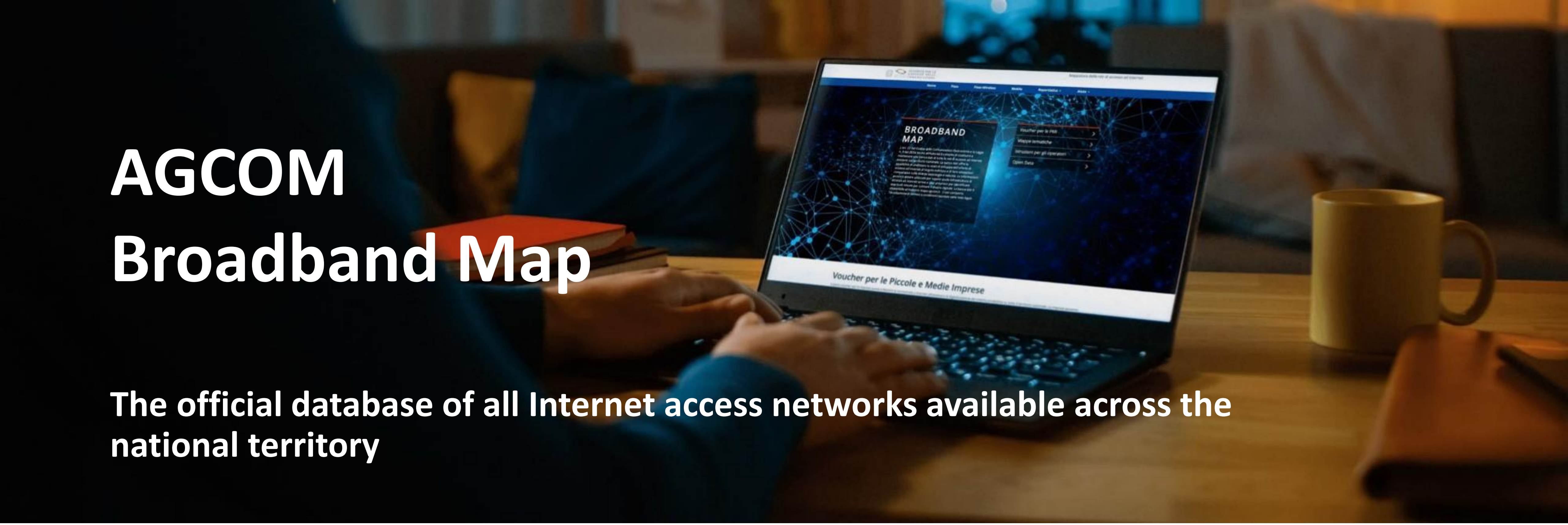
Mapping Connectivity

Experiences from the use of AGCOM’s Broadband Map

Aldo Milan – AGCOM

Italy



AGCOM Broadband Map

The official database of all Internet access networks available across the national territory

It enables the analysis of broadband infrastructure deployment at address level and supports comparative assessments of technologies and connection speeds. This information can help identify the available Internet infrastructure at any location and assist public authorities in defining policies to bridge the digital divide

State of the connectivity

- Detect the local availability of telephony and data services and identify the offered speeds for: Copper, Fiber and Wireless Technologies
- Produce summary indicators at various territorial levels to identify areas ready for the transition to copper network alternatives
- Support the development of regulation and identify potential remedies

Providing an Authoritative Reference

- ➢ The Broadband Map is part of the National Statistical System and, through the National Institute of Statistics (ISTAT), also of the European system (EUROSTAT)
- ➢ It serves as a stable reference for:
  - Internal processes of the Authority and Ministries
  - European institutions
  - End-users
  - Stakeholders
- ➢ BBmap is Neutral, Independent and Transparent
- ➢ It implements Net Neutrality principles

Policy & Regulation
Understanding The Regulatory Framework

Often less visible, but essential for the development of the Broadband Map.

- **EU Regulation** plays a central role in aligning Member States:
  - European Electronic Communications Code (Art. 22) → transposed in national laws (Italy: same numbering, Art. 22 of the Code).
  - Cost Reduction Directive → mapping of ducts to enable reuse.
  - State Aid Framework → managed by the European Commission, with specific guidelines.
  - General Block Exemption Regulation (GBER) is an EU regulation that allows MS to grant State aid for certain categories of projects and activities without the need for prior notification and approval by the EC.
  - INSPIRE, ISTAT, EUROSTAT
- **BEREC Guidelines** (Body of European Regulators for Electronic Communications)
  - ensure consistent implementation across Member States.
- **National Level**: license obligations linked to coverage and mapping.
- **Consumer Protection**: EU law and national code require transparency tools to allow service comparison.
- **Economic policy**: Digital Decade Policy Programme → targets for Fiber coverage and 5G coverage, draft methodology for 5G QoS mapping (guideline)

- **1. Technological Dimension**
- Defines the technological domain of analysis (Fixed, Mobile, FWA, Satellite, or technology-neutral).
  This dimension captures the technical characteristics of networks and services and allows comparative or aggregate assessments across technologies.
- **2. Functional Dimension**
- Distinguishes between **services** (what is delivered to end-users, including QoS and coverage) and **infrastructure** (the physical and logical enablers such as networks, ducts, or radio sites).
  It forms the basis for linking service-level coverage maps with infrastructure availability maps.
- **3. Competitive Dimension**
- Refers to market structure and the degree of competition, typically represented through the **white/grey/black area classification** used in State Aid and market analyses.
  It determines where public intervention may be justified.
- **4. Economic–Regulatory Dimension**
- Differentiates **subsidised** and **non-subsidised** areas or investments.
  It is essential to assess the impact and additionality of public measures (e.g. national or EU funding programmes such as PNRR or CEF).
- **5. Policy–Strategic Dimension**
- Frames the mapping within broader policy objectives such as the **Digital Decade targets**, **DESI indicators**, and **national digital strategies**.
  It connects the mapping outputs to measurable policy indicators and EU monitoring frameworks.
- **6. Licensing and Scarce Resources Dimension**
- Concerns the management of scarce public resources (notably **spectrum**) and associated **licence obligations** such as coverage commitments or KPI targets.
  This dimension ensures coherence between the legal rights of use and the effective territorial deployment of networks.

Mapping Dimension	Relevant EU / National Regulatory Framework	Where to verify / Evidence of existing mapping
1. Geographical	*INSPIRE Directive*, *Eurostat* (NUTS, LAU, DEGURBA) and *ISTAT* define the spatial framework and classification systems to be used in broadband mapping.	Check INSPIRE-compliant spatial datasets, national geographic databases (ISTAT boundaries, Eurostat layers), and Broadband Map territorial grids (20 m / 100 m).
2. Technological	*European Electronic Communications Code* (Art. 22) and its national transposition (Italy: Art. 22 of the Code) establish the obligation to map networks and services by technology.	Verify Broadband Map technology-specific coverage (FTTH, FWA, 4G, 5G) and operator data submissions under Art. 22 obligations; assess completeness and update frequency.
3. Functional	*Cost Reduction Directive* (2014/61/EU) promotes mapping of passive infrastructure (ducts, masts, fibre) to enable reuse; complemented by EECC Art. 22 for service coverage mapping.	Review infrastructure inventories and national databases (Infratel, regional GIS of ducts/backhaul) and check integration with service-level layers in Broadband Map.
4. Competitive	*State Aid Framework* and *BEREC Guidelines* define market classification (white/grey/black) for network competition and consultation procedures.	Verify existing national State Aid maps (Infratel/EC portals), AGCOM competitive area classifications, and their coherence with BEREC and EC guidelines.
5. Economic–Regulatory	*General Block Exemption Regulation* (GBER) and *State Aid Guidelines* regulate the use of public funds for broadband. Mapping provides evidence for aid justification and monitoring.	Assess presence of datasets distinguishing subsidised vs. non-subsidised areas (PNRR, CEF, regional programmes) and their linkage with Broadband Map layers.
6. Policy–Strategic	*Digital Decade Policy Programme* (DDPP) and *DESI* define EU connectivity and QoS targets. Mapping supports progress monitoring towards Gigabit and 5G coverage goals.	Check alignment between Broadband Map indicators and EU monitoring (DESI, Digital Decade dashboards); verify KPI consistency and periodic reporting.
7. Licensing and Scarce Resources	National licence frameworks under the *EECC* regulate spectrum rights and coverage obligations. In Italy, *AGCOM* and *MIMIT* oversee implementation and compliance.	Verify AGCOM and MIMIT databases on frequency licences, rights of use, and 5G coverage obligations; assess whether mapped deployment reflects licence commitments.

Ongoing Activities on the Regulatory Framework

- **Public consultation: draft methodology for 5G QoS mapping**
  - Covers 5G mobile and Fixed Wireless Access (FWA)
  - To be integrated in the Digital Decade reporting (beyond signal coverage, towards QoS)
  - Provides a harmonized EU approach to QoS → crucial for monitoring, investment planning, and State aid decisions

- **BEREC Report**
  - Implementation Report on **Guidelines for Geographical Surveys** (Art. 22 EECC)
  - Examines Member States' transposition and national databases
  - Basis for a possible **revision/update** of the Guidelines

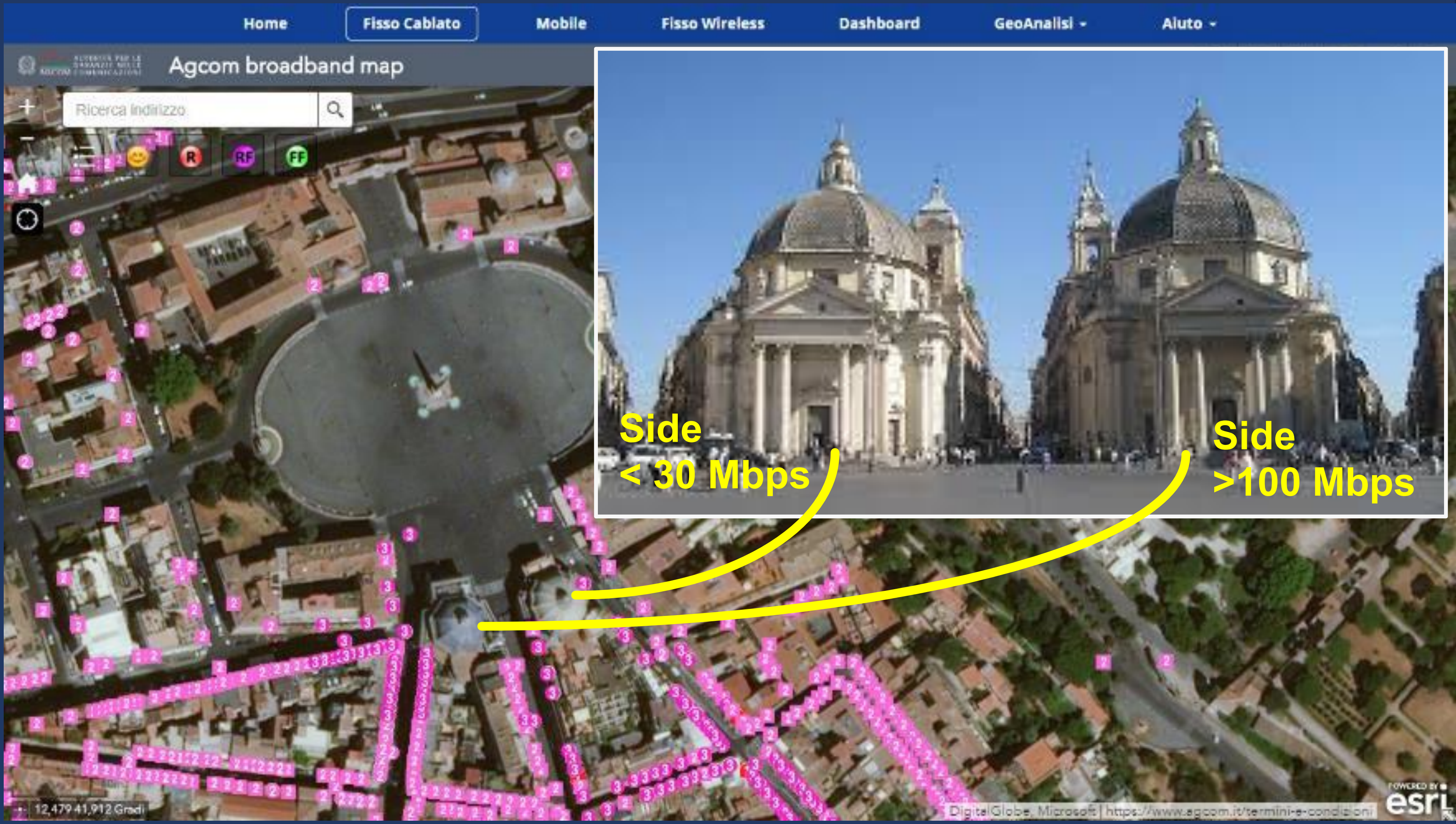
- **Digital Networks Act (DNA)** – proposed EU regulation
  - **Boost investment** in 5G/6G, fiber, cloud
  - **Accelerate deployment** and migration to fiber
  - **Harmonize rules** across Member States
  - **Enhance security** (networks, submarine cables)
  - **Fair share principle**: cost-sharing between telecom operators and content providers
  - **Support future tech** (AI, quantum, metaverse)

Understanding input

- Some security issues prevent full publication of all information, and our systems must be developed with strong attention to these aspects
- It is essential to keep in mind the characteristics of the information to be analyzed and possibly represented
- A key element is geographical variability:
  - Wired networks are structured as graphs
  - Wireless networks are affected by obstacles to propagation

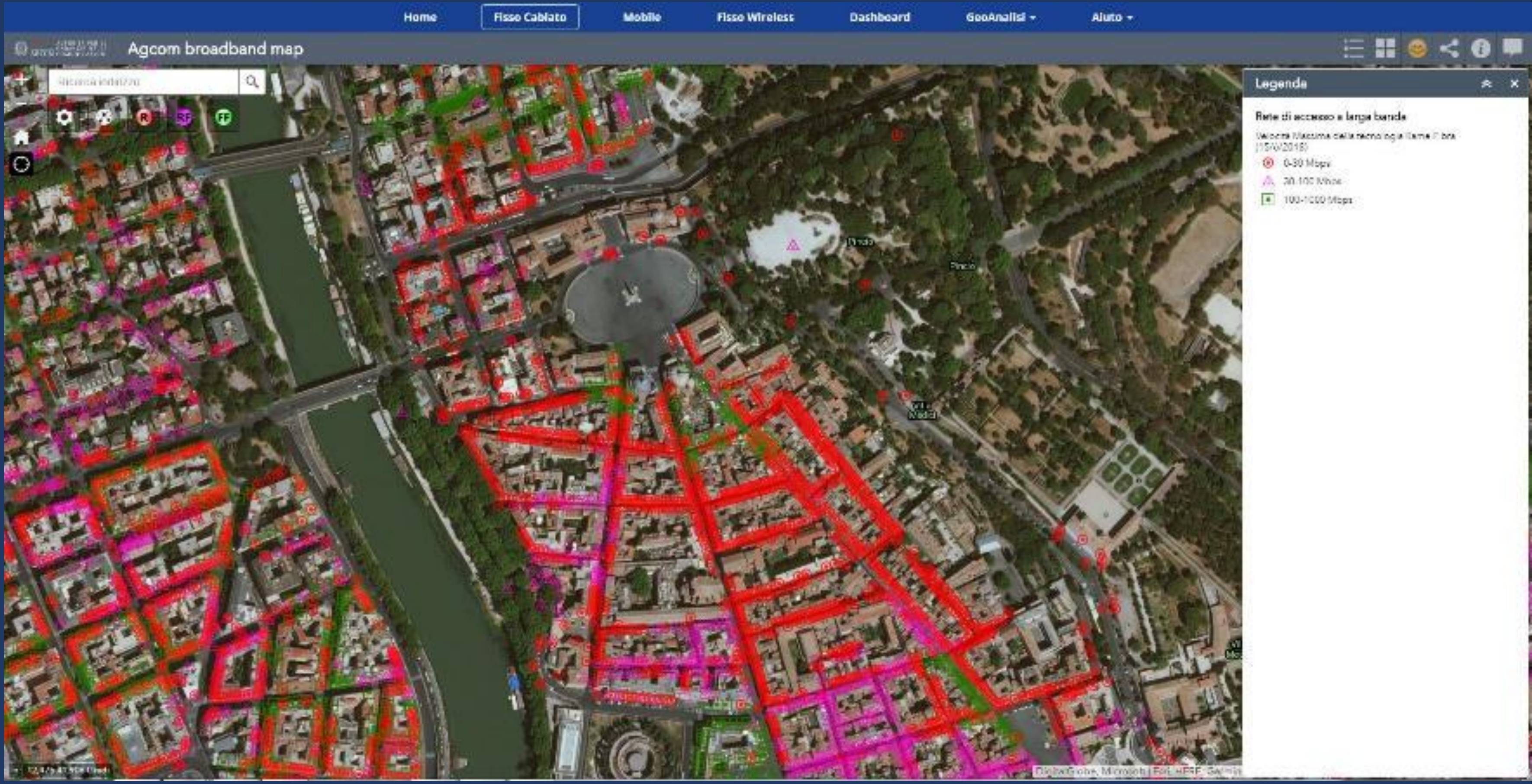
Wired connection substantial variability of the spatial distribution 1/2

- A wired network connects points (not areas)
- Coverage cannot be modeled with a continuous function as in mobile contexts
- Discontinuous and discrete function… graph theory
- With BBmap, “Unexpected” geographical patterns have been discovered
- Map is necessary to detect local connectivity status
- Resolution is a key aspect for GIS analysis
- Need to access elementary data



Wired connection substantial variability of the spatial distribution 2/2

- Streets has been “painted” on the base of estimated speed using following ranges: 0 to 30 Mbps, 30 to 100 Mbps, over 100 Mbps
- The Map communicates immediately the theoretical network performance of existing infrastructures (QoS)
- Ducts are located along streets.
- Linear model (poly-lines) provide a natural framework to analyse investments (ducts)
- Point model is the natural framework to analyse connections (distance is relevant for street crossing)



Understanding the geography

- Consider the orography of the territory
- Take into account the administrative boundaries
- Main routes
- Reflect on the building and demographic distribution
- GIS tools must rely on appropriate technologies. Mathematical models used in mapping play a central role. Data types: polygons, points, polylines
- Resolution
- Communication also matters: producing maps is partly an art
    - Writing speaks to the left hemisphere: logic, sequence, reasoning
    - Maps speak to the right hemisphere: image, color, intuition
- Maps can be powerful:
    - Some stand alone and move directly to action – Universal language
    - Others support analysis, becoming text, decisions, and policy

Mathematical models used in mapping

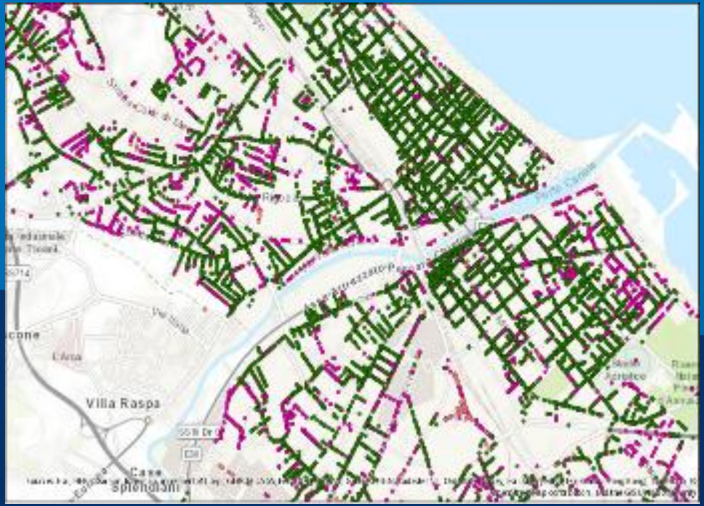
Math
used to present the coverage

Service vs Infrastructure

Admin Polygons (Nuts3)

LR Grids (1 Km grid)

HR Grids (100 - 10m)

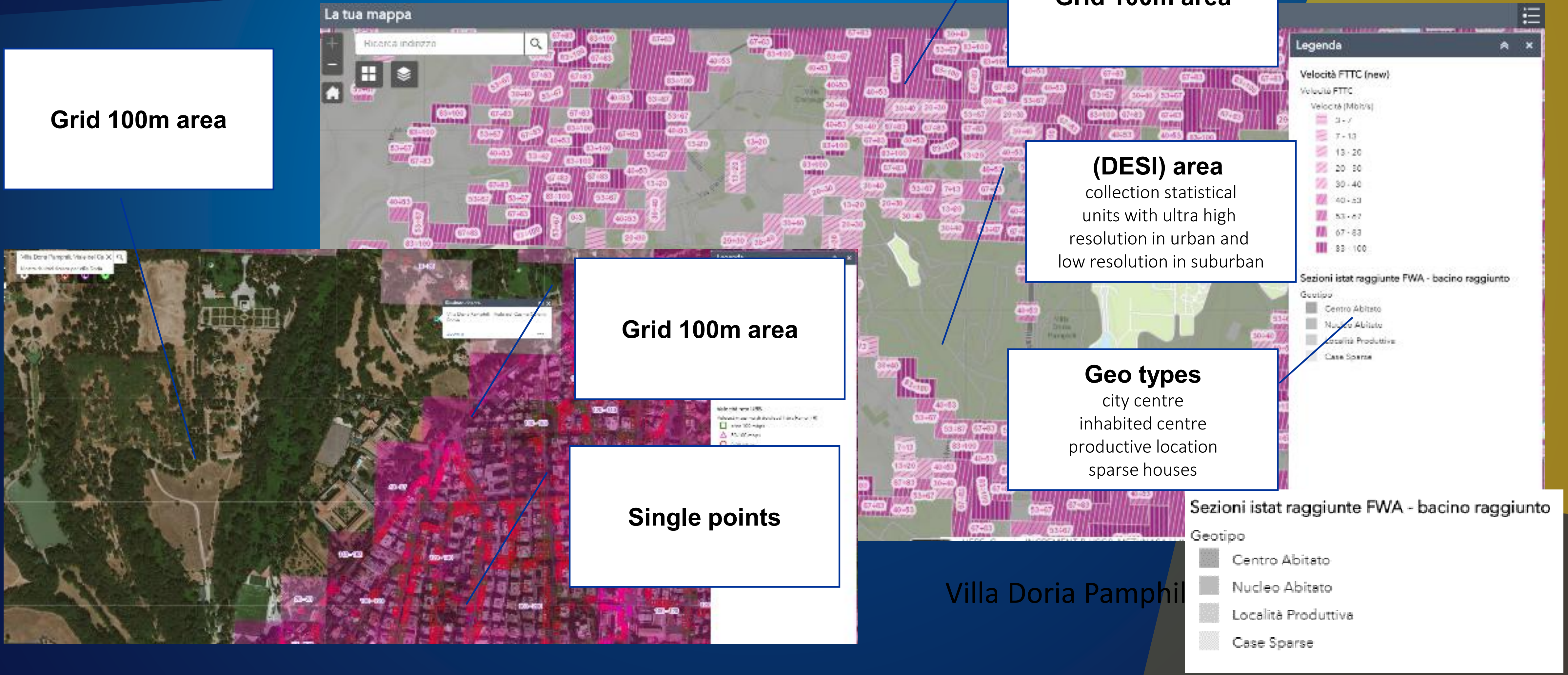


HR Points (addresses)

HR Poly-Lines (streets/ducts)

Select the resolution

Looking for the best compromise (implementation costs)

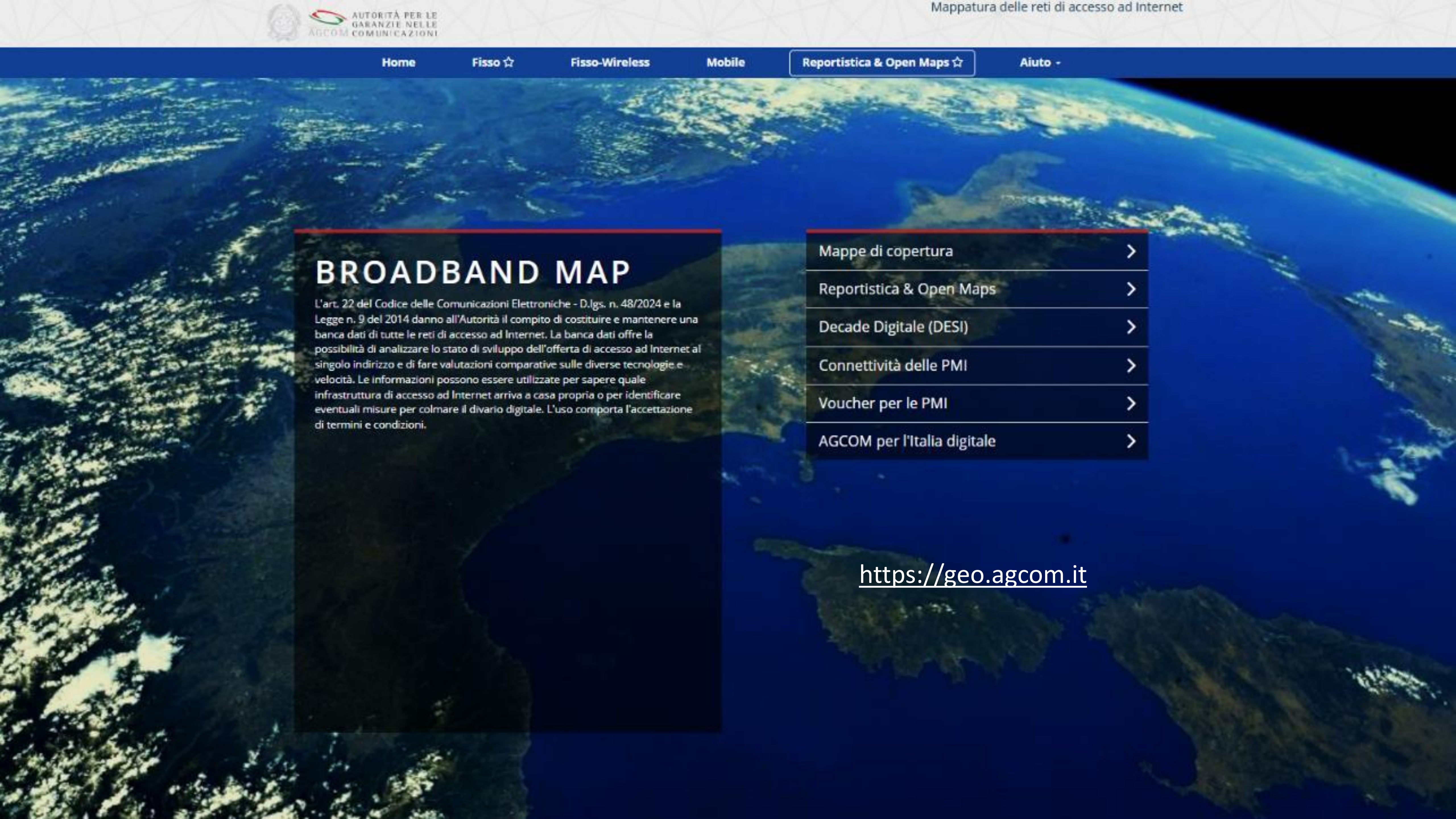


One Decade of Broadband Mapping

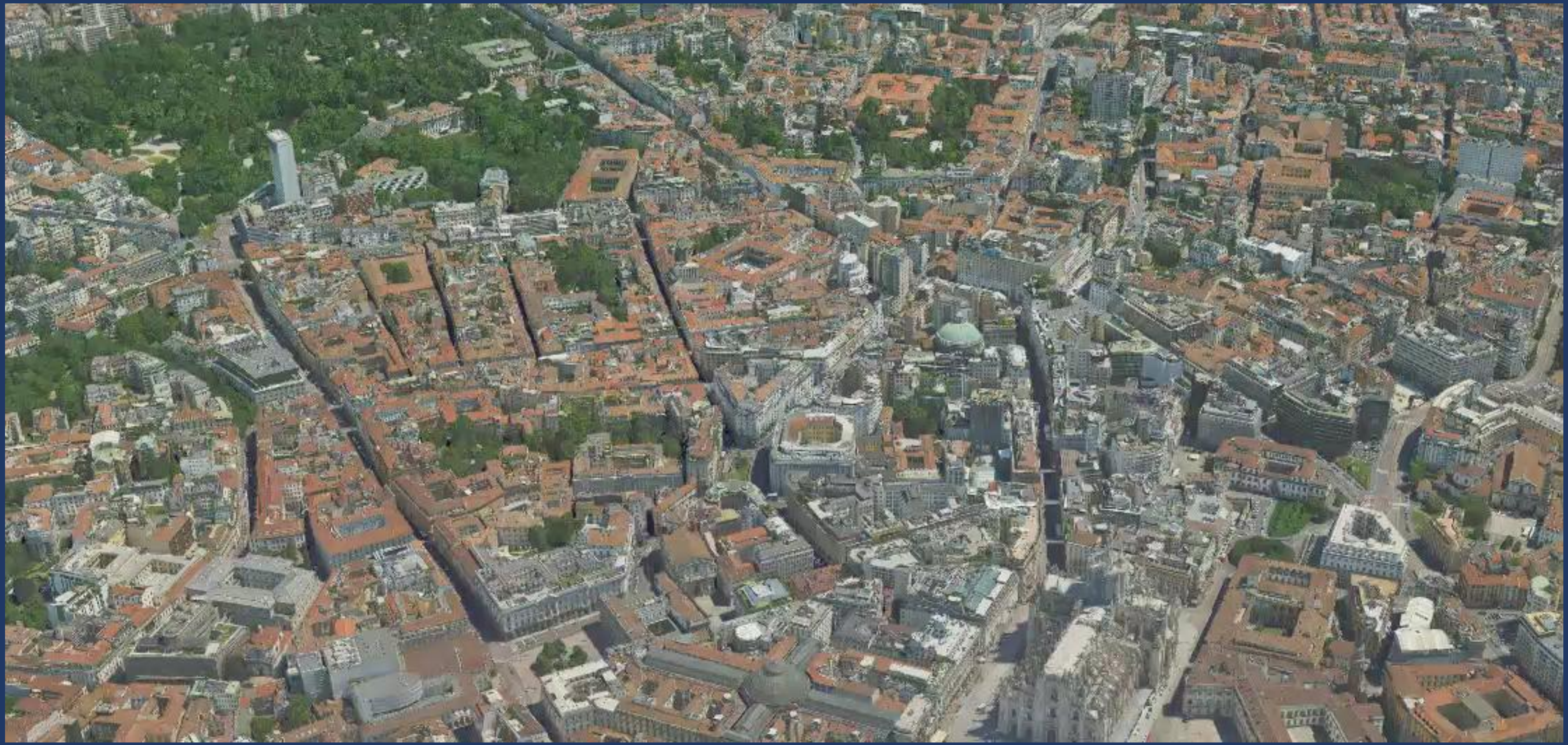
- Towards an International BBmap Conference
- Rome, celebrating one decade of broadband mapping

Part 2

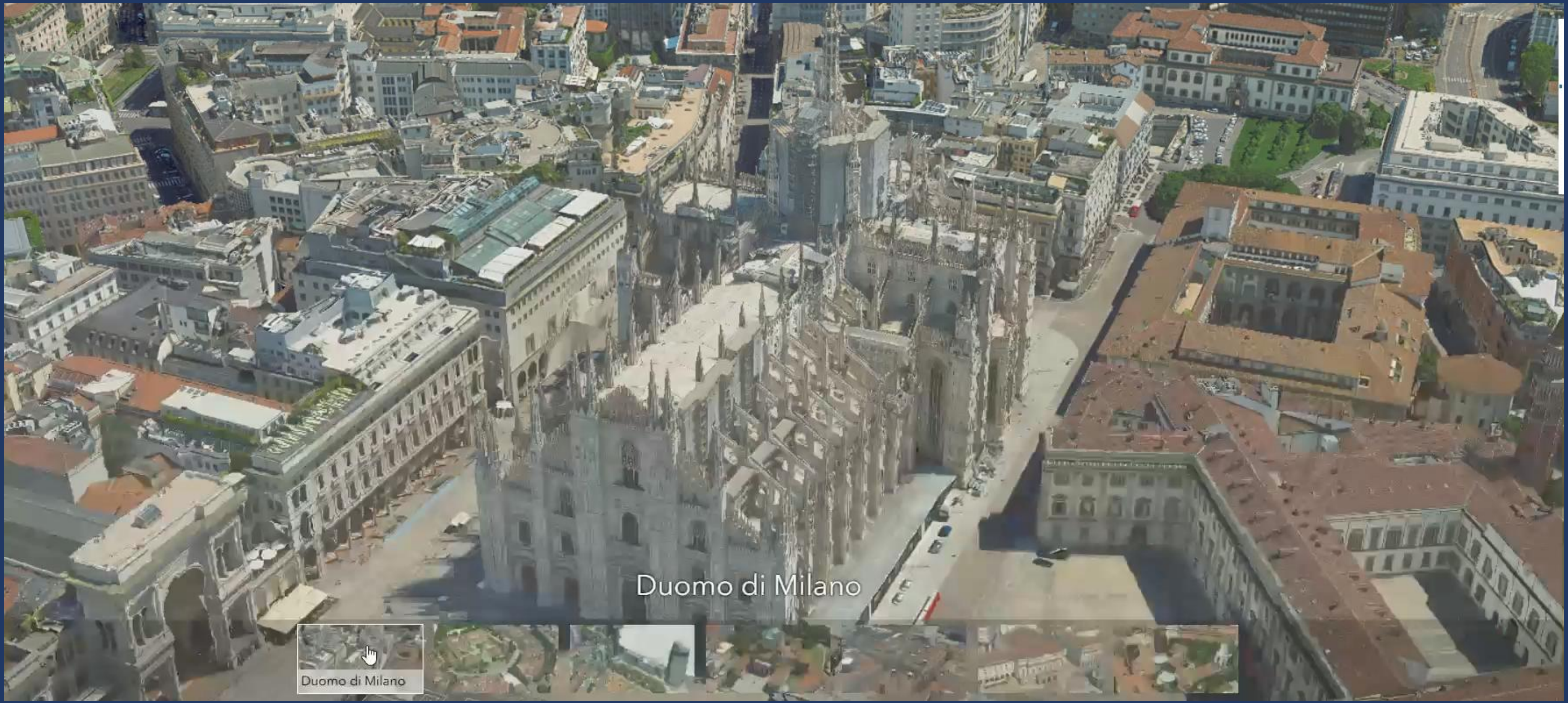
Demo & Tools


AUTORITÀ PER LE GARANZIE NELLE COMUNICAZIONI
AGCOM
Mappatura delle reti di accesso ad Internet
Home
Fisso
Fisso-Wireless
Mobile
Reportistica & Open Maps
Aiuto
BROADBAND MAP
L'art. 22 del Codice delle Comunicazioni Elettroniche - D.lgs. n. 48/2024 e la Legge n. 9 del 2014 danno all'Autorità il compito di costituire e mantenere una banca dati di tutte le reti di accesso ad Internet. La banca dati offre la possibilità di analizzare lo stato di sviluppo dell'offerta di accesso ad Internet al singolo indirizzo e di fare valutazioni comparative sulle diverse tecnologie e velocità. Le informazioni possono essere utilizzate per sapere quale infrastruttura di accesso ad Internet arriva a casa propria o per identificare eventuali misure per colmare il divario digitale. L'uso comporta l'accettazione di termini e condizioni.
Mappe di copertura
Reportistica & Open Maps
Decade Digitale (DESI)
Connettività delle PMI
Voucher per le PMI
AGCOM per l'Italia digitale
https://geo.agcom.it

Milano 3D Model – Digital Twin



Milano 3D Model – Digital Twin



KAMPALA

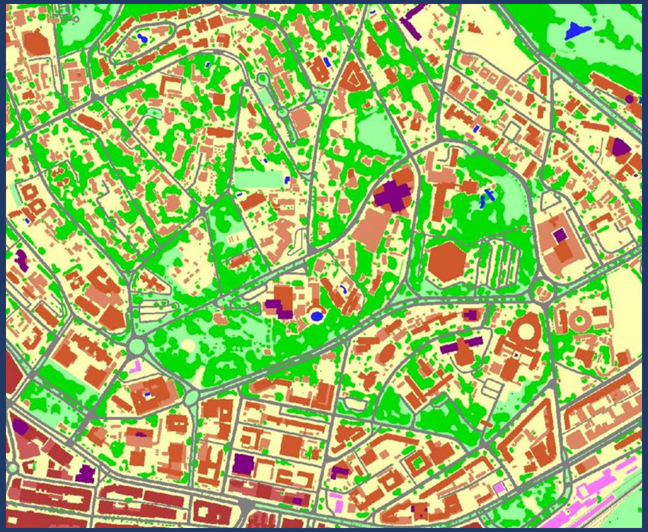
10 sq km Test area

3D City model, 1m resolution

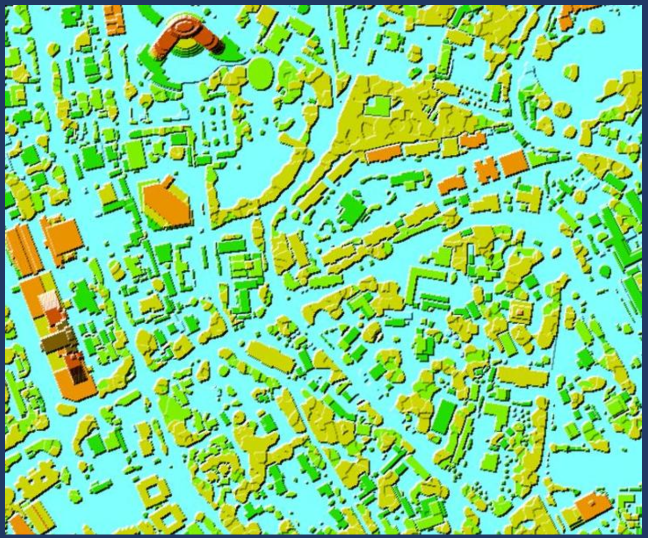
Vintage: 2025

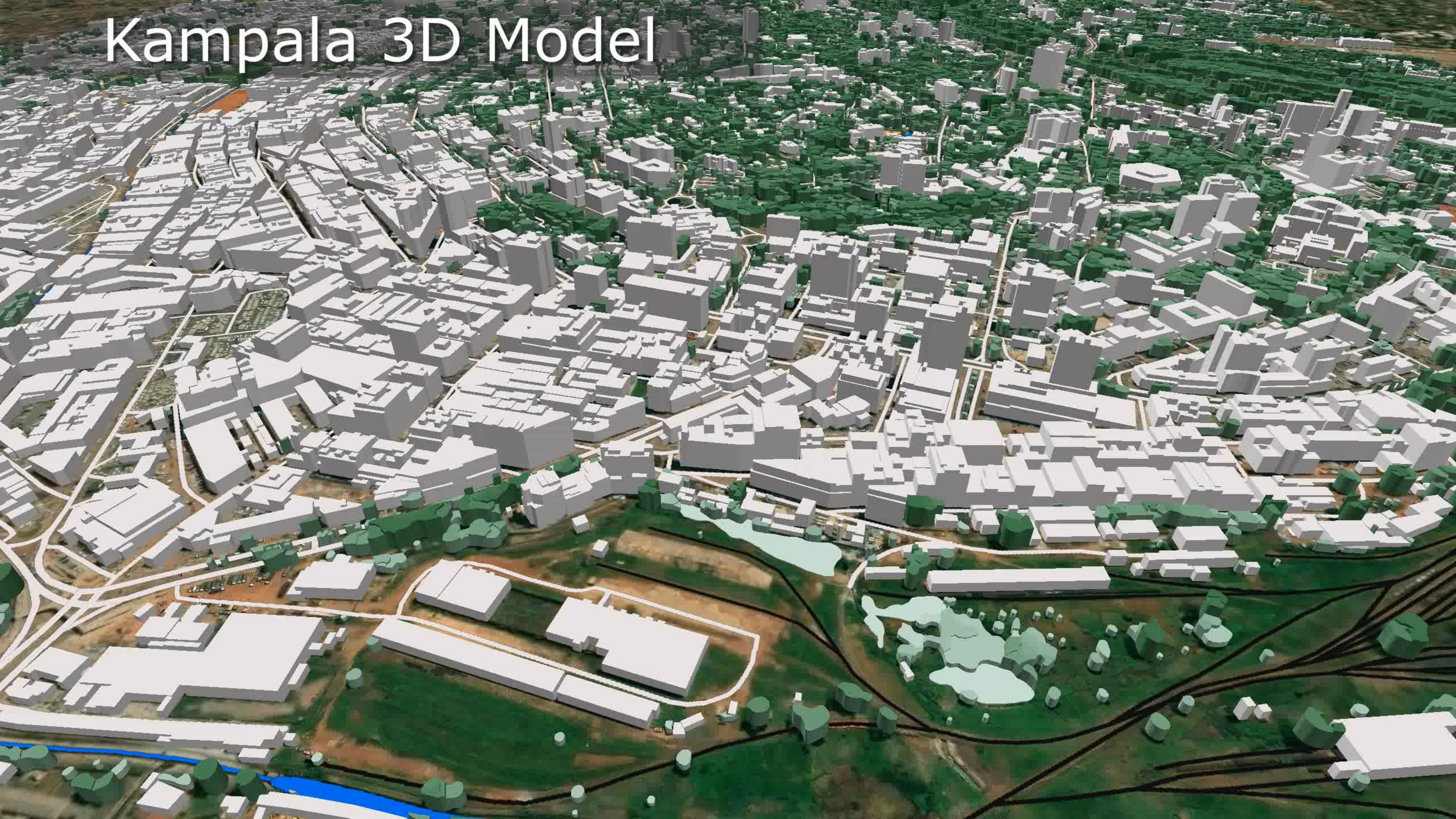
ORTHOIMAGE

LAND USE

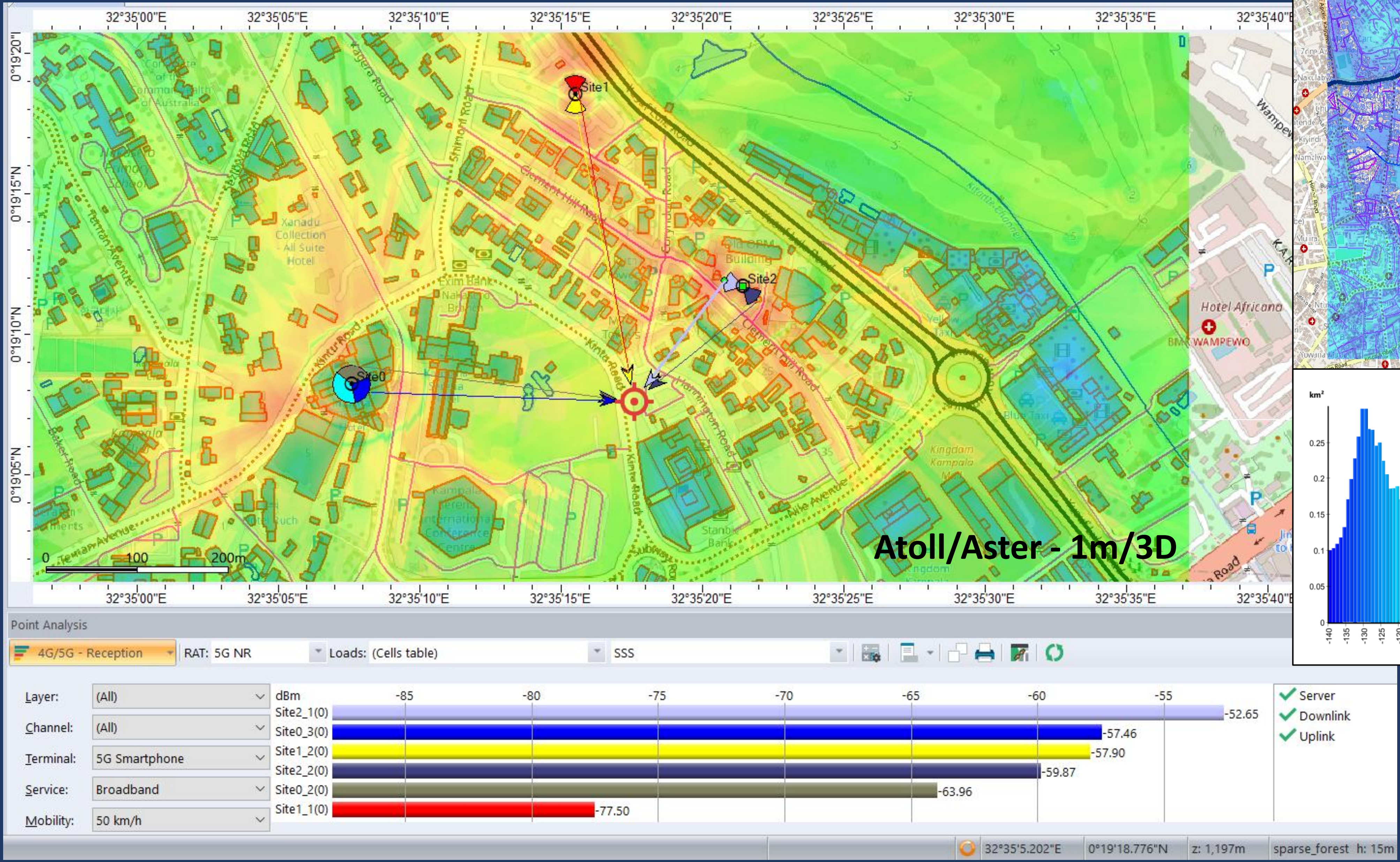


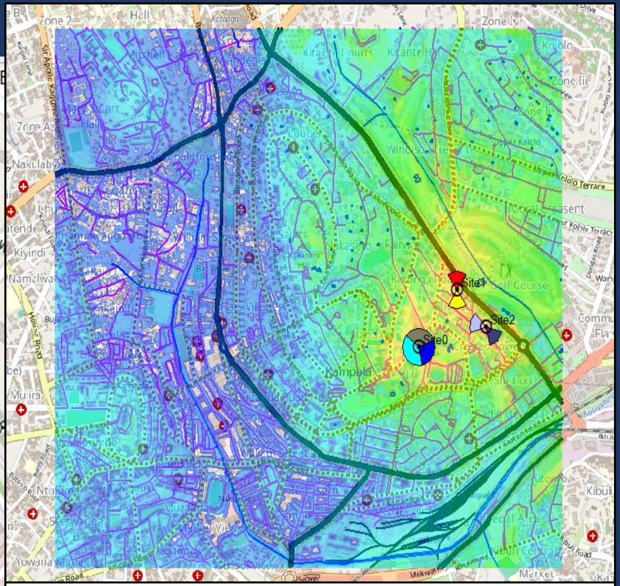
OBSTACLES HEIGHTS MODEL

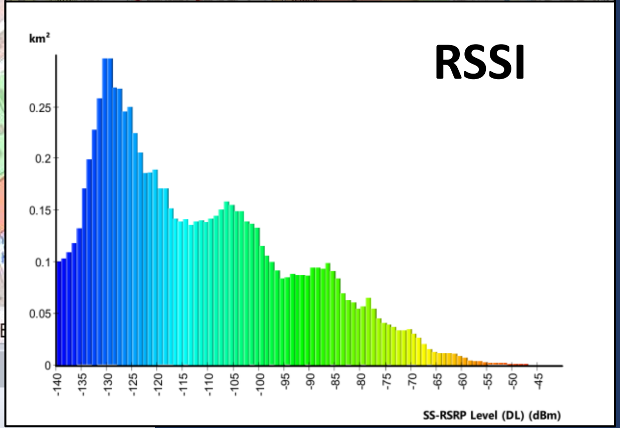



Kampala 3D Model

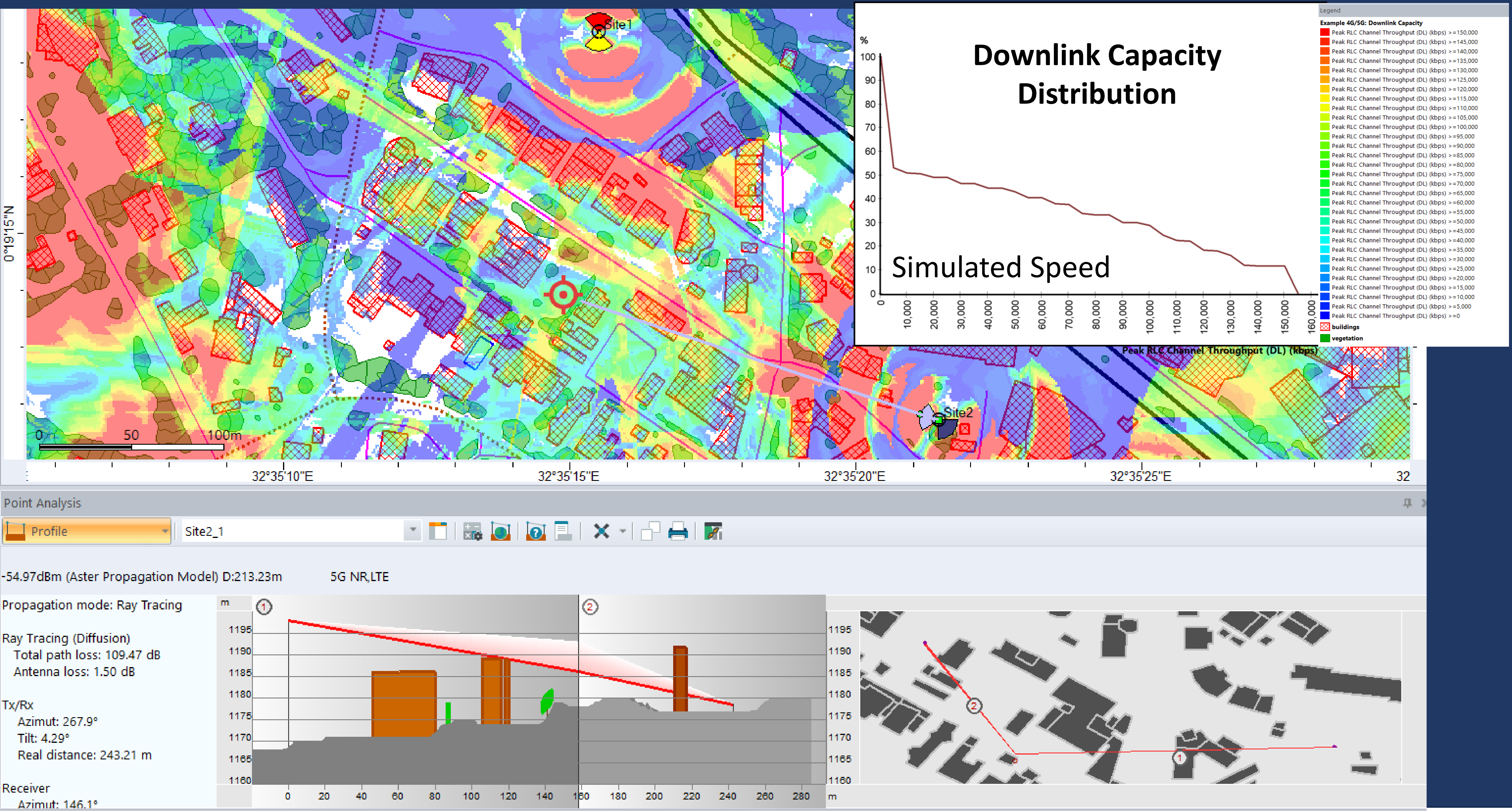
Received Signal Strength Indication (5G NR; LTE)







4G/5G Downlink Capacity (5G NR; LTE – 3D)



Part 3

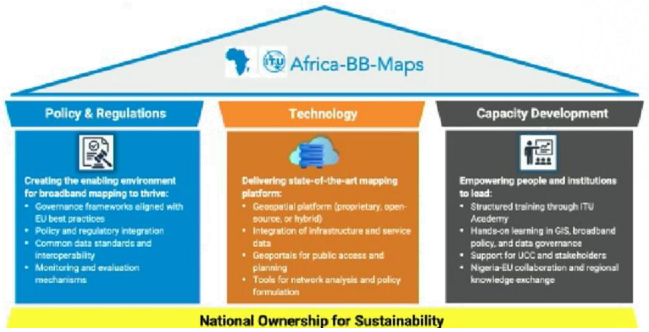
Technical Focus

Technical Focus

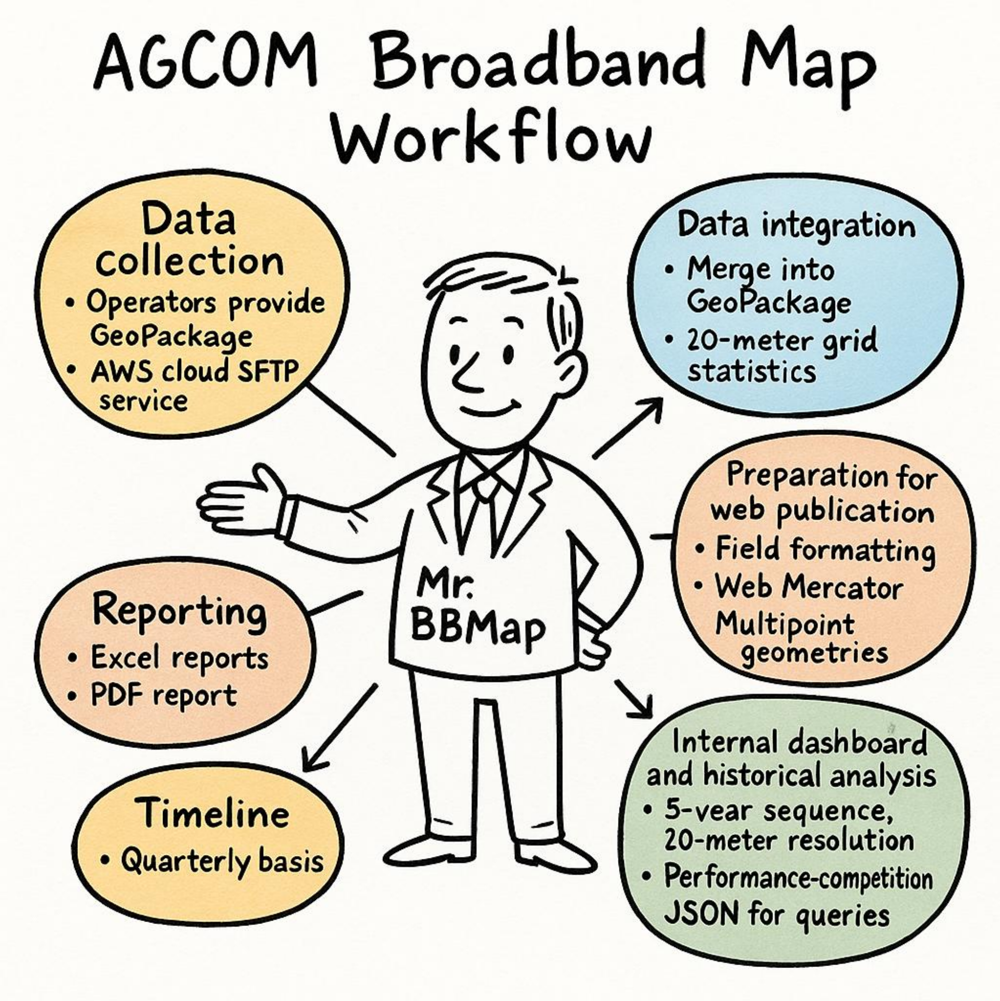
- ➢Key Tasks
- ➢The Workflow
- ➢Web GIS Platform
- ➢Main Components
- ➢Managing geo positions
- ➢Service vs Infrastructure Mapping
- ➢QoS Estimation
- ➢AI Mapping

Focus: Understanding key Tasks

- **Project Administration (Capacity Development)**
  - Project Management
  - Financial planning
  - Procurement
  - Administration
  - Training
  - User requests handling
  - Error reporting and escalation to operators
- **Policy & Regulation**
- **Special Projects**
- **Design (Technology)**
  - Geo Design
  - Fixed Methodologies
  - Mobile Methodologies
  - Reporting Systems (Dashboards)
  - It Architectures
  - SW Development / Opensource
- **Operation (Technology)**
  - Data Collection
  - Data Validation
  - Data Aggregation
  - Internal Repository
  - Mapping
  - Reporting
  - Open data/Metadata
- **Artificial Intelligence (Technology)**

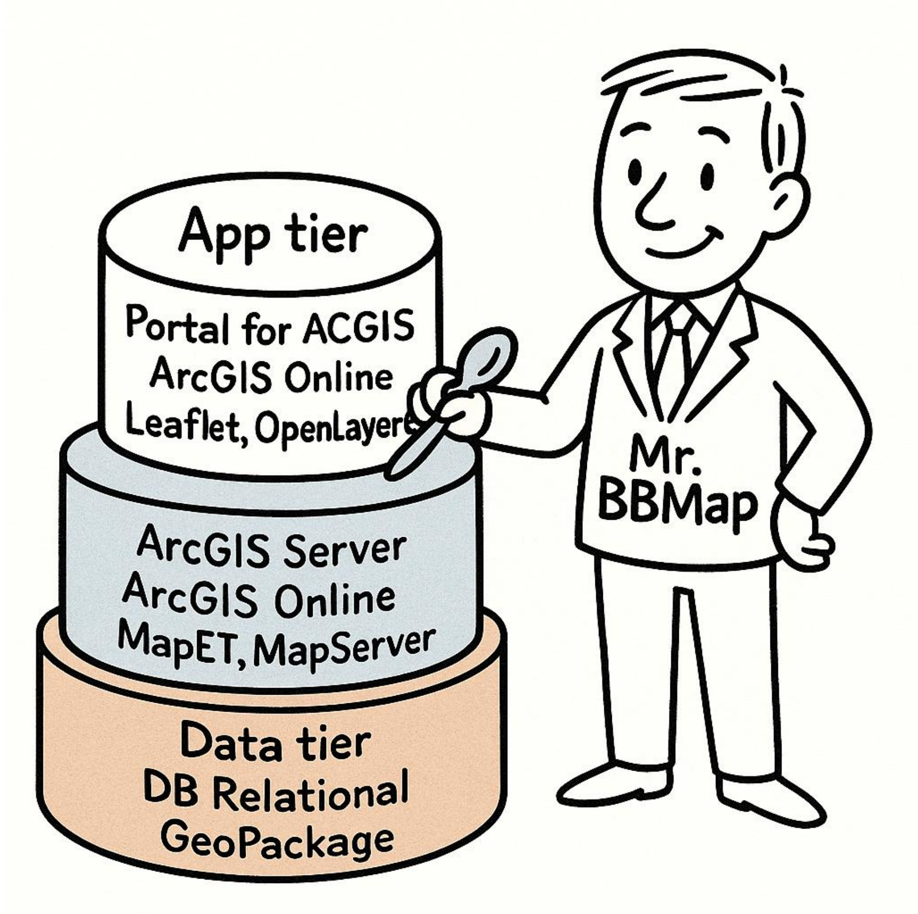


Focus: The workflow



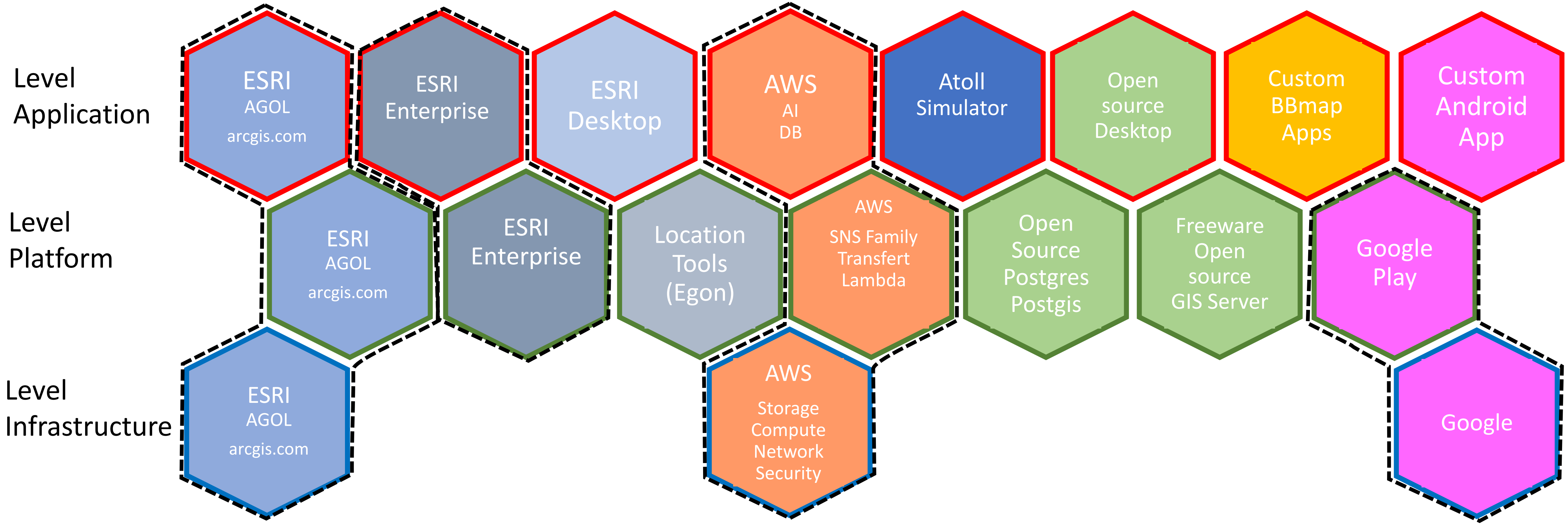
- **Data collection** → operators deliver GeoPackage files (points) via AWS SFTP. Full workflow repeated quarterly.
- **Integration** → AGCOM software merges data; 20 m grid aggregates points and computes statistics.
- **Web publication** → formatted tables, reprojection to Web Mercator, multipoint geometries for efficiency.
- **Reporting** → Excel outputs and PDF report on national connectivity.
- **Dashboard & history** → 5-year, 20 m resolution monitoring; JSON data allow selective queries, dynamic competition analysis, metrics on housing units and population.

Focus: Web GIS Platform



- **Three-tier architecture** (App · Server · Data) same for proprietary & open source
- **Compatibility** via common REST API subset
- **Proprietary (ArcGIS)** → advanced features (3D, editing, analytics), strong enterprise integration
- **Open-source** → 2D publishing, flexible, low cost, open standards (GeoPackage/OGC)
- **Use cases** → proprietary for complex services, open for simple mapping
- **Overall vision** → one architecture, multiple options; open tools reduce vendor lock-in
- **Server interchangeability** → individual components can be swapped without replacing the entire stack

Focus: BBmap components 1/2



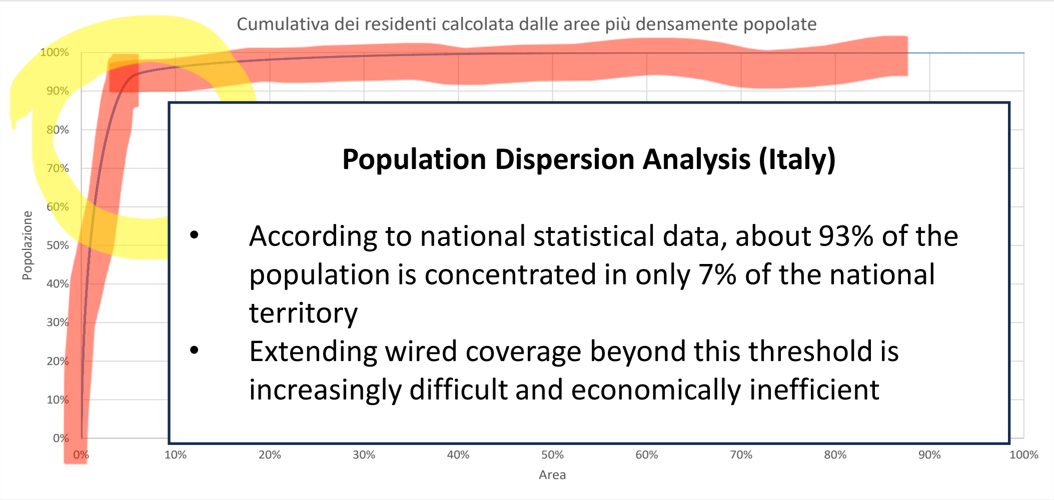
Focus: BBmap components 2/2

- The system integrates both **licensed components** and **open source solutions**.
- In recent years, **development efforts have increasingly focused on open source**, across all layers of the technology stack.
- The architecture is designed to be **modular and adaptable**, allowing for **low-investment evolutions** in response to changing needs.
- Particular attention is paid to **maintenance and upgrade costs**: a sophisticated system with high update costs risks becoming **unsustainable in the long term**.

Understanding Metrics and Targets

- **Coverage is usually analyzed in terms of households covered**
- **Depending on the accounting conventions applied, reported coverage may reach 100% or plateau just above 90%**

- *For example, the European Commission's Digital Decade targets aim for 100% coverage*
- *However, detailed address-level checks may still reveal unserved households, even in areas classified as served highlighting the challenge of reaching the last households*



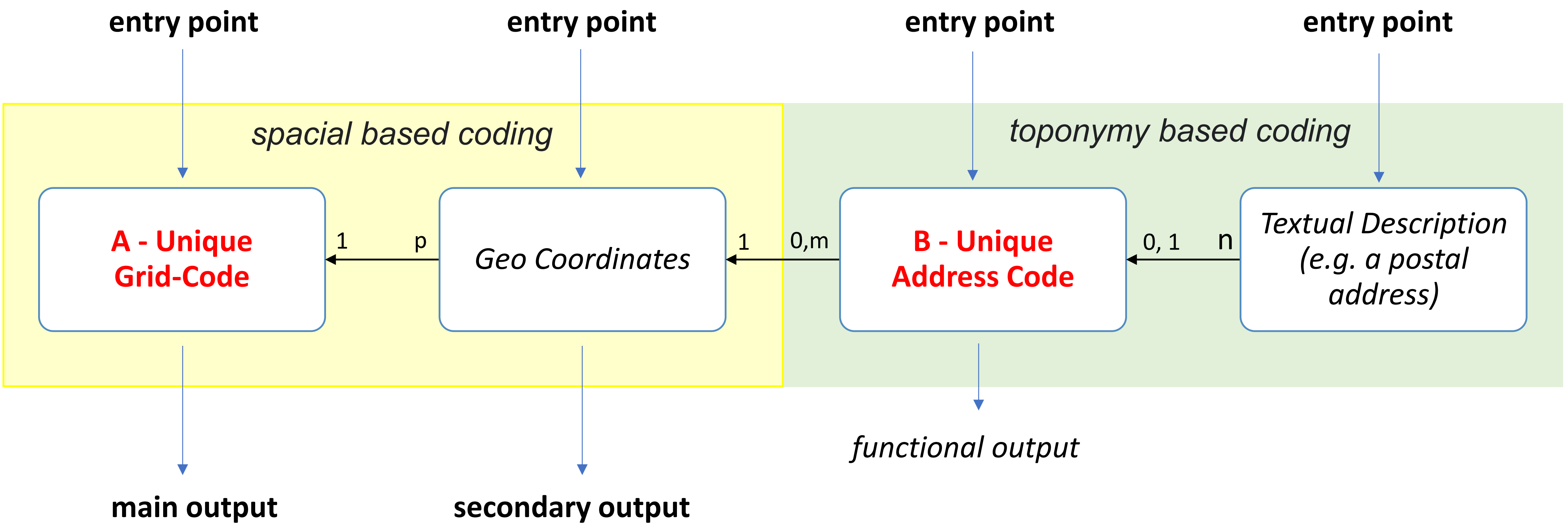
Metrics and Targets: coverage measurement vs identification of new operations

Percentages vs

list of streets

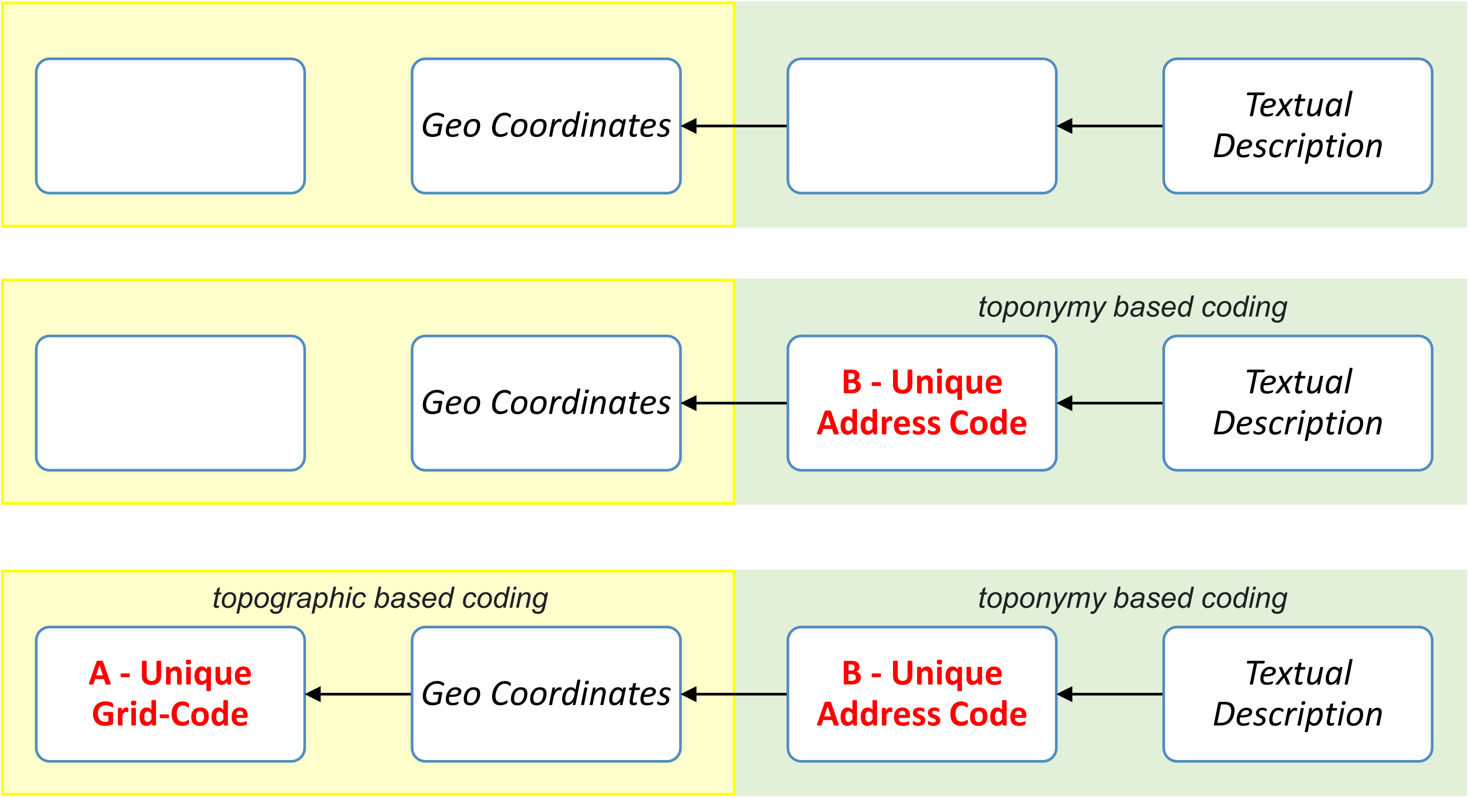
Focus: managing geo positions 1/2

Key classes and relations



Focus: managing geo positions 2/2

A scalable path: from essential functions to advanced capabilities



Common geocoding process

Math: F(«Textual Description») → R^2

Introduced in 2015-2016 to support wholesale regulated market (and reduce disputes)
Adopted with Incumbent's commitments

Introduced in 2019-2020 to support general mapping (multiple infrastructure) and national vouchers

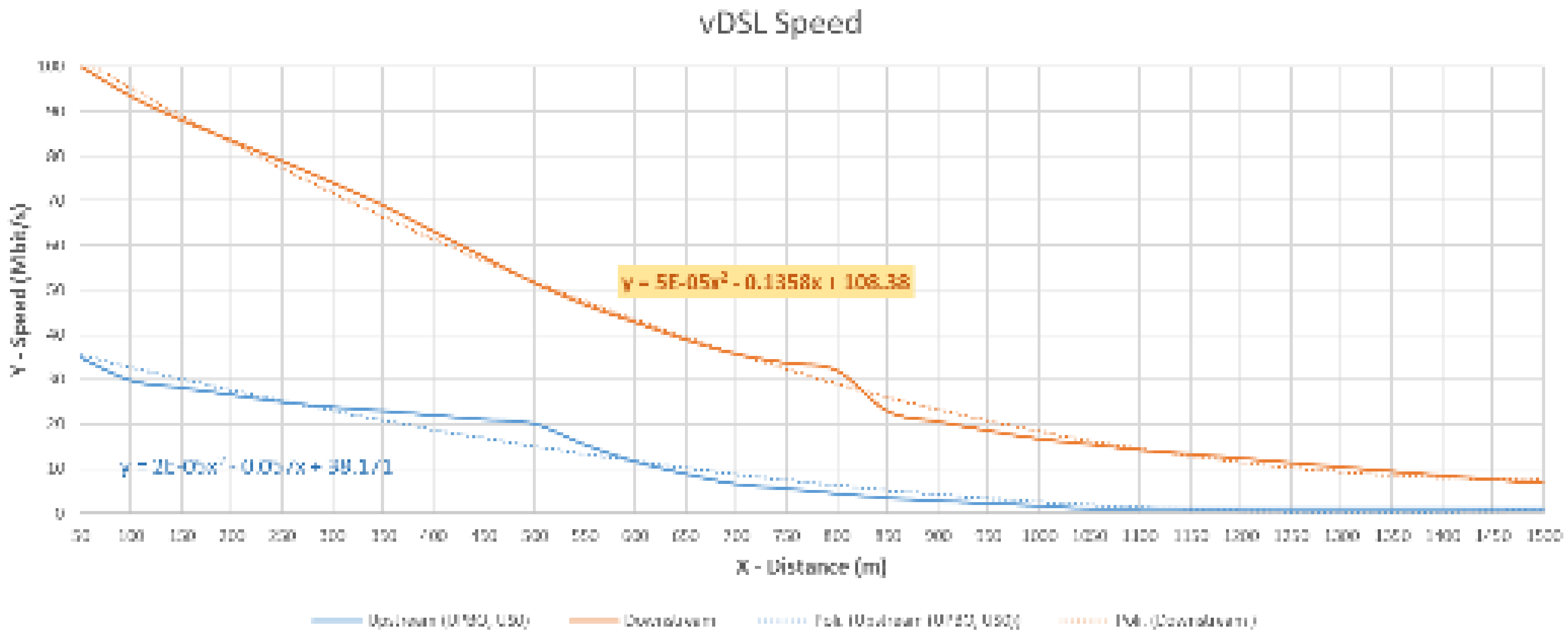
Math: P(a,b) – Best matching

Focus: Service vs Infrastructure Mapping

- **Infrastructure data is sensitive and must be handled with care.**
- It is essential to distinguish between **service availability** (what is offered to end users) and the **underlying infrastructure** (which may include commercially or nationally sensitive elements).
- The mapping system must be both **flexible and robust**, capable of adapting to **local requirements** and **regulatory constraints**.
- Different levels of **data security and access control** must be ensured.
- Not all geographic databases can or should be exposed on the open web — **data exposure must be selective and risk-aware**.
- Overriding principles (Service vs Infrastructure also the Geographic/Regional overriding)
- In Regulation Service and Infrastructure are usually handled separately
- Telephony vs Electronic Communications (the modern vision)

Focus: Estimate the speed – case FTTC

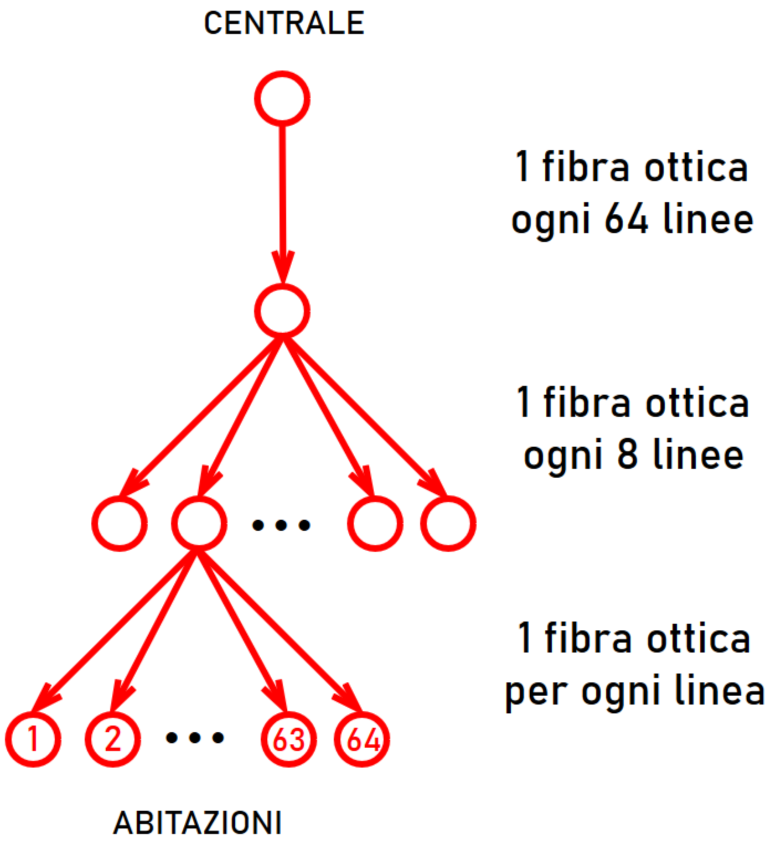
Speed Models



Focus: Traffic Model

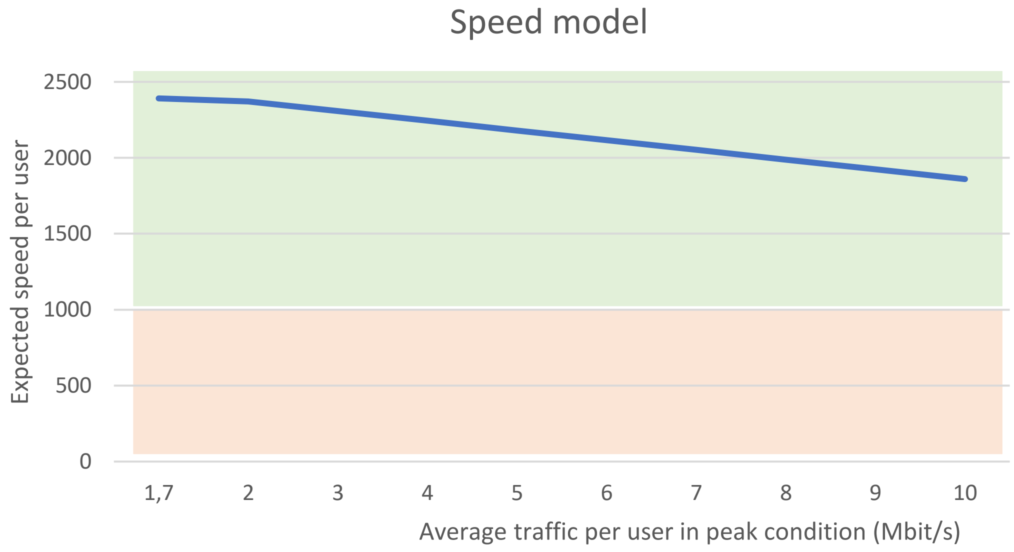
- We need models that are neutral across technologies and based on real quality, not just nominal speed
- Key entry point to understand the system load is the verification methods generally accepted by regulation
- It is generally agreed that we can check the speed using the speed test tools
- Speed Test output is the direct consequence of the: 1) maximum speed (that is the capacity C defined as speed experienced when there is only one user in the system); 2) system load (ρ): $S = C\,(1-\rho)$
- By extending traffic models, we can better describe how broadband networks actually perform
- This approach was validated with operator data and used in Italy to guide public policies in areas with market failure

Focus: estimate the speed – Case FTTH



2.5 Gbit/s shared by 64 users

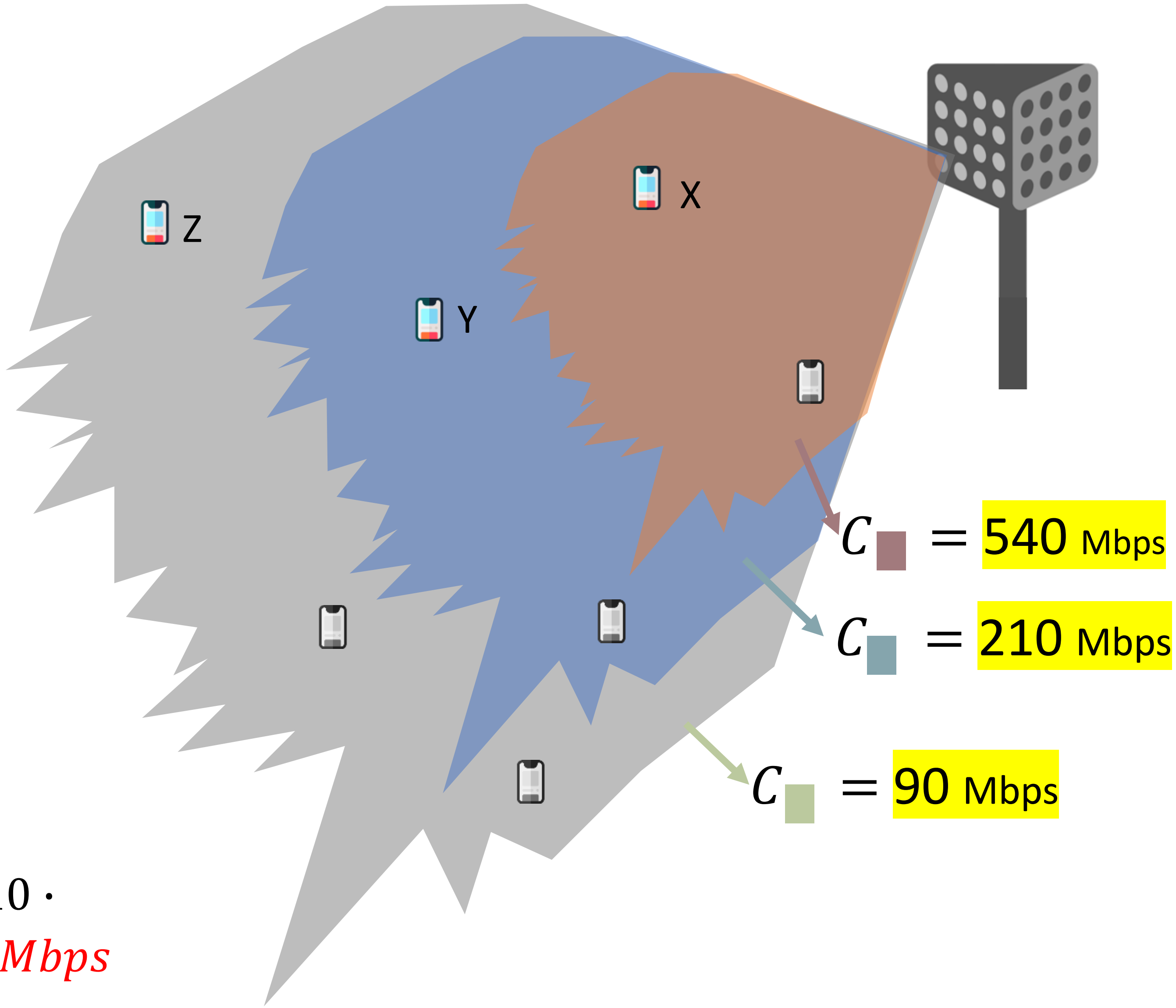
- Maximum load: 2.5/64= 39 Mbit/s (clearly not realistic)
- With traffic model we get higher speeds



Focus: Estimate the speed – Case 5G

- **Deterministic model**
  - X, Y, Z always active (full buffer)
  - No other traffic
  - *Instantaneous rates*:
    - $c_X = \frac{540}{3} = 180\ Mbps$; $c_Y = \frac{210}{3} = 70\ Mbps$; $c_Z = \frac{90}{3} = 30\ Mbps$

- **Traffic model**
  - Average traffic generated:
    - Red area: 108 Mbps
    - Blu area: 21 Mbps
    - Green area: 21.6 Mbps
  - $\rho = \frac{108}{540} + \frac{21}{210} + \frac{21.6}{90} = 0.5$
  - *Peak rates*:
    - $S_p^X = 540 \cdot 0.5 = 270\ Mbps; S_p^Y = 210 \cdot 0.5 = 105\ Mbps; S_p^Z = 90 \cdot 0.5 = 45\ Mbps$



Focus AI

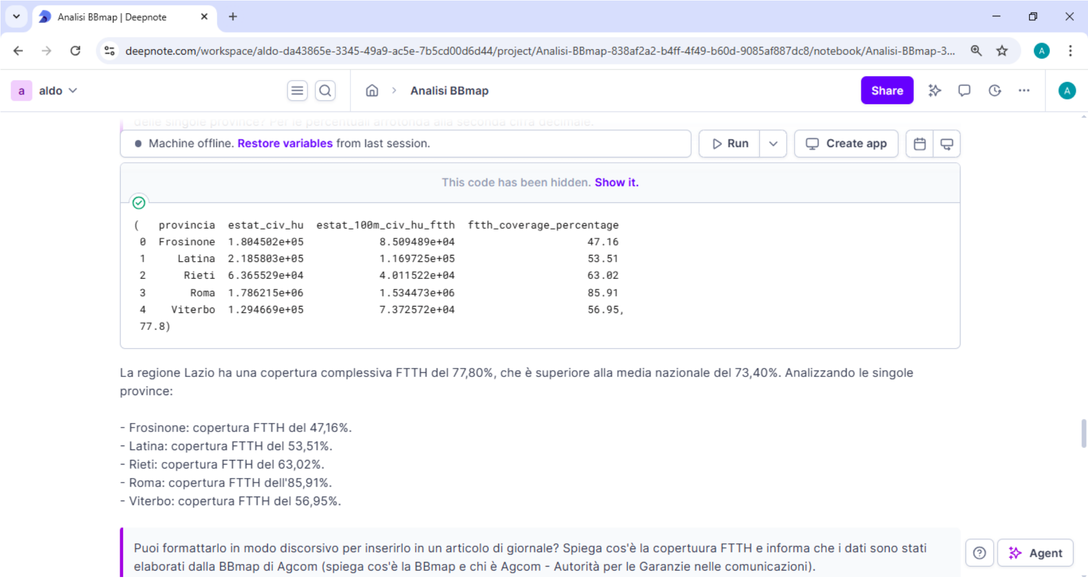
In order to ease Broadband Mapping:

- **Automatic image analysis (in use):** AI models are applied to aerial imagery for the identification of buildings and land-use classification. The system automatically detects and classifies polygons, a task hardly feasible through manual processing.
- **Automatic drafting of reports (in use):** AI tools generate structured reports from BBmap data (example of AI Generated Textual Report), following an *agentic RAG* approach (data are retrieved from authoritative systems, not generated by the LLM). All outputs are subject to human supervision to prevent prompt poisoning or hallucinations; the AI does not publish directly on the website.
- **AI middleware for the BB search engine (under development):** a generative AI layer is being tested as middleware to allow natural-language interaction with the BBmap search engine, improving accessibility and data exploration. Data are retrieved from authoritative systems, not generated by the LLM.

Focus AI - Automatic image analysis

- Roof Detection - deep learning from aerial images

Benefits of AI-powered notebooking for the Broadband Map



- Direct access to BBmap data without writing complex queries
- Automatic narrative generation (clear texts for articles and reports)
- Fast reporting: tables, charts, and summaries from official AGCOM data
- Easier collaboration between technical experts, analysts, and communicators
- Improved efficiency: less time, fewer errors, more transparency

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