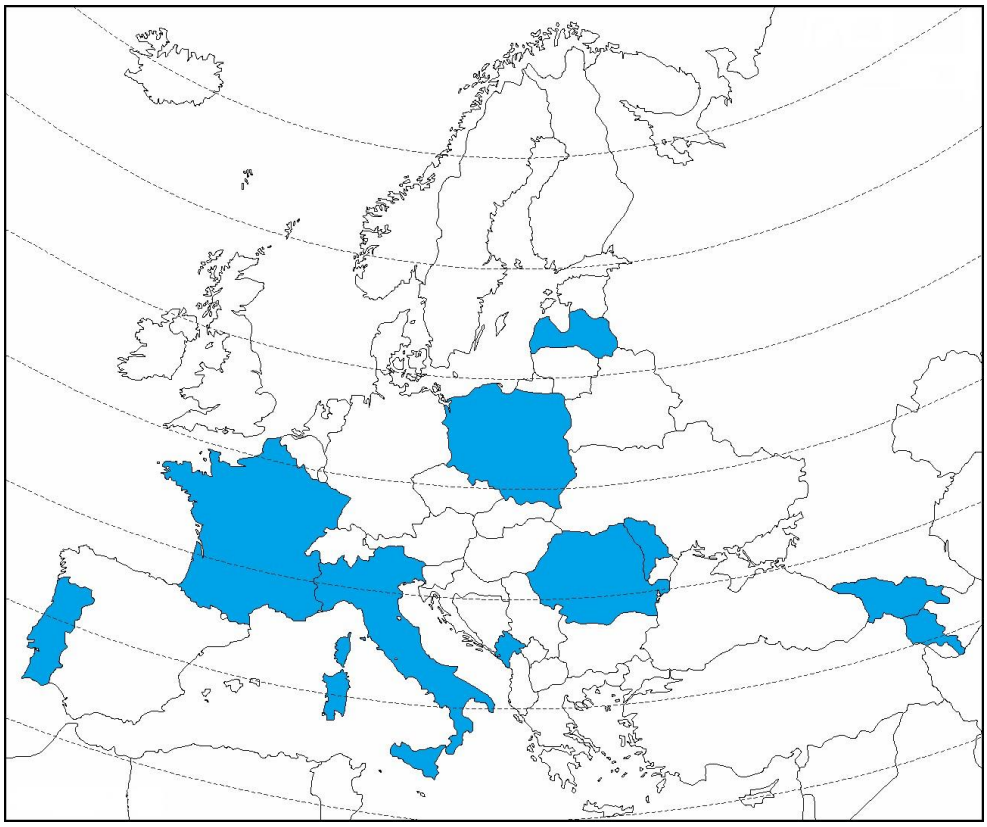
International Telecommunication Union



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

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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 European Mediterranean Regulators Group (EMERG) and Eastern Partnership Electronic Communications Regulators Network (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.

1. Introduction and Purpose

The International Telecommunication Union (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 International Telecommunication Union (ITU), the European Mediterranean Regulators Group (EMERG) and the Eastern Partnership Electronic Communications Regulators Network (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 Information and Communication Technology (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 Memorandum of Understanding (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 National Regulatory Authorities (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 United Nations' Sustainable Development Goals (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.

2. 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 Geographic Information Systems (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 European Union (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 Digital Agenda for Europe (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 Broadband Cost Reduction Directive (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 European Electronic Communications Code (EECC) (2018) requires member states to conduct geographical surveys of network deployments and update this information regularly. The EECC empowers the Body of European Regulators for Electronic Communications (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.

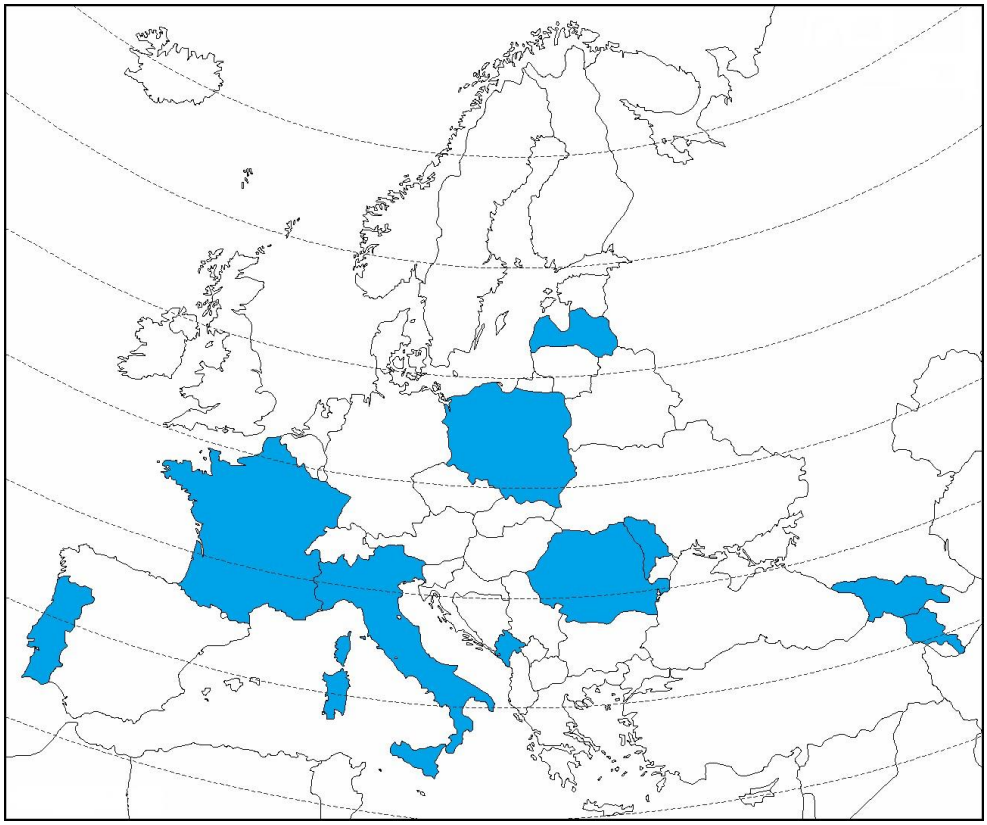


Figure 1. Map presenting countries, subject to case studies for 2023 Workshops

3. Case study 1: Montenegro

Montenegro, a nation of 620,029 people residing across 13,883 km², is making significant strides in enhancing its digital infrastructure through a comprehensive broadband mapping system led by the Agency for Electronic Communications and Postal Services (EKIP). This system, pivotal to the country's digital transformation, integrates national legislation, sophisticated system architecture, diverse data sources, and advanced visualization tools, while also addressing several challenges. At the core of Montenegro's broadband mapping initiatives is a robust legal framework. Key legislative instruments 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 establish the regulatory foundation. These laws, aligned with the Digital Transformation Strategy (2022-2026), provide a structured approach to managing and developing the nation's digital infrastructure.

Managed by EKIP, the broadband mapping system's architecture is built on collaborative efforts with operators, planners, and national and local institutions. Data sources range from infrastructure details like antenna poles, buildings, and cables provided by operators, to demographic data from national institutions. This comprehensive documentation includes individual data entries directly on the map and group imports via shapefiles. The system's technological backbone comprises QGIS, Geoportal, PostgreSQL/PostGIS, and Java software applications, supported by HPE ProLiant servers for efficient data storage and processing. Regular backups safeguard against data loss, ensuring the system's reliability and integrity. A standout feature of Montenegro's broadband mapping system is its user-friendly interface accessible through public portals. This interface allows various users, including operators, planners, and institutions, to review geographical locations, ownership details, and broadband coverage. The system visualizes coverage grids based on endpoint locations, providing

insights into speeds, technologies, and the number of operators in each region. This transparency is crucial for both public and private stakeholders.

Despite its successes, EKIP faces challenges, particularly inconsistencies between database information and real-world conditions. To address these issues, EKIP employs meticulous data control methods, cross-referencing information received from operators with other agency systems. Future enhancements will focus on adding functionalities for monitoring broadband coverage and infrastructure development, along with improved data control tools. The case study of Montenegro, presented by EKIP on September 28, 2023, with key speakers Dubravka Aleksić and Matija Tomčić, provided an in-depth look into the country's broadband mapping system and its impact on the digital landscape. Montenegro, consisting of 25 municipalities and 1,307 settlements, has its capital in Podgorica, with Cetinje as the historical capital.

The presentation began with an overview of the national legislation related to mapping, highlighting the Law on Electronic Communications and the Digital Transformation Strategy 2022-2026. It detailed the mapping system's structure, data types collected, and primary users, ranging from operators and planners to local institutions and the public. Methodologies for data entry and import, including both individual and grouped entries, were discussed. The current state of broadband coverage, visualized through various mapping tools, was presented, showcasing how data from operators is utilized. Challenges such as discrepancies between the database and actual conditions were acknowledged, with methods for verification and control highlighted. EKIP's future steps include planned improvements to the Geoportal and the mapping system functionalities to better monitor broadband and infrastructure development.

In terms of technical infrastructure, the presentation covered the use of QGIS, Geoportal, PostgreSQL/PostGIS, Java software applications, Geoserver, and server hardware like HPE ProLiant DL380 Gen10 servers. The system's robust technological framework ensures effective data management. Public access to the web portal allows users to view the geographical location and ownership of electronic communication infrastructure and review broadband coverage. The broadband coverage is visualized based on operator data on endpoint locations, characterized by ownership, type, technology, and speed, displayed in 100x100m grids. The methodology for calculating broadband coverage includes data from operators, the National Statistics Authority (MONSTAT), and the Cadastre and State Property Administration. This approach allows for nuanced calculations of coverage percentages and detailed visualizations of broadband spread in terms of speed, technology, and the number of operators.

In conclusion, the presentation by EKIP at the ITU-EMERG-EaPeReg Joint Workshops highlighted the complexity and depth of Montenegro's approach to broadband mapping. It showcased a commitment to evolving and improving digital infrastructure, addressing real-time challenges, and planning future enhancements. This approach not only serves Montenegro's immediate needs but also sets a benchmark for other nations striving to enhance their digital landscapes.

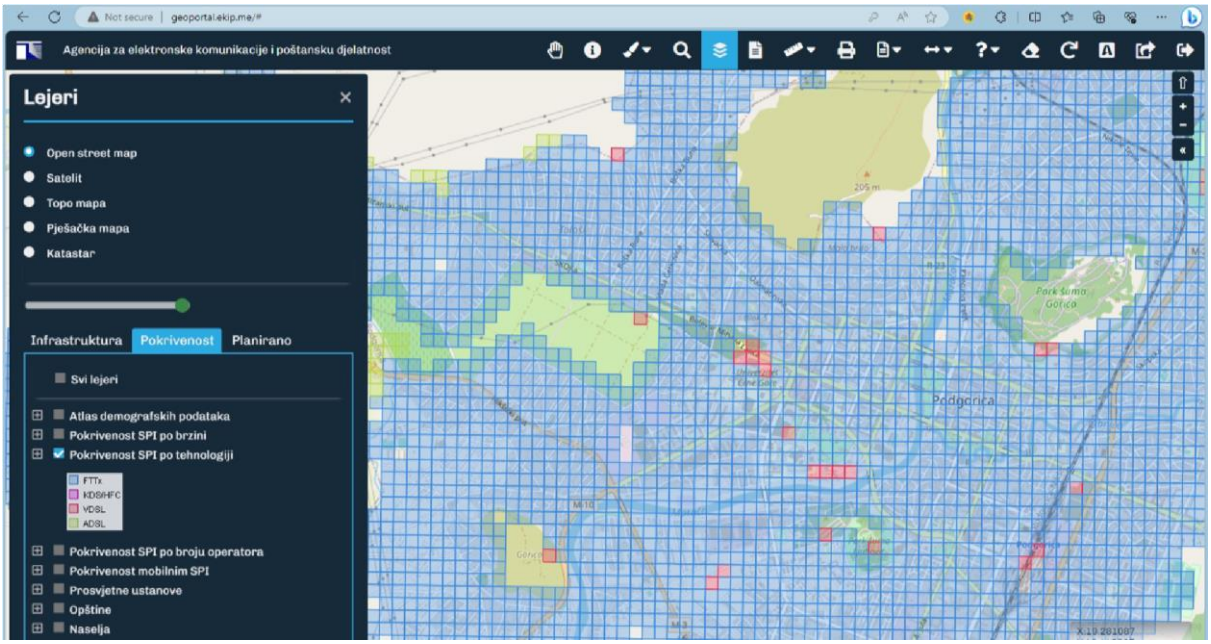


Figure 2. Montenegro's geoportal.ekip.me Broadband Coverage view by technologies

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	Agency for Electronic Communications and Postal Services (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

4. Case study 2: Moldova

The Republic of Moldova is actively engaged in strengthening its broadband infrastructure and services. The presented case study explores Moldova's broadband mapping system under the leadership of the Electronic and Postal Communications Policy Directorate at the Ministry of Economic Development and Digitalization. With a comprehensive scope, Moldova aims to achieve broadband objectives through reliable data, legislative frameworks, and stakeholder collaboration.

Recognizing the fundamental importance of accurate data on existing broadband infrastructures, Moldova has initiated a broadband mapping project. The mapping system serves various crucial purposes, including identifying coverage gaps, determining suitable investment areas, avoiding

financial duplications, and providing detailed data for policy-setting. In compliance with relevant regulations, the mapping system also facilitates efficient use of existing infrastructure, thereby reducing the cost of construction and renovation.

Moldova's broadband mapping efforts are supported by a robust legal framework, including laws on access to properties, electronic communications, spatial data infrastructure, and the register of town-technical infrastructure objects. These legislations align with European directives and aim to ensure the legality, efficiency, and coordination of broadband initiatives.

Managed by various entities, the broadband mapping system in Moldova includes contributions from the National Regulatory Agency for Electronic Communications and Information Technology (ANRCETI), which has developed road and fixed broadband coverage maps. Telecom operators such as Moldtelecom, Orange Moldova, and Moldcell have also provided coverage maps for different technologies. Furthermore, the Public Services Agency has initiated the implementation of the Registry of Engineering Infrastructure Facilities (REIF) to consolidate spatial data.

Moldova is actively aligning its data sets with relevant EU directives, specifically Directive 2014/61/EU. The REIF focuses on engineering infrastructure facilities and encompasses various elements such as water supply, electric and gas networks, heating systems, road and railway networks, and electronic communication networks. The alignment process involves monitoring, expert reports, and recommendations to ensure compliance and effectiveness.

Broadband coverage visualization is a critical aspect of Moldova's digital infrastructure development. This process aims to provide accurate insights into the availability and quality of broadband services across the country. The key objectives of broadband mapping include identifying gaps in broadband coverage, assessing the quality of service, facilitating the identification of suitable investment areas, avoiding duplication of financing, and ensuring regulatory compliance. Additionally, it aims to program funds efficiently and monitor their execution at regional and national levels while reducing the cost of broadband network construction and renovation by coordinating with existing infrastructure.

Stakeholder collaboration is crucial for the success of Moldova's broadband mapping system. Entities such as the Ministry of Economic Development and Digitalization, ANRCETI, network operators, local authorities, and public institutions like the Information Technology & Cyber Security Service and the Public Services Agency play integral roles. Their collective efforts are directed towards achieving seamless data integration, providing reliable information, and ensuring the success of the mapping system.

Moldova's commitment to broadband mapping exemplifies its dedication to digital progress. With a robust legal framework, existing implementations, and ongoing alignment efforts, Moldova is poised to address coverage gaps, ensure efficient resource allocation, and elevate its digital connectivity. The collaborative engagement of stakeholders underscores the nation's holistic approach to building a comprehensive and effective broadband mapping system, paving the way for a digitally empowered future.

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 state of play and scope of the broadband mapping project at the "Strengthening Broadband Infrastructure and Services across the Europe Region and beyond" workshop in Budva, Montenegro, on September 28, 2023.

The presentation highlighted the fundamental importance of having reliable data on existing broadband infrastructures and services. Such data are crucial not only for identifying gaps in coverage and service quality but also for determining appropriate areas for investment, avoiding duplication in funding, and ensuring regulatory compliance. Moldova's legal framework, comprising various laws and government decisions, aligns with EU directives and provides a comprehensive approach to electronic communications and spatial data infrastructure.

However, the implementation of broadband mapping in Moldova has been somewhat fragmentary, with different entities providing separate coverage maps. These include ANRCETI's road coverage maps and fixed broadband development maps, as well as coverage maps provided by major telecommunications companies like Moldtelecom, Orange Moldova, and Moldcell. Moldova's national spatial data infrastructure plays a crucial role in the country's broadband mapping efforts, including a wide range of spatial data sets and services integral to the engineering infrastructure facilities registered in the REIF system. The methodology for calculating broadband coverage, based on operator data and information from national institutions like MONSTAT, illustrates a detailed and systematic approach to visualizing broadband coverage across the nation.

The challenges encountered in the implementation of broadband mapping have led to various analyses and recommendations by organizations such as EU4Digital and the World Bank. These efforts have been instrumental in identifying gaps in the existing laws and providing guidelines for aligning Moldova's approach with EU standards. The collaboration between key stakeholders, including policymakers, regulatory authorities, network operators, and local authorities, is vital in the development and implementation of an effective broadband mapping system. The Public Services Agency's initiative in implementing the REIF and the collaboration with STISC highlight the coordinated efforts necessary for successful broadband mapping.

In conclusion, the presentation by Vitalie Boboc emphasized the importance of comprehensive and accurate broadband mapping for policy-making and infrastructure development in Moldova. The country's commitment to broadband mapping, supported by a robust legal framework and collaborative stakeholder engagement, positions Moldova to effectively address coverage gaps, ensure efficient resource allocation, and enhance its digital connectivity.

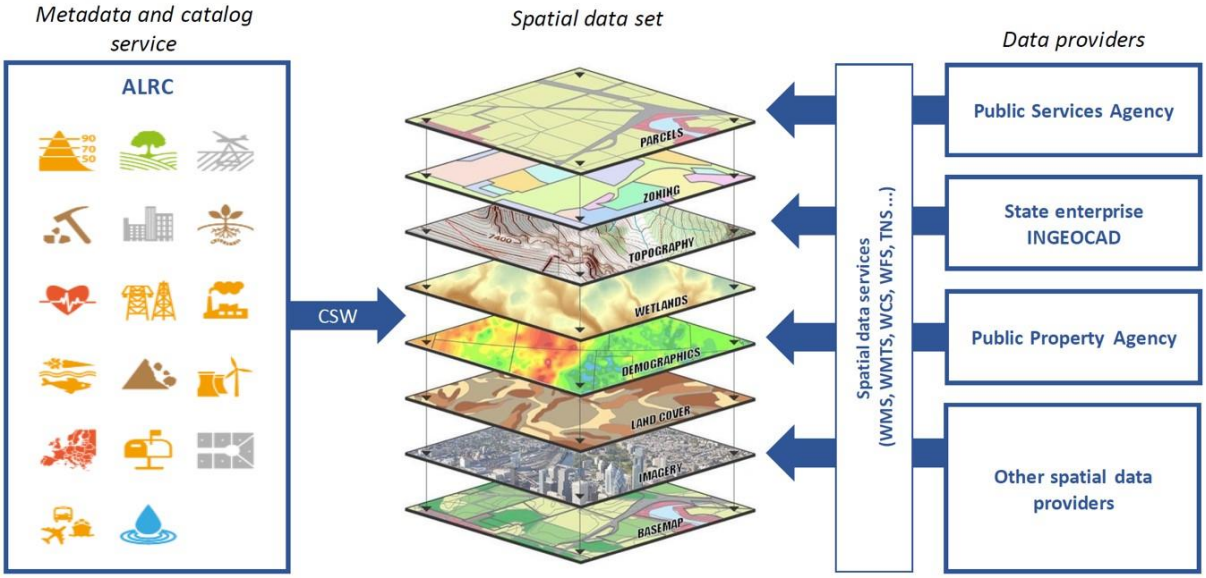


Figure 3. National Spatial Data Infrastructure of Moldova

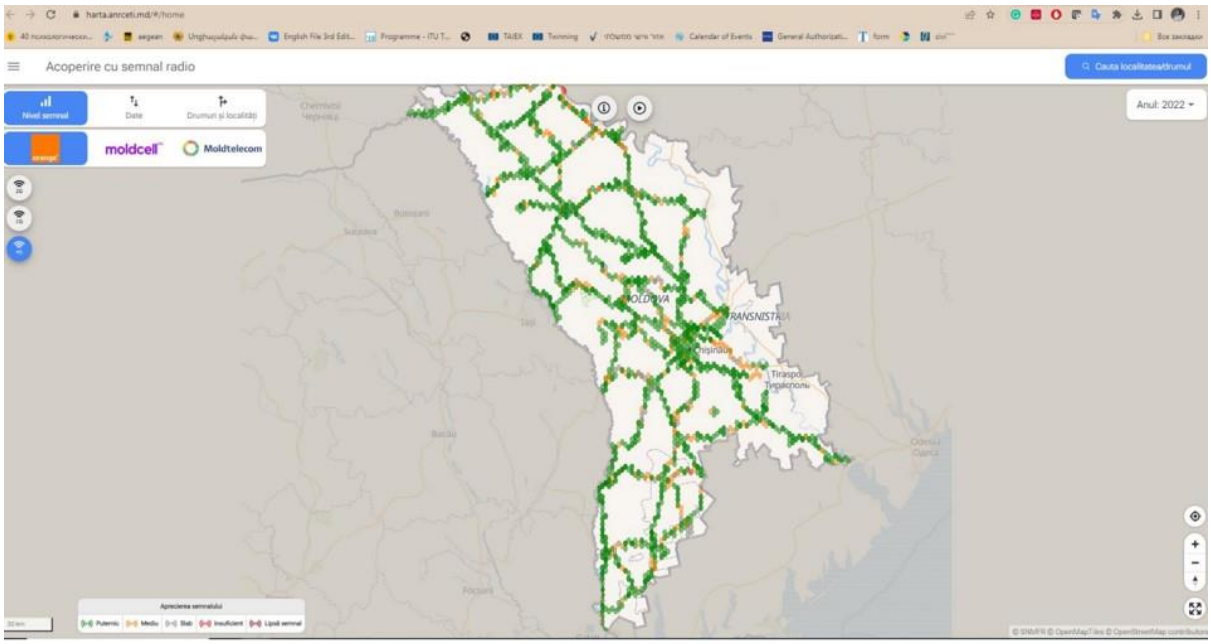


Figure 4. ANRCETI's Interactive Map of coverage and quality of mobile services on public roads (htps://harta.anrceti.md/#/home)

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

5. Case study 3: Poland

Poland's broadband mapping system is designed around the Single Information Point (PIT) and several complementary systems that gradually integrate into or transfer data to PIT. This integrated approach enhances the country's broadband infrastructure through a strong legal framework, advanced system architecture, and diverse data sources.

Supported by key legislations such as the Polish Act on Supporting the Development of Telecommunications Services and Networks, the Polish Telecommunications Law, and Directive 2014/61/EU aimed at reducing the cost of deploying high-speed electronic communications networks (BCRD), Poland's legal framework provides a solid foundation. Additionally, the recent Gigabit Infrastructure Act, presented by the European Commission on February 23, 2023, sets actions to achieve Gigabit connectivity across the EU by 2030. Regulatory changes effective from January 1, 2023, require the President of UKE to prepare bi-annual inventories of telecommunications infrastructure, services, and colocation buildings, improving the granularity of reported data.

The PIT platform, accessible at https://pitmap.uke.gov.pl/, serves as a comprehensive tool for data analysis, report generation, and advanced search functionalities. Reporting in PIT includes telecommunications infrastructure, services, colocation buildings, and declarations of non-telecommunications infrastructure. Complementary systems such as SIDUSIS, SIMBA, inTELi, and MapBook provide additional functionalities, including internet availability checks, project management, and detailed data analysis. These systems underscore the multifaceted nature of Poland's broadband mapping efforts, integrating various aspects of digital infrastructure development.

Poland's mobile networks mapping includes parameters specified in the Regulation of the Minister of Digital Affairs, covering antenna location, cell characteristics, and band/channel parameters. The draft methodology for 4G/5G network throughput measurements outlines parameters, criteria, conditions, and estimation methodologies to assess network capacity. The comprehensive approach to data collection and analysis reflects a meticulous approach to network analysis.

Broadband coverage visualization in Poland incorporates various datasets, such as information about foreign entities, nodes, flexibility points, routes of cable lines, base stations, wireless lines, mobile network range, services at address points, and buildings enabling colocation. Visualization tools like PIT address challenges related to infrastructure ownership and cable line routes, enhancing the understanding of the broadband landscape. Continuous regulatory improvements and reporting mechanisms, along with the development of new tools, contribute to the ongoing enhancement of broadband coverage visualization in Poland. The Gigabit Infrastructure Act aligns with the broader goal of improving gigabit connectivity across the EU. Visualization tools play a crucial role in tracking progress toward this goal.

Michał Chojnowski, Ph.D., from the Office of the President of the Office of Electronic Communications, provided a comprehensive overview of Poland's approach to broadband infrastructure and services mapping. His presentation focused on the legal framework, particularly highlighting the Polish Act on Supporting the Development of Telecommunications Services and Networks, the Telecommunications Law, and alignment with EU directives such as the Broadband Cost Reduction Directive. Recent developments like the Gigabit Infrastructure Act demonstrate Poland's commitment to achieving widespread Gigabit connectivity by 2030, in line with broader EU objectives.

A key element of Poland's strategy is the Single Information Point (PIT), a central platform designed for effective data management, analysis, and reporting. PIT serves as a repository for data related to telecommunications infrastructure, services, colocation buildings, and infrastructure ownership. The system's capability to handle various data formats and provide advanced search and reporting functions underscores its significance in Poland's broadband mapping ecosystem. The complementary systems and services, such as SIMBA, SIDUSIS, and MapBook, further enhance the scope of broadband mapping by offering functionalities ranging from internet coverage checks and project management to detailed data analysis.

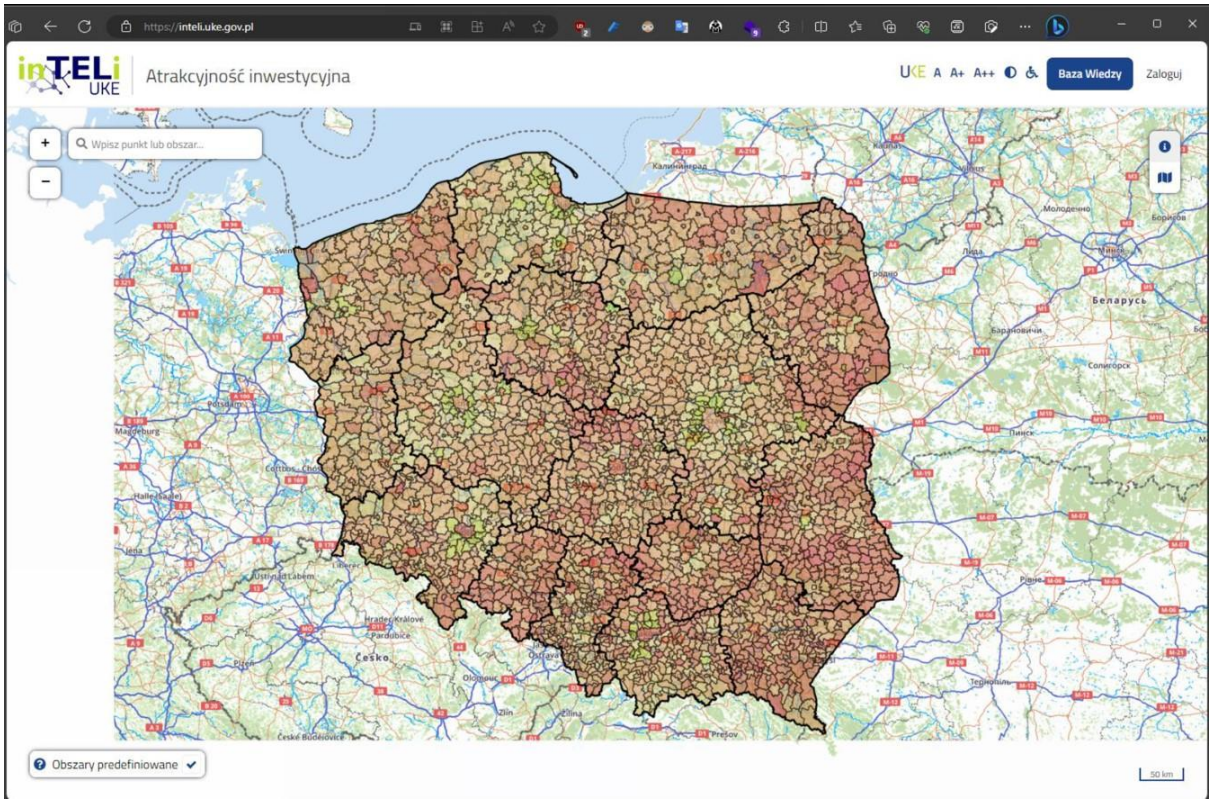


Figure 5. Thanks to mature registration systems operating in Poland, UKE provides map services presenting derivative

The mobile networks inventory parameters focus on capturing comprehensive data on base station cells, including antenna location, cell characteristics, and emission parameters. The methodology for 4G/5G network throughput measurements, emphasizing a detailed reference grid, measurement locations, and both passive and active measurements, reflects a meticulous approach to network analysis. The presentation of results, with detailed data tables, device specifications, and geographical coordinates, illustrates the thoroughness of Poland's approach to data collection and analysis. The methodology for throughput measurements, used to analyze area and communication route coverage, provides a robust framework for understanding and improving network performance.

In summary, Michał Chojnowski's presentation effectively conveyed the complexity and sophistication of Poland's broadband infrastructure and services mapping efforts. The combination of a strong legal framework, advanced data platforms like PIT, and comprehensive measurement methodologies positions Poland as a leading example in broadband mapping and network analysis. This approach serves Poland's immediate digital infrastructure needs and contributes to broader objectives of digital connectivity and development within the European Union.

Summary table for Poland

Aspect	Details
Legal Framework	Polish Act on Supporting the Development of Telecommunications Services and Networks, Polish Telecommunications Law, Directive 2014/61/EU, Gigabit Infrastructure Act
Responsible Entities	President of UKE (Office of Electronic Communications)
System Name	Single Information Point (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

6. Case study 4: Armenia

Armenia has been actively working on implementing broadband mapping systems to enhance the visibility and accessibility of high-speed internet services across the country. These systems play a crucial role in informing policy decisions, bridging the digital divide, and improving overall connectivity.

The legal framework governing broadband mapping in Armenia is primarily overseen by the Electronic Communications Law and related regulations. The Regulatory Authority for Electronic Communication and Postal Services (ERCB) ensures the effective deployment of broadband infrastructure. These legal provisions emphasize the importance of accurate broadband mapping to facilitate informed decision-making and bridge the digital divide.

The broadband mapping system in Armenia employs a comprehensive architecture to collect and analyze data. Key components include GIS (Geographic Information System) technology, data from internet service providers (ISPs), and user-generated data. GIS technology spatially represents broadband infrastructure, allowing for detailed analysis and planning. Data from ISPs includes network coverage, technology used, and service speeds. Additionally, user-generated data, collected through surveys and feedback mechanisms, provides valuable insights into the end-user experience.

Broadband coverage visualization is a crucial aspect of the mapping system, providing stakeholders with a clear depiction of connectivity across Armenia. Interactive maps highlight areas with varying degrees of broadband availability, encompassing different technologies such as DSL, cable, fiber-optic, and wireless. This visualization helps policymakers, businesses, and the general public assess the quality and extent of broadband services in different regions.

Despite progress, challenges persist in Armenia's broadband mapping landscape. Ensuring data accuracy, especially from ISPs, remains a challenge, as discrepancies between reported coverage and actual service quality may impact broadband maps' effectiveness. The rapid evolution of broadband technologies also poses a challenge in keeping maps updated. Limited financial resources and challenging terrain in certain regions hinder broadband infrastructure deployment, affecting mapping accuracy and service availability.

To address these challenges and enhance broadband mapping in Armenia, several steps are recommended. Implementing stringent data validation mechanisms can ensure accuracy and reliability. Fostering collaboration between the government, private sector, and local communities can address funding challenges and expedite infrastructure deployment. Establishing a framework for regular updates to the broadband mapping system can incorporate new technologies and developments promptly. Conducting awareness campaigns can educate the public on the importance of contributing to user-generated data, fostering community involvement in improving broadband services. Periodic policy reviews and updates can align regulatory frameworks with technological advancements and evolving connectivity needs.

Armenia's commitment to broadband mapping demonstrates a dedication to fostering digital inclusion. By addressing challenges and implementing future-focused strategies, Armenia can continue to improve broadband coverage, ensuring equitable access to high-speed internet services across the country.

Zaruhi Stepanyan, Head of the International Cooperation Division at the Public Services Regulatory Commission (PSRC) of Armenia and Co-Chair of IRB EWG (EaPeReg), presented the state of broadband infrastructure in Armenia. Established in 2012, the Eastern Partnership Electronic Communications Regulators Network (EaPeReg) collaborates with Eastern Partnership (EaP) and EU countries on various aspects of electronic communications.

The EU4DIGITAL initiative has provided significant technical assistance, contributing to broadband strategies, gap analysis, and mapping recommendations. This initiative has greatly influenced Armenia's strategic planning and implementation of broadband strategies.

Armenia has been actively regulating the telecommunications sector since 2006 under the RA Law on Electronic Communications, with the Public Services Regulatory Commission overseeing its implementation. Significant strides have been made in mobile network coverage, progressing from limited coverage in 2006 to 100% public mobile network coverage with widespread 3G and 4G+(LTEA) technologies. Strategic actions, such as the entry of a third operator in 2008 and radio frequency band auctions, have played key roles in extending network coverage, including the introduction of LTE ADVANCE/4G+ technology and plans for 5G. The fixed network coverage in Armenia has also seen remarkable development. From more than 200 settlements lacking fixed telephony access in 2006, today all settlements are covered with fixed telephony networks and broadband internet services, utilizing both wired and wireless technologies. This expansion is attributed to competitive development, the construction of fiber optic backbone networks by major operators, and the entry of new communication operators in regions.

Actions aimed at developing fixed network coverage have included fulfilling license obligations for incumbent operators and major telecom companies. These efforts have led to a significant increase in the capacity of fixed (wired) broadband internet and the number of broadband subscribers.

In summary, Ms Zaruhi Stepanyan's presentation highlighted Armenia's comprehensive and strategic approach to developing its broadband infrastructure and services. Through regulatory reforms, strategic partnerships, and targeted actions, Armenia has achieved significant coverage in both mobile and fixed networks, 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 (Regulatory Authority for Electronic Communication and Postal Services)
Responsible Entities	Public Services Regulatory Commission (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	Geographic Information System (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

7. Case study 5: Italy

The evolution of mapping, from ancient clay tablets to modern Geographic Information Systems (GIS), reflects humanity's ceaseless pursuit of understanding and navigating its surroundings. Contemporary societies, including Italy, recognize the crucial role of advanced mapping systems in shaping their digital landscapes. This report delves into the realm of broadband mapping in Italy, exploring the legal foundations, the intricacies of the mapping system architecture, data sources, broadband coverage visualization, existing challenges, and the strategic steps envisioned for the future. As Italy endeavors to bridge the digital divide and enhance connectivity, an exploration of its broadband mapping initiatives becomes imperative, drawing parallels between the historical quest for knowledge and the contemporary pursuit of a digitally inclusive society.

Italy has established a comprehensive legal framework to regulate broadband mapping, aligning with the nation's commitment to improving digital infrastructure. The Italian Communications Code and regulatory oversight by the Communications Regulatory Authority (AGCOM) form the basis for the legal landscape. These regulations outline the obligations of Internet Service Providers (ISPs) in reporting accurate and up-to-date information for broadband mapping purposes. AGCOM plays a crucial role in

enforcing compliance and ensuring that mapping initiatives contribute to the overall goal of enhancing digital connectivity.

Italy's broadband mapping system is built on a sophisticated architecture that leverages modern Geographic Information System (GIS) technology. The GIS allows for the spatial representation of broadband infrastructure, enabling detailed analysis and planning. Data sources include contributions from ISPs, detailing network coverage, technology types, and service speeds. Additionally, user-generated data, obtained through surveys and feedback mechanisms, provides valuable insights into the real-world experience of broadband users. This multi-faceted approach ensures a comprehensive and accurate depiction of broadband coverage.

Interactive maps are a key feature of Italy's broadband mapping system, providing stakeholders with a visual representation of broadband coverage across different regions. These maps showcase varying degrees of connectivity and include different broadband technologies such as DSL, cable, fiber-optic, and wireless. This visualization not only aids policymakers but also serves as a transparent tool for the public to assess the quality and availability of broadband services in specific areas.

While Italy has made significant progress in broadband mapping, certain challenges persist. Ensuring the accuracy of data reported by ISPs remains a challenge, and efforts are ongoing to implement mechanisms for rigorous data validation. The dynamic nature of broadband technologies requires continuous updates to the mapping system to reflect new infrastructure developments and technology upgrades. Italy's diverse geography poses challenges to broadband infrastructure deployment in certain regions, impacting mapping accuracy and service availability.

To address these challenges and further enhance broadband mapping in Italy, the following steps are recommended: implementing more robust mechanisms for data validation to ensure that reported information accurately reflects the current state of broadband infrastructure; establishing a framework for regular updates to the broadband mapping system, incorporating new technologies and infrastructure developments promptly; encouraging public participation in user-generated data through awareness campaigns and engagement initiatives, fostering a sense of community involvement in improving broadband services; strengthening collaboration between government entities, the private sector, and local communities to address funding challenges and expedite broadband infrastructure deployment; and periodically reviewing and updating regulatory frameworks to align with technological advancements and evolving connectivity needs, ensuring that the legal background remains conducive to effective broadband mapping.

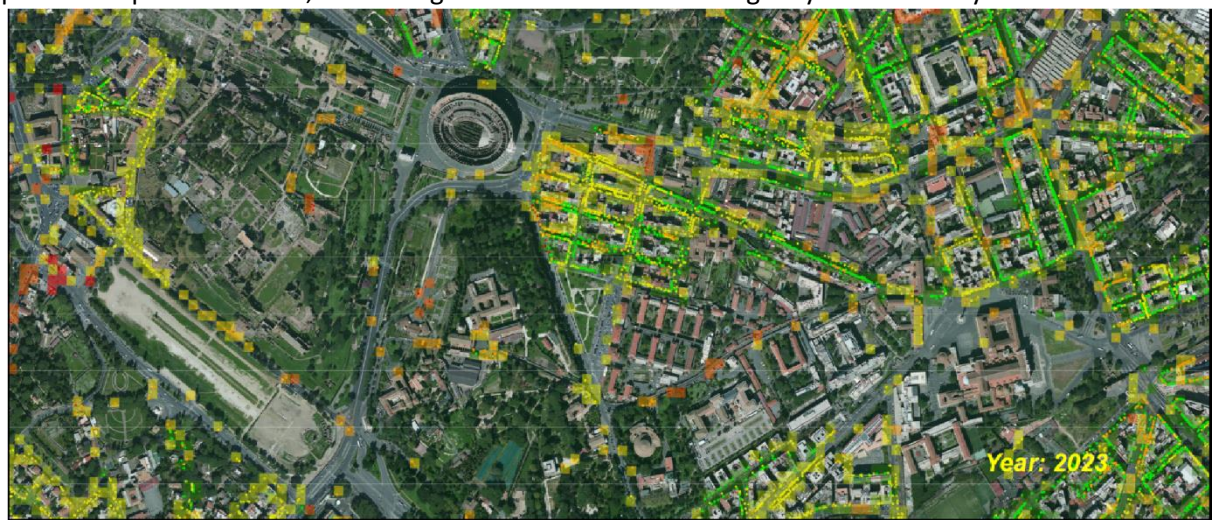
Italy's broadband mapping efforts are integral to the nation's digital development. Addressing challenges while implementing future-focused strategies will further contribute to equitable access to high-speed internet services across the country. The broadband mapping initiative in Italy, as delineated by Agcom's BBmap, is a methodical endeavor aimed at providing a granular view of the country's broadband infrastructure. The mapping objectives are clear-cut: to furnish end-users with detailed information about the broadband services' technical framework and to supply authorities with dependable indicators for infrastructure availability. These indicators are critical for appraising the distribution and scope of broadband services throughout the nation.

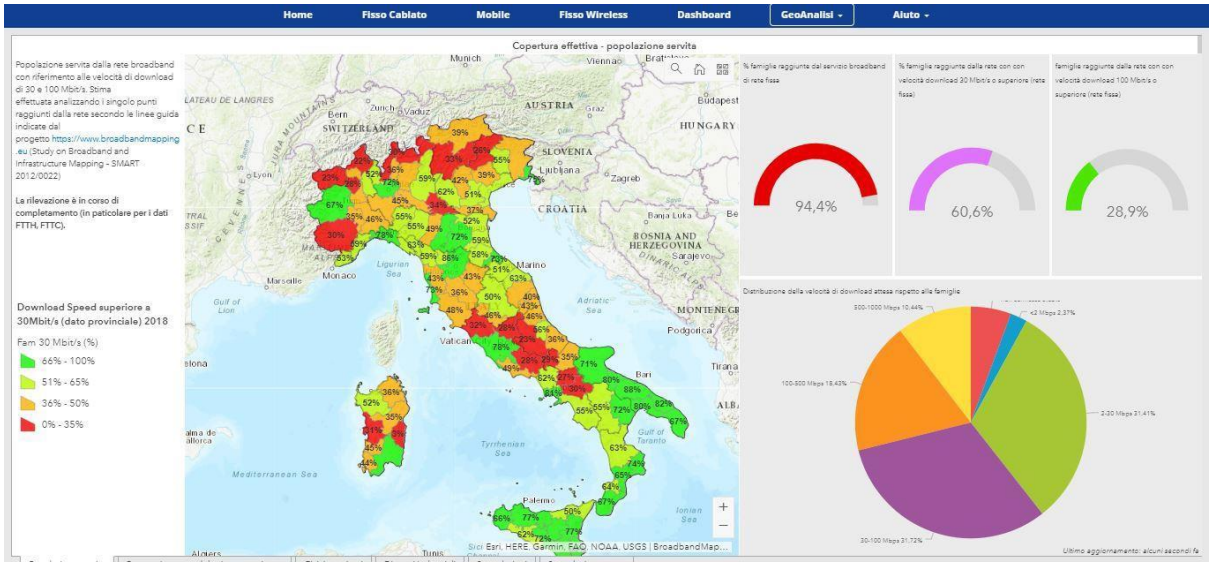
Agcom's BBmap brings to light the spatial variability inherent in Italy's fixed network, a feature that necessitates the utilization of high-resolution GIS analysis. This technical approach ensures that the actual state of local connectivity is accurately reflected, regardless of its unpredictability. The mapping process goes beyond simple connectivity outlines; it delves into the specifics of speed and technology deployment across different regions. To achieve these objectives, BBmap harnesses a spectrum of

data, ranging from user distribution to the technical capabilities of infrastructure. The emphasis on data resolution and frequency of GIS analysis is paramount, as it influences the accuracy of the mapping outcome. For stakeholders, the map is more than a visual aid—it is a repository of data that drives strategic planning and policy-making.

The utility of BBmap in Italy extends across various sectors. It is a resource for telecommunications companies to benchmark their services against national coverage goals and for government bodies to pinpoint areas needing infrastructural investment. The dashboard feature of BBmap stands out as a crucial component for tracking the progress of national broadband plans. It reports on the advancements made towards achieving the European Digital Agenda's targets and assists in formulating incentive policies tailored to specific regional needs.

The technical data provided by BBmap is instrumental in fostering an environment where end-users are well-informed about their connectivity options. For policy-makers, the map serves as a foundational element in the digital strategy, enabling a focused and informed approach to bridging digital divides and enhancing connectivity. Italy's approach to broadband mapping through the BBmap is characterized by its technical rigor and comprehensive data utilization. It underscores the importance of high-resolution mapping and GIS analysis in understanding and enhancing the nation's broadband infrastructure. The initiative is an essential step towards informed decision-making in both public and private sectors, facilitating a more connected and digitally inclusive Italy.





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

Summary table for Italy

Aspect	Details
Legal Framework	Italian Communications Code, regulatory oversight by AGCOM
Responsible Entities	AGCOM (Autorità di Regolazione per le Comunicazioni)
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

8. Case study 6: Latvia

In the rapidly advancing realm of digital connectivity, enhancing and comprehending broadband infrastructure is paramount. Latvia's significant efforts in broadband mapping serve as a cornerstone for its digital transformation, impacting both local and national levels. This comprehensive case study, presented by Rinalds Ritmanis, Head of the Radio Frequency Planning Division at the Electronic Communications Office of Latvia, details Latvia's progress and experiences shared during the Second ITU-EMERG-EaPeReg Joint Workshop on Strengthening Broadband Infrastructure and Services.

Latvia's broadband mapping initiative, encapsulated in the Broadband Availability Geographical Information System (PPĢIS), unfolds against the backdrop of European directives and national legislation. This report navigates through the legal landscape, the intricate architecture of the mapping system, the diverse data sources that fuel it, and the visualizations that bring broadband coverage to life. Alongside the successes, we delve into the challenges faced and articulate strategic future steps to propel Latvia toward a more connected and digitally inclusive future. As we embark on this exploration, we recognize Latvia's commitment to not only meet European connectivity targets but also to lay the foundation for a digital landscape where broadband availability is not just a technological achievement but a catalyst for societal advancement.

Directive (EU) 2018/1972 establishes the European Electronic Communications Code, guiding Latvia's legal framework for broadband mapping. The Electronic Communications Act of Latvia empowers the Ministry of Transport to create a geographical information system (GIS) for broadband availability. Article 22 of the European Electronic Communications Code mandates regulators, including Latvia's Public Utilities Commission (PUC), to conduct a survey of electronic communications networks by the end of 2023. This legal framework ensures that broadband mapping efforts are aligned with national goals and international best practices, providing a structured approach to digital development.

Latvia's broadband mapping system is constructed with sophisticated Geographic Information System (GIS) technology, which plays a pivotal role in visualizing broadband coverage, enabling detailed

analysis and planning. The system integrates data from multiple sources, including internet service providers (ISPs), government agencies, and user-generated inputs. ISPs contribute critical information on network coverage, technology types, and service speeds. This data is complemented by user-generated feedback collected through surveys and other participatory mechanisms, providing a comprehensive view of broadband availability and performance.

Interactive maps are central to Latvia's broadband mapping efforts. These maps offer a visual representation of broadband coverage across different regions, showcasing the extent and quality of internet services. They highlight various broadband technologies such as DSL, cable, fiber-optic, and wireless, enabling stakeholders to assess the state of digital connectivity accurately. This visualization aids policymakers in identifying areas that require intervention and helps the public understand the availability of broadband services in their locality.

Despite significant advancements, Latvia faces several challenges in its broadband mapping initiatives. Ensuring the accuracy of data reported by ISPs is a persistent issue, as discrepancies between reported and actual service quality can affect the reliability of the maps. The rapidly evolving nature of broadband technologies necessitates continuous updates to the mapping system to reflect new developments and infrastructure upgrades. Additionally, Latvia's diverse geography presents challenges in deploying broadband infrastructure in certain regions, impacting mapping accuracy and service availability.

To address these challenges and further enhance broadband mapping in Latvia, several strategic steps are recommended. Implementing robust data validation mechanisms will ensure that the information provided by ISPs is accurate and reliable. Establishing a framework for regular updates to the mapping system will help incorporate new technologies and infrastructure developments promptly. Encouraging public participation through awareness campaigns and engagement initiatives can foster a community-driven approach to improving broadband services. Strengthening collaboration between government entities, the private sector, and local communities is essential for addressing funding challenges and accelerating infrastructure deployment. Periodically reviewing and updating the regulatory framework will ensure that it remains conducive to effective broadband mapping and aligns with technological advancements and evolving connectivity needs.

Latvia's broadband mapping efforts are crucial to the nation's digital development. By addressing current challenges and implementing future-focused strategies, Latvia can ensure equitable access to high-speed internet services for all its citizens. The broadband mapping initiative in Latvia is characterized by its technical rigor and comprehensive data utilization. It underscores the importance of high-resolution mapping and GIS analysis in understanding and enhancing the nation's broadband infrastructure. This initiative is an essential step towards informed decision-making in both public and private sectors, facilitating a more connected and digitally inclusive Latvia.

Latvia's broadband mapping system, known as PPĢIS (Broadband Availability Geographical Information System), relies on a structured architecture. Logical components include public access for viewing, restricted access for analytics, and data input for information submission. Data sources encompass consultations with mobile and fixed operators, state authorities, and adherence to BEREC Guidelines. The GIS integrates data from multiple providers, ensuring a comprehensive representation of broadband availability.

PPĢIS provides various views for public and restricted access. Public access includes a broad overview of broadband availability, while restricted access offers detailed analytics, reports, and data views. The visualization component includes maps displaying best coverage, mobile technologies (3G, 4G, 5G),

fixed technologies (xDSL, coaxial, optics), and filters for specific broadband data. These visualizations enable policymakers and the public to assess the quality and availability of broadband services.

Latvia's broadband mapping initiative faces several challenges: The lack of vector format data and insufficiently accurate information, including addresses and coordinates, pose challenges to accurate mapping. Harmonizing data from different sources and dealing with various formats create challenges in maintaining a standardized and coherent dataset. Establishing automated processes for data gathering is essential for efficiency, but it presents technical challenges.

To overcome challenges and further enhance broadband mapping in Latvia, the following steps are recommended: Implement automated processes for data gathering to streamline the collection of accurate and up-to-date information. Address challenges related to data accuracy by implementing stringent validation mechanisms and ensuring the completeness of information. Strengthen collaboration with data providers, including telecom operators and state authorities, to improve the accuracy and reliability of data. Conduct awareness campaigns to educate the public on the importance of providing accurate data for broadband mapping, fostering community involvement. Regularly update the mapping system to incorporate new technologies and infrastructure developments, ensuring it remains aligned with evolving connectivity needs.

In conclusion, Latvia's broadband mapping initiative demonstrates a commitment to digital transformation, and addressing challenges while implementing future-focused strategies will contribute to achieving European connectivity goals and bridging the digital divide.

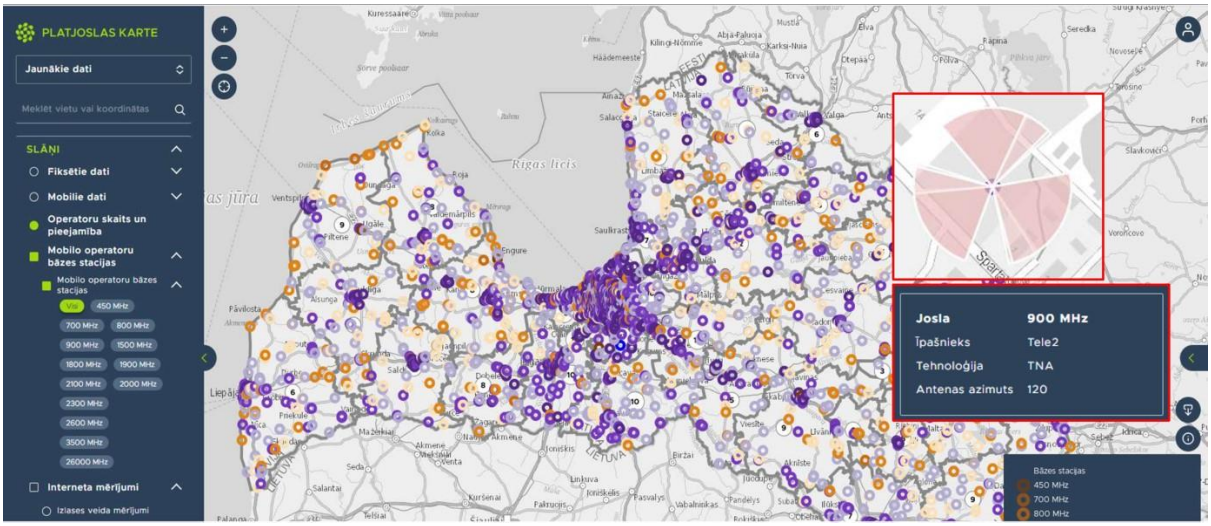


Figure 8. Example analysis and visualisation of mobile networks stations and their parameters in Latvia.

Summary table for Latvia

Aspect	Details
Legal Framework	EU Directive 2018/1972, Electronic Communications Act of Latvia
Responsible Entities	Ministry of Transport, Electronic Communications Office, Public Utilities Commission (PUC)
System Name	Broadband Availability Geographical Information System (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

9. Case study 7: France

In the rapidly evolving landscape of digital connectivity, France stands at the forefront of innovation and strategic planning. This chapter delves into the comprehensive broadband mapping initiative undertaken by ARCEP (Autorité de Régulation des Communications Électroniques et des Postes) in November 2023. As a testament to France's commitment to digital transformation, this initiative navigates the complex interplay of legal frameworks, cutting-edge mapping system architecture, and data-driven visualizations.

France's ambitious targets include achieving full broadband coverage by the end of 2022, establishing Fiber to the Home (FttH) as the primary technology by 2025, and phasing out the historical copper network by 2030. The initiative takes a user-oriented data approach, emphasizing premises eligibility over infrastructure specifics, ensuring that the broadband mapping system serves practical needs.

The broadband mapping system leverages advanced architecture, integrating interactive and statistical maps to provide a granular view of broadband coverage. Employing Extract, Transform, Load (ETL) operations with tools like Airflow and PostGIS, the system ensures accuracy and reliability. Data sources include contributions from internet service providers (ISPs), administrative borders, premises details, and addresses, creating a comprehensive and accurate depiction of broadband availability.

Visualizing broadband coverage through maconnexioninternet.fr brings data to life. The interactive map at the address level empowers users with information about service providers, eligible technologies, and theoretical internet speeds. Additionally, aggregated statistics by administrative strata facilitate informed decision-making for local authorities, contributing to their digital strategies. These visualization tools underscore the system's user-centric design, offering a visual representation of the best-available services across the country.

Despite its successes, the initiative faces challenges. Ensuring data reliability over time, automating manual processes, and balancing mapping performance with storage use are key considerations. Addressing these challenges involves implementing automated data gathering processes, enhancing data validation mechanisms, fostering collaboration with data providers, conducting public awareness campaigns, and regularly updating the mapping system to incorporate new technologies and infrastructure developments. These strategic steps reflect a proactive stance in ensuring continued leadership in digital connectivity.

France's broadband mapping initiative operates within a robust legal framework, reflecting the nation's commitment to digital connectivity. The key elements include achieving full broadband coverage by the end of 2022, establishing Fiber to the Home (FttH) as the primary broadband technology by 2025, and phasing out the historical copper network by 2030. This approach aligns with broader European connectivity goals, adopting a user-oriented data approach that focuses on premises eligibility rather than infrastructure specifics.

The system integrates interactive and statistical maps to provide detailed information at both the address and administrative levels. Data processing involves sophisticated ETL operations to ensure accuracy and reliability, integrating various data sources such as operator data, administrative borders, premises details, and addresses. This multi-faceted approach allows for a holistic view of broadband availability across the country.

The interactive service at www.maconnexioninternet.fr visualizes broadband coverage in several ways. It includes a speed map at the address level, which allows users to view eligibility details, available internet service providers, eligible technologies, and theoretical maximum internet speeds.
Additionally, aggregated coverage rates displayed by administrative strata aid local authorities in making informed decisions about their digital strategies. This level of granularity is critical in empowering users to make informed decisions and stimulates a competitive market environment conducive to innovation and growth.

ARCEP identifies several challenges in its broadband mapping initiative. Ensuring data reliability amid technological evolutions and automating manual processes for enhanced efficiency are ongoing issues. Addressing these challenges involves implementing automated data gathering processes, enhancing data validation mechanisms, fostering collaboration with data providers, conducting public awareness campaigns, and regularly updating the mapping system to incorporate new technologies and infrastructure developments. These strategic steps demonstrate a proactive stance in ensuring continued leadership in digital connectivity.

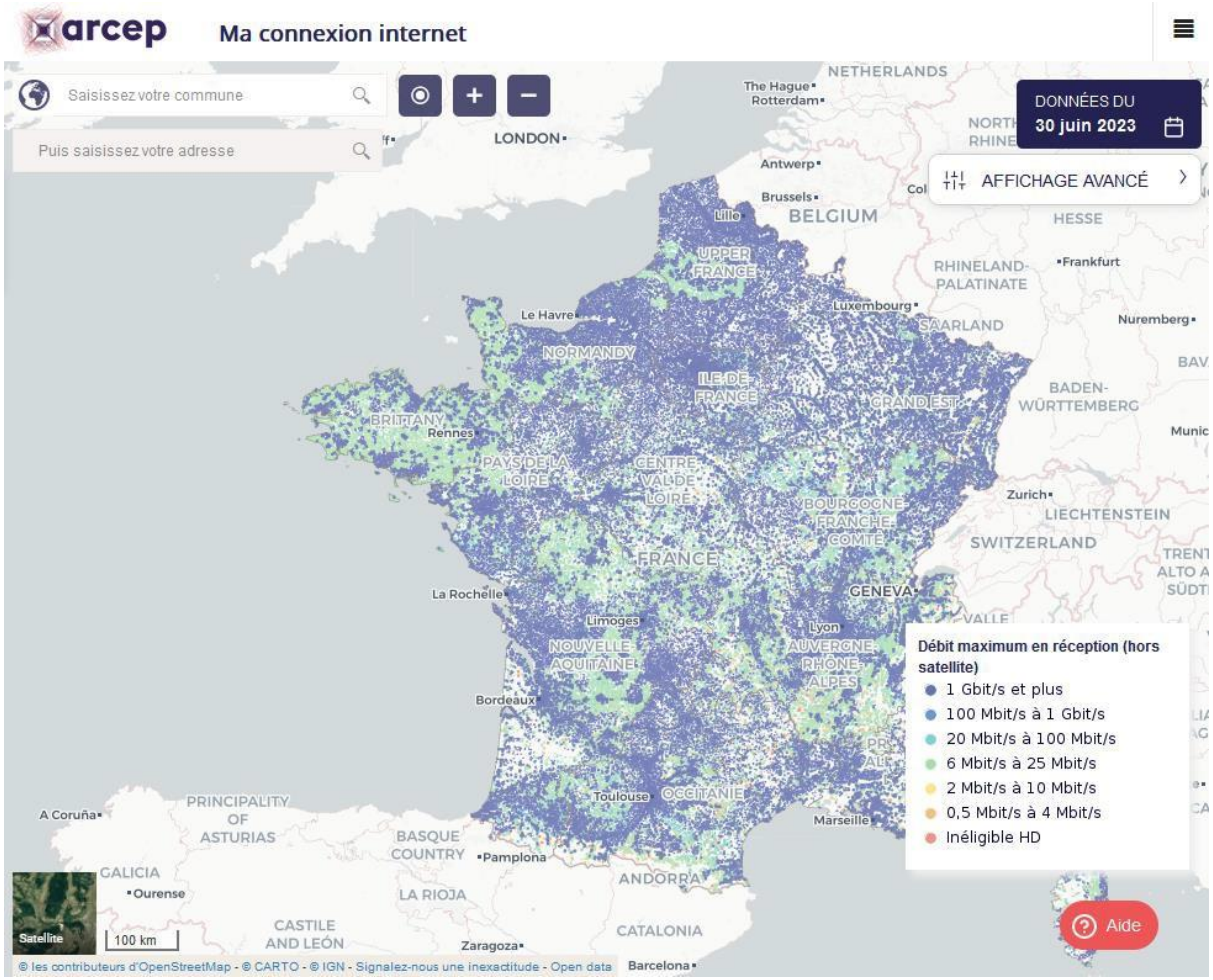


Figure 9. Example view of Arcep interactive service visualising available throughput.

The broadband mapping initiative in France signifies a pioneering approach to digital transformation. The legal framework, system architecture, and visualization tools underscore a commitment to transparency and accessibility. While challenges are acknowledged, the strategic steps outlined for the future demonstrate a proactive stance in addressing them, ensuring that France continues to lead in the digital connectivity landscape. ARCEP's organizational setup, equipped with data analysts and the necessary technical infrastructure, exemplifies an institution ready to harness the potential of data to steer market dynamics and regulatory practices. France's broadband mapping system is a testament to the power of data-driven decision-making, reflecting a thoughtful and comprehensive approach to addressing both present connectivity needs and future infrastructure developments. By empowering users with detailed information and providing a platform for market actors to contribute to the dialogue, France's broadband mapping initiative stands as a model for effective digital infrastructure planning and regulation.

In conclusion, France's broadband mapping initiative exemplifies a sophisticated and user-centric approach to digital connectivity. The robust legal framework, comprehensive system architecture, and detailed visualizations reflect a commitment to transparency and accessibility. By addressing challenges through strategic future steps, France is well-positioned to continue its leadership in the digital connectivity landscape. Presentation of the case study of France:

Summary table for France:

Aspect	Details
Legal Framework	EU Directive 2018/1972, Electronic Communications Act of France, national targets for full broadband coverage by 2022, FttH by 2025, and copper phase-out by 2030
Responsible Entities	ARCEP (Autorité de Régulation des Communications Électroniques et des Postes)
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

10. Case study 8: Georgia

In Georgia, broadband mapping initiatives are shaped by a combination of federal regulations and state legislation. At the federal level, the Broadband DATA Act (Digital Opportunity Data Collection) enacted in 2020 mandates the Federal Communications Commission (FCC) to improve broadband mapping accuracy by establishing new data collection requirements. Additionally, Georgia's state laws provide supplementary guidelines or requirements for broadband mapping efforts, ensuring alignment with local priorities and objectives.

The telecommunications industry in Georgia has witnessed significant growth and innovation in recent years. With a population of over 3.7 million people, the telecom market is dynamic and competitive, characterized by a diverse range of services and providers. The telecom sector has experienced steady growth, driven by advancements in mobile, fixed broadband, and IPTV services. Revenue from telecommunications has been on the rise, with significant contributions from mobile communications, fixed broadband, and other related services.

Historically, the Georgian National Communications Commission (ComCom) has utilized digital mapping systems for various purposes, including regulatory compliance, infrastructure planning, and public service delivery. These legacy systems have served as foundational elements in the development of more advanced broadband mapping initiatives. Beyond telecommunications, Georgia has undertaken various geographic information system (GIS) projects aimed at enhancing spatial data management, urban planning, and environmental monitoring. These projects have contributed to the evolution of GIS capabilities and expertise within the country.

ComCom's journey towards developing a comprehensive broadband mapping system dates back to the country's commitment to the European Union Association Agreement. Legislative efforts, such as the

Infrastructure Sharing Law and Universal Service Regulation, have laid the groundwork for broadband mapping initiatives, emphasizing the importance of data transparency and infrastructure sharing.

Broadband mapping systems in Georgia typically comprise a multi-tiered architecture involving data collection, aggregation, and visualization components. Data sources commonly include FCC Form 477 data, Georgia Broadband Deployment Initiative (GBDI) data, geospatial data, and crowdsourced data. The mapping systems integrate these diverse datasets using Geographic Information System (GIS) technologies and spatial analysis techniques to create comprehensive representations of broadband coverage and availability across Georgia.

As of November 2023, Georgia is in the process of establishing a robust broadband mapping system to meet regulatory requirements and facilitate informed decision-making. Key developments include the adoption of the Infrastructure Sharing Law by parliament in June 2023, paving the way for the creation of a Single Information Point (SIP) to centralize broadband infrastructure data. ComCom aims to develop a Universal GIS Platform capable of integrating various data layers, including passive and active infrastructure, broadband service coverage, and additional datasets from ComCom and public registries.

Collaboration with international partners, including the World Bank's "Log-In Georgia" program, supports the outsourcing of development and ensures alignment with global best practices and standards. However, challenges such as identifying experienced GIS developers, collecting quality data from telecom operators and other entities, and fostering cooperation from other state agencies providing relevant data persist.

Visualization plays a crucial role in conveying broadband coverage information to stakeholders and the general public. Common visualization techniques include choropleth maps, heatmaps, and interactive web maps. These visualization tools are designed to be user-friendly and accessible, facilitating data-driven decision-making and public engagement in broadband infrastructure planning and development efforts.

Despite significant progress, broadband mapping initiatives in Georgia face several challenges. Ensuring the accuracy and reliability of broadband coverage data remains a persistent challenge, particularly in rural and underserved areas where reporting discrepancies and data gaps are more prevalent. Securing adequate funding and resources for ongoing data collection, system maintenance, and infrastructure investments is essential for sustaining broadband mapping efforts in the long term. Enhancing collaboration among government agencies, ISPs, community organizations, and other stakeholders is critical for improving data sharing, coordination, and decision-making processes.

To address these challenges and advance broadband mapping efforts in Georgia, several future steps are recommended. Implementing robust data validation mechanisms, including field surveys and independent audits, to verify broadband coverage data accuracy and completeness is essential. Fostering greater collaboration between public and private sector entities to leverage complementary resources, expertise, and networks for expanding broadband infrastructure and improving data quality is also crucial. Empowering local communities through education, outreach, and participatory mapping initiatives to collect firsthand data and advocate for equitable broadband access and investment will further enhance the effectiveness of broadband mapping efforts.

By addressing these challenges and embracing collaborative, data-driven approaches, Georgia can strengthen its broadband mapping systems and accelerate efforts to bridge the digital divide, ensuring that all residents have access to reliable, high-speed internet connectivity.

Presentation of the case study of Georgia:

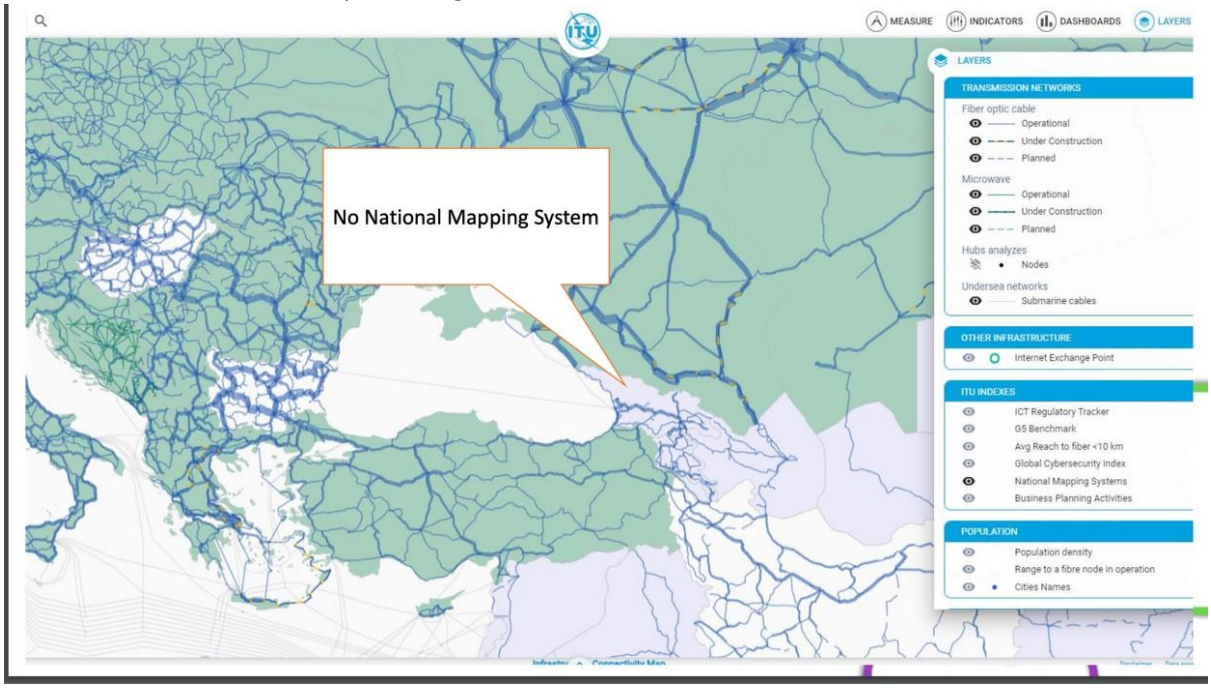


Figure 10. Slide from COMCOM's presentation displaying Georgia on the ITU Broadband Map

Summary table for Georgia:

Aspect	Details
Legal Framework	Broadband DATA Act (2020), Infrastructure Sharing Law (2023), Universal Service Regulation
Responsible Entities	Federal Communications Commission (FCC), Georgian National Communications Commission (ComCom)
System Name	Universal GIS Platform (under development)
Main objectives	Centralize broadband data, publicize broadband availability, identify unserved areas, comply with EU Association Agreement
Data Sources	FCC Form 477 Data, Georgia Broadband Deployment Initiative (GBDI), 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	Automated data gathering, enhanced data validation, public-private partnerships, community engagement, regular system updates

11. Case study 9: Portugal

Portugal has established a comprehensive legal framework to ensure the development and implementation of broadband mapping systems. This framework includes the National Broadband Plan, which promotes the deployment of high-speed internet infrastructure throughout the country and aligns with European Union directives such as the Digital Agenda and the European Electronic Communications Code. The Portuguese Regulatory Authority for Communications (ANACOM) plays a central role in regulating the telecommunications sector, including broadband services, and sets requirements for broadband providers to report coverage data.

Article 22 of the European Electronic Communications Code (EECC) establishes requirements for member states to develop broadband mapping systems to assess coverage and availability of broadband services. Portugal complies with these regulations through Decree-Law nr 40/2022, which implements an information platform for citizens, companies, and government entities to access broadband coverage data. The BEREC (Body of European Regulators for Electronic Communications) Guidelines provide further guidance to National Regulatory Authorities (NRAs) like ANACOM on the consistent application of geographical surveys of network deployments to ensure accurate and standardized broadband mapping.

Portugal's broadband mapping system collects data on fixed and mobile broadband coverage, including technologies used, network properties, and speed metrics, at the address level. This comprehensive system covers various network types, including fixed networks (broadband, voice, and narrowband), mobile networks (broadband, voice, SMS, and MMS), transport and access networks, submarine cables, and satellite coverage. To ensure granularity and accuracy, the system utilizes a unique address database provided by the National Statistical Office (INE), which includes geographical coordinates for approximately 3.5 million residential buildings and is regularly updated. ANACOM collaborates with operators to match their data with the INE database, requiring operators to provide detailed information on network coverage for each building, including technology, network ownership, and speed metrics. Geoprocessing techniques and GIS tools are employed to effectively integrate data from different sources.

The broadband mapping system relies on a robust architecture, integrating data from various sources to provide comprehensive coverage information. Data collection mechanisms involve gathering broadband coverage data from multiple sources, including internet service providers (ISPs), government agencies, and crowdsourcing platforms. ISPs report coverage data to regulatory authorities, while government agencies contribute data on public broadband initiatives and infrastructure projects. Geospatial analysis tools are utilized to process and visualize broadband coverage data, with GIS technology playing a crucial role in mapping broadband availability, speeds, and technology types across different regions of Portugal. Crowdsourcing platforms enable citizens to report their broadband experiences and contribute data on coverage quality and service availability, enhancing the accuracy and granularity of broadband mapping efforts. Data from various sources are integrated into a centralized database and visualized through interactive maps and dashboards, enabling policymakers, regulators, and stakeholders to assess broadband coverage gaps and prioritize investment decisions.

The broadband mapping system provides users with intuitive visualization tools to assess broadband coverage and performance metrics. Interactive maps allow users to explore broadband coverage at different geographic scales, from national-level overview maps to detailed regional maps. Users can zoom in on specific areas and view detailed information on broadband availability, speeds, and

technologies. Color-coded layers indicate different levels of service availability and performance, enabling users to easily distinguish between areas with high-speed broadband access, underserved areas, and areas with limited or no coverage. Performance metrics such as download/upload speeds, latency, and reliability indicators help users assess the quality of broadband service in different locations and identify areas in need of improvement.

Despite significant progress, challenges in mapping fixed broadband coverage include the unavailability of data from all operators, inconsistencies in address databases, and difficulties in matching operator data with the INE database. To address these challenges, ANACOM has developed solutions such as utilizing a georeferenced database of buildings provided by INE, ensuring accurate georeferencing within building perimeters, and employing geoprocessing techniques for data integration. The use of a unique ID per building and standardized data formats for network coverage information facilitates data sharing and interoperability among stakeholders. ANACOM's collaboration with INE and operators ensures that the mapping system remains up-to-date and provides accurate information on broadband coverage across Portugal.

The Portuguese broadband mapping initiative represents a critical step towards the European Union's vision for a gigabit society by 2025. The country's commitment to this vision is enshrined in its adherence to the European Electronic Communications Code, specifically Article 22, and further cemented by the enactment of Decree-Law nr 40/2022. This decree has established a multifaceted platform designed to disseminate comprehensive information on broadband and mobile network coverage across Portugal. The granular approach adopted for mapping is evident in the focus on premises passed, considering both the maximum achievable speeds and the expected speeds during peak times. This dual-speed metric is pivotal, providing a realistic portrayal of service levels that end-users can expect, thereby enhancing transparency and consumer trust.

Despite its ambitious goals, the mapping project is not without challenges. A significant hurdle is the lack of universally available data across all operators and the absence of a unified address database. This has led to difficulties in harmonizing data from different operators, each with their unique database structures and address nomenclatures. To address these challenges, Portugal has sought collaboration with the National Statistical Office (INE), tapping into their georeferenced database of buildings. This database, equipped with unique IDs for over 3.5 million residential buildings, presents a solution that circumvents the need for a singular address database. It provides an immutable reference point for each building, ensuring data integrity and facilitating easier data sharing with operators.

The integration of operator data with the INE database leverages geographic information system (GIS) tools and Python scripts, enabling the mapping of coverage at an address level despite the discrepancies in operator data. This process has been meticulously designed to ensure that the data points fall within the perimeter of the respective buildings, meeting the criteria set out by INE. The resulting mapping system offers a comprehensive view of fixed broadband coverage, detailing the technology used, network ownership, and available speeds. It also highlights areas lacking Very High Capacity Networks (VHCN), commonly referred to as "White Areas," aiding in the strategic planning of network expansions and upgrades. The GEO.ANACOM public portal, an offshoot of the mapping initiative, serves as an interactive platform featuring various layers of information. These layers cover the spectrum and management planning, monitoring and supervision, and coverage for fixed, mobile, and satellite services. The portal extends to include postal services, market statistics, and general infrastructure data, thereby enriching the digital ecosystem for stakeholders across the board.

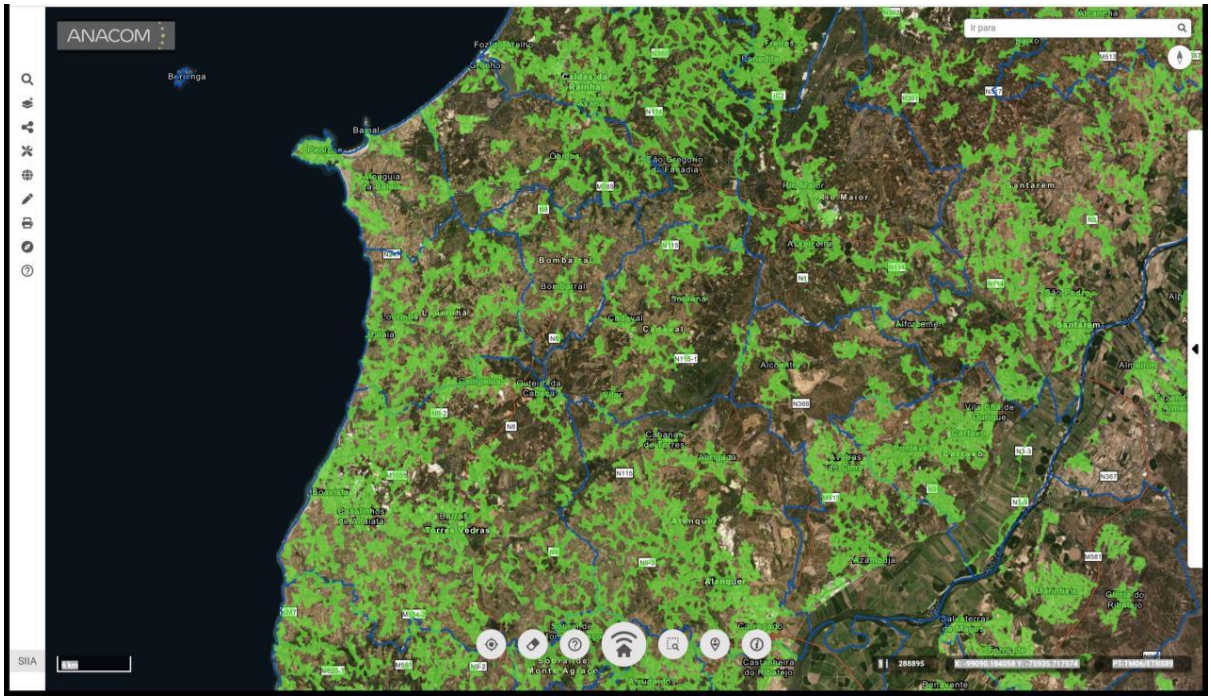


Figure 11. Example view of fiber optical broadband services availability in geo.ANACOM

Summary table for Portugal:

Aspect	Details
Legal Framework	National Broadband Plan, ANACOM, EU Directives, Decree-Law nr 40/2022, BEREC Guidelines
Responsible Entities	ANACOM, National Statistical Office (INE)
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

12. Case study 10: Romania

In Romania, broadband mapping systems operate within the framework of legal regulations established by the National Regulatory Authority for Electronic Communications and Information Technology (ANCOM). The legal background for broadband mapping primarily stems from EU directives, such as the European Electronic Communications Code (EECC), which aims to promote efficient and transparent broadband infrastructure deployment across member states. Additionally, Romania has enacted specific legislation, including the Electronic Communications Law, to govern the mapping, monitoring, and reporting of broadband coverage within its borders.

The regulatory framework for mobile electronic communication in Romania encompasses frequency bands ranging from 800 MHz to 2600 MHz, each allocated for specific technologies such as 2G, 3G, and 4G. ANCOM imposed stringent coverage obligations on mobile operators following the 2012 spectrum auction to ensure comprehensive mobile connectivity across Romania. These obligations included coverage of "white areas" where operators were mandated to provide data services in several villages lacking coverage. Operators had to ensure at least 98% population coverage with voice services through their own radio access networks within specified timeframes. They were also required to offer data transfer speeds of at least 2 Mbps with a 95% probability of indoor reception in areas inhabited by at least 60% of the population. ANCOM closely monitored operators' compliance with these obligations through measurement campaigns and other control mechanisms.

The broadband mapping system in Romania relies on a robust architecture designed to collect, process, and visualize data related to broadband infrastructure and coverage. Key components of the architecture include data collection mechanisms involving information gathering from internet service providers (ISPs), government agencies, and crowdsourcing platforms to compile comprehensive datasets on broadband availability and performance. Geographic Information Systems (GIS) play a crucial role in spatially representing broadband coverage data. By integrating geospatial information with other datasets, GIS enables the creation of detailed maps and analytical tools for assessing broadband accessibility. The primary sources of data for broadband mapping in Romania include ISP reports, regulatory filings, national surveys, and geolocation data from consumer devices. Crowdsourced data, collected through user feedback and speed tests, also contribute to enriching the accuracy of broadband coverage maps.

ANCOM conducted extensive measurement campaigns in 2018, 2019, 2020, 2021, and 2022 to assess actual coverage for 2G, 3G, and 4G technologies, as well as compliance with licensing conditions. These campaigns involved measuring accessible roads in localities with more than 10 inhabitants, FTP downloads in fixed locations across cities, and coverage along national and county roads. The analysis of measurements, conducted using ROMES software and a PostgreSQL database system, provided valuable data for evaluating coverage with voice and data services. Notable results included the evolution of coverage percentages for major operators like Orange, Digi, Vodafone, and Telekom over the years.

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 of Romania. The visualization of broadband coverage typically involves interactive maps that allow users to visualize 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. In addition to depicting broadband availability, visualization tools may display performance metrics such as download/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. Broadband mapping systems may also include features for analyzing temporal trends in coverage and performance data, enabling stakeholders to track improvements or gaps in broadband infrastructure over time and identify areas in need of targeted interventions.

ANCOM outlined ambitious future plans to further enhance mobile coverage measurement capabilities. These plans include introducing measurements for quality FTP upload/download and 5G coverage, creating an independent database for geocoding and reverse geocoding, updating actual coverage maps and all related layers, and calibrating propagation models, potentially leveraging AI technologies. Despite advancements in broadband mapping technology, several challenges persist in accurately assessing and improving internet connectivity in Romania. Ensuring the accuracy and completeness of broadband coverage data remains a challenge, particularly in rural and remote areas where infrastructure deployment may be limited or underreported. Enhancing data sharing and collaboration among stakeholders, including ISPs, government agencies, and community organizations, is essential for maintaining up-to-date broadband maps and addressing coverage gaps.

Bridging the digital divide between urban and rural regions remains a priority for Romania's broadband policy. Future steps may involve targeted investment in underserved areas, public-private partnerships, and incentive programs to encourage broadband deployment in remote communities. Embracing emerging technologies such as 5G, satellite internet, and smart infrastructure will be key to expanding broadband access and improving connectivity speeds in Romania. Policymakers should continue to support research and innovation in broadband technology to meet evolving consumer demands.

Romania's approach to broadband mapping encompasses a systematic collection and analysis of mobile coverage data, reflective of the regulatory perspective. The country's methodology incorporates comprehensive frequency band measurements that span from 800 MHz to 2600 MHz, ensuring that all relevant spectrums are accounted for in determining network coverage. These efforts stem from the coverage obligations set forth in the 2012 Auction, which mandated significant coverage of "white areas" and established benchmarks for population coverage with both voice and data services.

The analysis of Romania's diverse geotypes and landforms plays a pivotal role in the mapping process. By correlating coverage percentages with specific geographic features, the Romanian authorities can pinpoint areas requiring further infrastructure development. This granular approach extends to monitoring and control mechanisms, with the Electronic Communications Authority (ANCOM) employing dedicated equipment to address user complaints and ensure compliance with licensing conditions. ANCOM's rigorous measurement campaigns span several years, yielding vast quantities of data that are meticulously processed using the ROMES software suite and additional bespoke tools. The authority employs PostgreSQL with PostGIS for a robust and detailed analysis of the data, ensuring accuracy in evaluating coverage against the conditions imposed by licenses.

This meticulous data analysis culminates in the public dissemination of coverage maps through the portal www.aisemnal.ro. These maps provide end-users and stakeholders with transparent access to actual coverage data across 2G, 3G, and 4G technologies. Additionally, the internal use of these maps by ANCOM facilitates informed regulatory decisions and aids in tracking the evolution of network coverage over time. The strides in coverage over the years showcase the commitment of Romanian operators to enhance connectivity, as evidenced by the reported increases in coverage percentages. These advancements have yielded tangible benefits, not only in terms of broadened coverage for citizens but also in fostering a collaborative environment between operators and the regulatory

authority. The mutual respect and professionalism have led to increased infrastructure sharing and accelerated technological advancements within the sector.

Looking ahead, Romania has charted a course for the future that includes embracing new measurement methodologies for 5G networks and enhancing data service quality assessments. The plans also indicate the development of a comprehensive geocoding database to support the updating of coverage maps, which will likely involve calibration of propagation models potentially utilizing artificial intelligence to refine accuracy. Romania's journey in broadband mapping is marked by data-driven strategies, advanced technological deployment, and a forward-looking stance that promises to keep pace with the evolving landscape of electronic communications. This approach not only serves the immediate connectivity needs of the Romanian populace but also sets the stage for embracing the challenges and opportunities presented by the next wave of telecommunications advancements.

Aspect	Details
Legal Framework	EU Directives, European Electronic Communications Code (EECC), Electronic Communications Law
Responsible Entities	National Regulatory Authority for Electronic Communications and Information Technology (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

13. 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.

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

To summarise: 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

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

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

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	FCC Form 477 Data
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

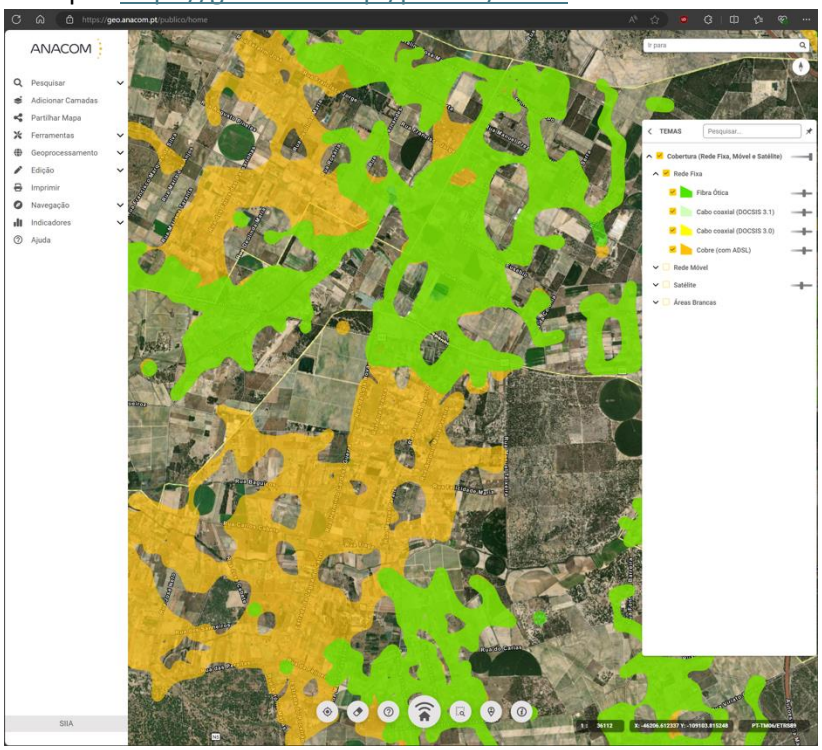
Broadband coverage visualization serves as a vital tool for policymakers, regulators, and consumers to assess the availability and quality of internet connectivity across different regions. Interactive maps and performance metrics are key components of effective visualization.

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.

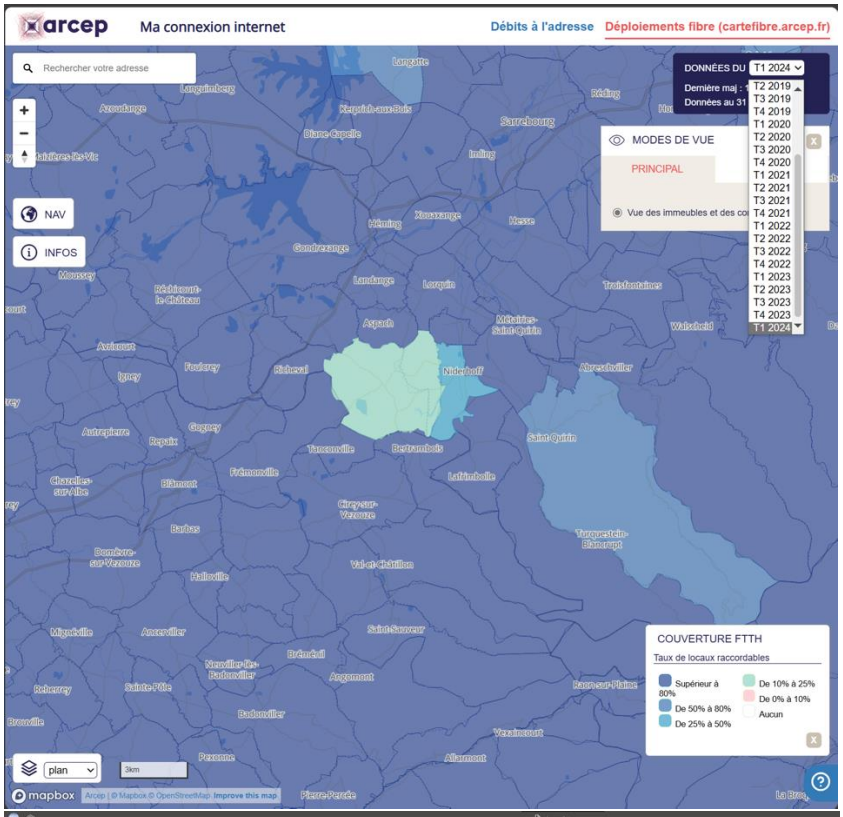
Visualization Technique	Description	Example Features
Interactive Maps	Web-based maps that allow users to explore broadband coverage at various geographic scales.	Zoomable maps, address level detail Fixed-wireless services: https://agcom.maps.arcgis.com/apps/MapSeries/index.html?appid=bd6a4b303dcc491188d1b7584927ce58 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 croudsourced and NRA measured data: https://monreseaumobile.arcep.fr/

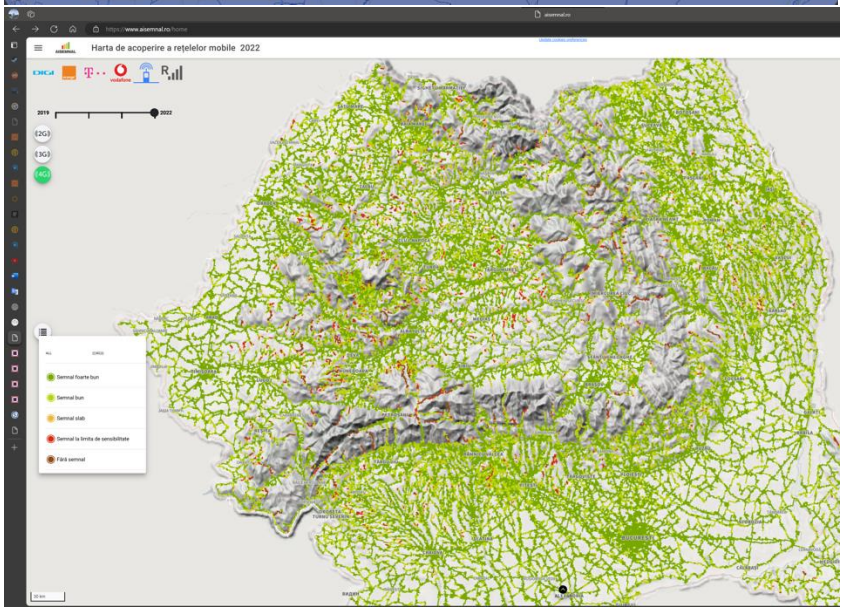
Trend Analysis Tools	Features for analyzing temporal trends in coverage and performance data.	Year-over-year comparisons Example of comparison-enabled feature: https://cartefibre.arcep.fr/index.html?lng=6.988105275215503&lat=48.613357454476585&zoom=11.594625088154315&mode=normal&legende=true&filter=true&trimestre=2024T1 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 data visualization 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)

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



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]





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

14. Common challenges found in the EMERG and EaPeReg Region

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.

15. 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 CenterLines: Fiber Optic Cable, Copper • CableServices: Internet, VoIP
Attributes (Level ii)	Master description, additional info about infrastructure existence or broadband service availability	• Node: Operational Status, • CapacityLine: Length, • Installation DateService: Bandwidth, Latency
Values/Terms (Level iii)	Defined values or terms for second-level attributes	• Node Status: Active, • InactiveLine Material: Fiber, CopperService 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 dataFormat: • CSV, • XML
Update Frequency	High	Regular updates from municipal records, yearly updates, or as per European Commission and BEREC guidelinesUpdate 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 LawRoles: Government sets policy, ISPs provide data

Legal Mandates	Legislative support for data sharing and compliance	European Electronic Communications CodeMandate: 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 AgendaAgency: Ministry of Digital Transformation ANACOM in PortugalBody: National Regulatory Authority (NRA)
Telecommunication Operators	Data provision, infrastructure deployment	Public-private partnerships in ItalyOperator: Telecom Italia
Community Organizations	Crowdsourced data collection, public awareness	Local initiatives in GeorgiaOrganization: Georgia Broadband Alliance
Data Collection and Standardization	**Details**	**Example**
Speed	Measurement of download and upload speeds	FCC Form 477 DataDownload Speed: 100 Mbps, Upload Speed: 20 Mbps
Technology Type	Types of broadband technology (e.g., fiber, DSL, cable)	ITU StandardsTechnology: Fiber Optic, DSL, Cable
Coverage	Geographic extent of broadband service	GIS-based mappingCoverage Area: 10 km radius
Data Source	Origin of data (e.g., ISP reports, surveys, crowdsourcing)	Polish Regulation on telecom infrastructure and service inventorySource: 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	Type: Office Type: Residential

	- Industrial - Service - Public - Sacred object - Power grid - Tower - Mast - Container - Pole - Cable well	
Sharing Surface Area	Yes/No	Yes
Layers of Node	- Backbone - Distribution - Access	Layer: Backbone
Transmission Medium	- Fibre optic - Coax - Copper - Radio	Medium: Fibre Optic
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	- Fibre optic - Coax - Copper - Radio	Type: Fibre Optic
Fibres	- Fibres of the optical cable	Fibres: 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 - Street name - Building number	Province: Lombardy Commune: Milan Identifier: 67890 Town: Milan 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	- Fibre 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	