MANAGING COMPLEXITY: AUGMENTED INTELLIGENCE FOR 5G RADIO ACCESS DESIGN AND OPTIMIZATION

Simone Bizzarri, Paolo Goria, Roberto Lanzo, Andrea Schiavoni

The challenges of 5G Radio Access Design

5G will enable a wide variety of applications leading to significative challenges for the evolution of Radio Access design methodologies. As an example, the exploitation of "Internet-of-Things" will extend connectivity requirements to any kind of device, in any possible position, from the underground (e.g. pipe monitoring, metering, etc) to the sky (e.g drones applications - see dedicated box *"Design of Drone Ready Radio Access Network"*).

As a further challenge, frequency ranges are extended, both in terms of new available bands and in term of aggregated bandwidth. As an example, frequency ranges auctioned in Italy in 2018 include 700 MHz band and 3700 MHz band, in the same frequency range of traditional mobile communication, ranging from hundreds up to thousands MHz, but also 26 GHz, in the millimeter waves (mmW) band.

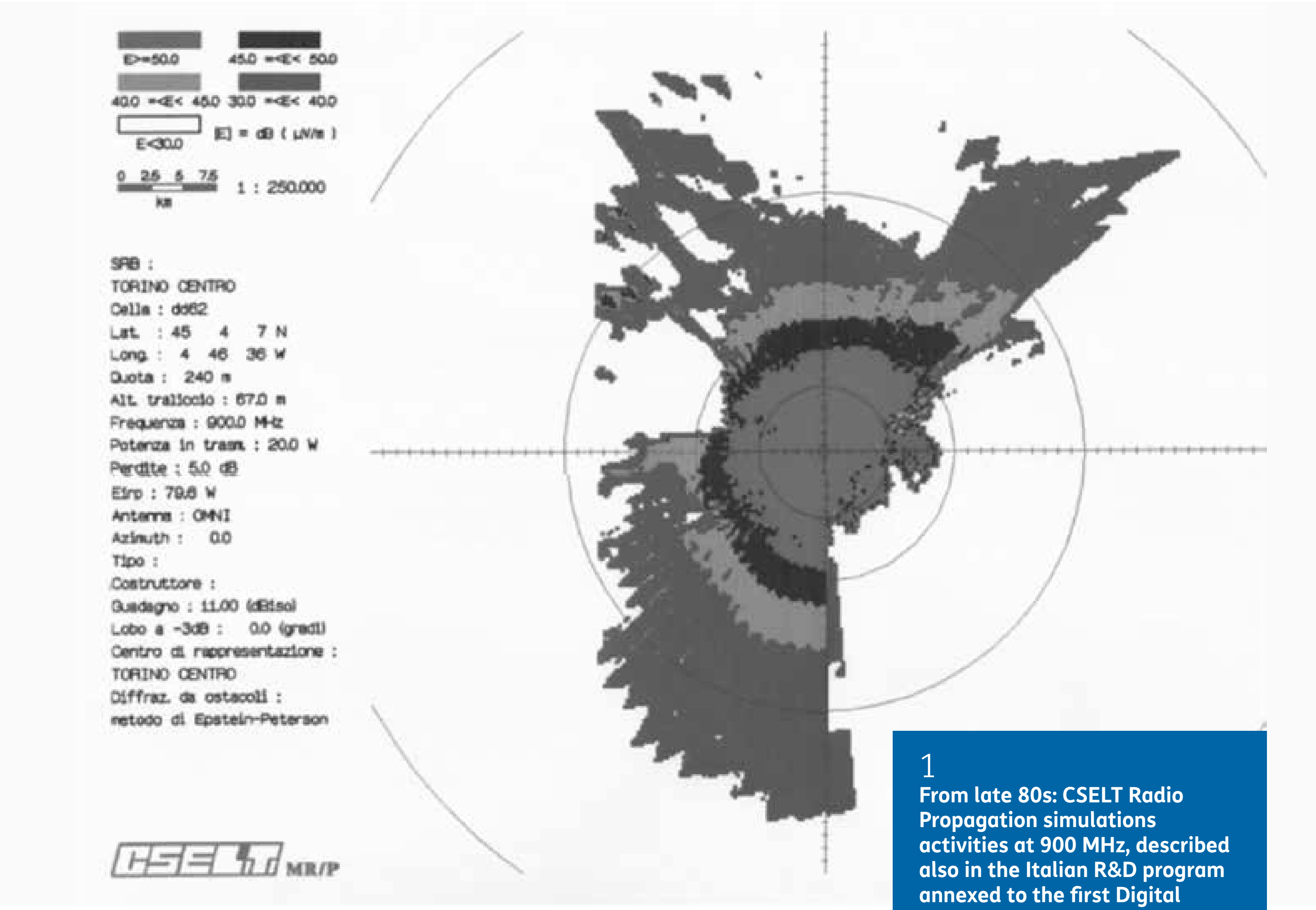
To cope with this fast evolution, a new approach to the whole mobile network planning, optimization, maintenance and management is required. In details, the following streams have to be addressed by the mobile network operator to manage and drive the changes:

- Evolution in coverage methodologies able to manage the use cases heterogeneity;
- Network optimization techniques evolution to manage new technological opportunities enabled, e.g. beamforming and MU-MIMO (*Multi User MIMO*);
- Automation, to manage complexity through an effective SON (*Self Organizing Network*).

Augmented intelligence, enabled by software aided methodologies and solutions, is considered by TIM a key factor to manage the above-mentioned challenges.

Background: propagation modelling up to 4G

Since the early '80s TIM, has developed internally its proprietary radio coverage planning tools to control the whole network design process. The propagation models used for cellular coverage estimation were based on *statistical methods* enhanced in precision through drive test *measurement campaigns*. A basic assumption for these methods is the definition of *typical conditions* to characterize few different environments surrounding the user equipment, typically considered at ground level. The most known example of statistical models was described in 1968 by *Okumura*, whose paper [1] showed some propagation curves based on several measurement campaigns carried out in the years 1962-1965, and *Hata* [2] whose objective was to define an



1
From late 80s: CSELT Radio Propagation simulations activities at 900 MHz, described also in the Italian R&D program annexed to the first Digital Cellular Cooperation Agreement at the origins of GSM, 1987.

equation to analytically represent Okumura's propagation curves. Hata's equation can be considered a reference milestone, still valid to estimate the propagation loss in a radio mobile environment.

The statistical macro-cellular propagation models mentioned before, in general, do not consider specific effects such as fluctuations of the radio channel, multi-path, outdoor-to-indoor penetration, etc. These effects are accounted through appropriate parameters, namely *margins*, that are statistically characterized by means of measurement campaigns.

In the TIM's approach the original Hata equation has been updated, modified and tuned to increase its precision and to manage more detailed territorial information:

- The refraction phenomenon is considered by using the equivalent earth radius, since in the troposphere the propagation path is not parallel to the earth surface;
- The diffraction due to multiple obstacles is modelled by means of "knife edges" approach whose contribution depends on the material and is derived from dedicated measurements campaigns;
- The effect of buildings and green areas is calculated with empirical approach and depends on a detailed territorial classification (more than 100 classes with respect to the standard environments Urban, Suburban, Rural).

Deterministic approaches, such as Ray Tracing described in the next section, were introduced in the 70's – a large reference section can be found in [3], but – due to the challenging computational requirements – were limited to specific application, such as microcells coverage design or electromagnetic field exposure evaluation in proximity of antennas [4].

Intelligent ray tracing: an enabler for 5G Radio Design

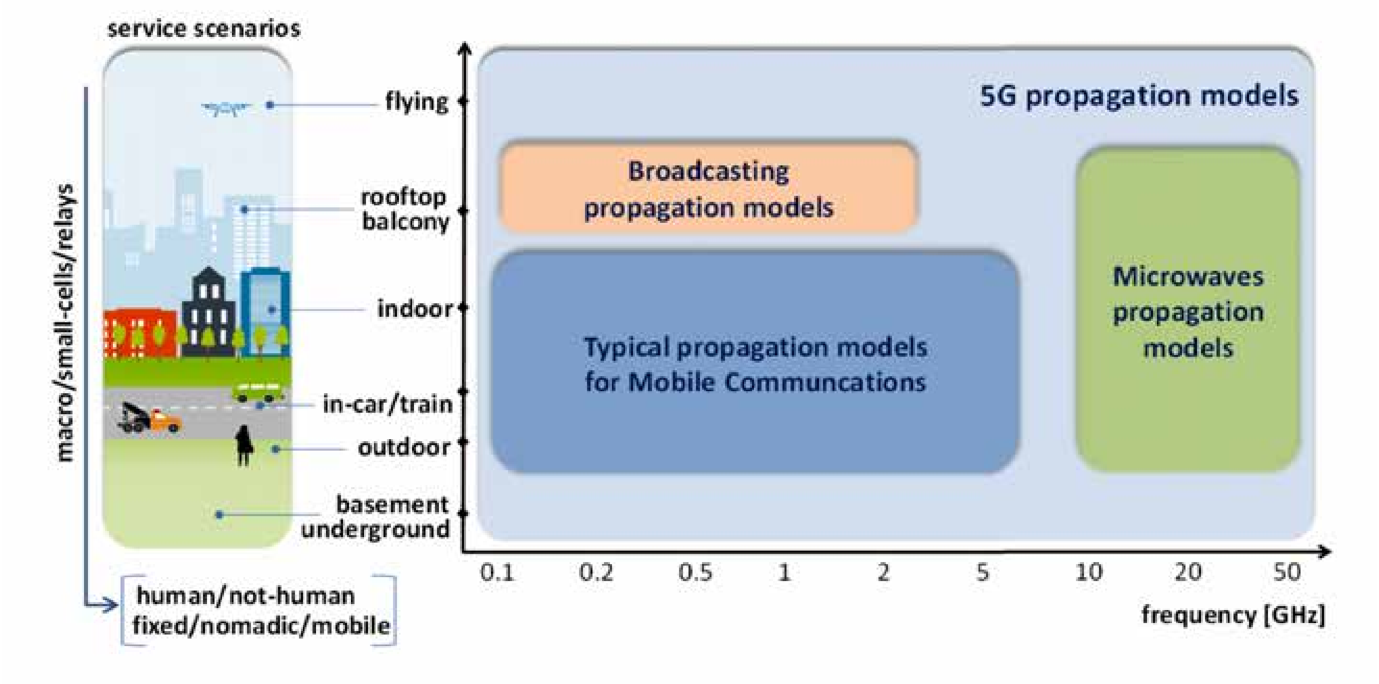
When facing 5G radio design, propagation models have to evolve, in order to cope with the challenges mentioned in the introduction:

- Connectivity for any device, in any possible location, facing the extreme heterogeneity of 5G application scenarios.
- New Frequency Ranges: 5G technologies exploit frequencies that range from 0.7 to 70 GHz (even 100 GHz and beyond are going to be considered too), requiring a new approach to evaluate the electromagnetic field distribution in the environment, focused on deterministic models.
- New Antenna Systems: TVA (*Time Variant Antennas*) represent a relevant improvement in the 5G technology. Differently by traditional passive antennas, time variant antennas (or active antennas) change the radiation behavior depending on the user requirements, in terms of location and services, in order to optimize the whole system performances. The active antenna can modify, over the time, its radiation characteristics to deliver the field where it is needed, with the needed intensity, for the time needed. Time Variant Antennas require new approaches for the management of the SINR (*signal-to-interference-ratio*) and, consequently, the management of the quality of service.

Figure 2 shows the relationships between scenarios and propagation models in a 5G perspective.

In order to face all these issues, without using a plurality of models defined on a case-by-case basis (that would lead to operational

2
5G propagation scenarios and models



DESIGN OF “DRONE READY” RADIO ACCESS NETWORK

domenico.arena@telecomitalia.it
marco.gaspardone@telecomitalia.it
simone.piacco@telecomitalia.it

Nowadays, UAVs (*Unmanned Aerial Vehicles*), commonly known as drones, are being proposed for main IoT (*Internet-of-Things*) scenarios: they are being used for several applications in real time video surveillance or environment monitoring, envisaged in the context of 5G ecosystems (*verticals applications*). These applications are typically limited when considering traditional dedicated point-to-point radio control, not suitable for a massive-UAV scenario: a *cloud architecture* based on 4G/5G mobile network can be the best solution to enable and optimize vertical services.

More specifically, UAV can play the role of a mobile sensor node that collects data from target sites and transfer it to the cloud, exploiting all *cloud computing* capabilities. On the other hand, a cloud based architecture allows remotely to set and coordinate critical missions for connected UAV’s. For this purpose, the UAV should relay both on good aerial wireless coverage and radio resources management able to control interference and optimally allocate resources.

In 2018 TIM launched *Drones Ready Network* project, an activity aimed to characterize and optimize radio coverage also at drone altitudes, in order to guarantee high quality services, manly in terms of throughput and latency.

In this framework, the capability of simulating mobile coverage, either for 4G and 5G networks, is a fundamental brick for the design of “drone ready” wireless networks. Thanks to proprietary IRT (*Intelligent Ray Tracing*) *models, TIM is pioneering this field*, exploiting advanced tools for the prediction of *aerial coverage* in connected drones scenario (3GPP UAV propagation models).

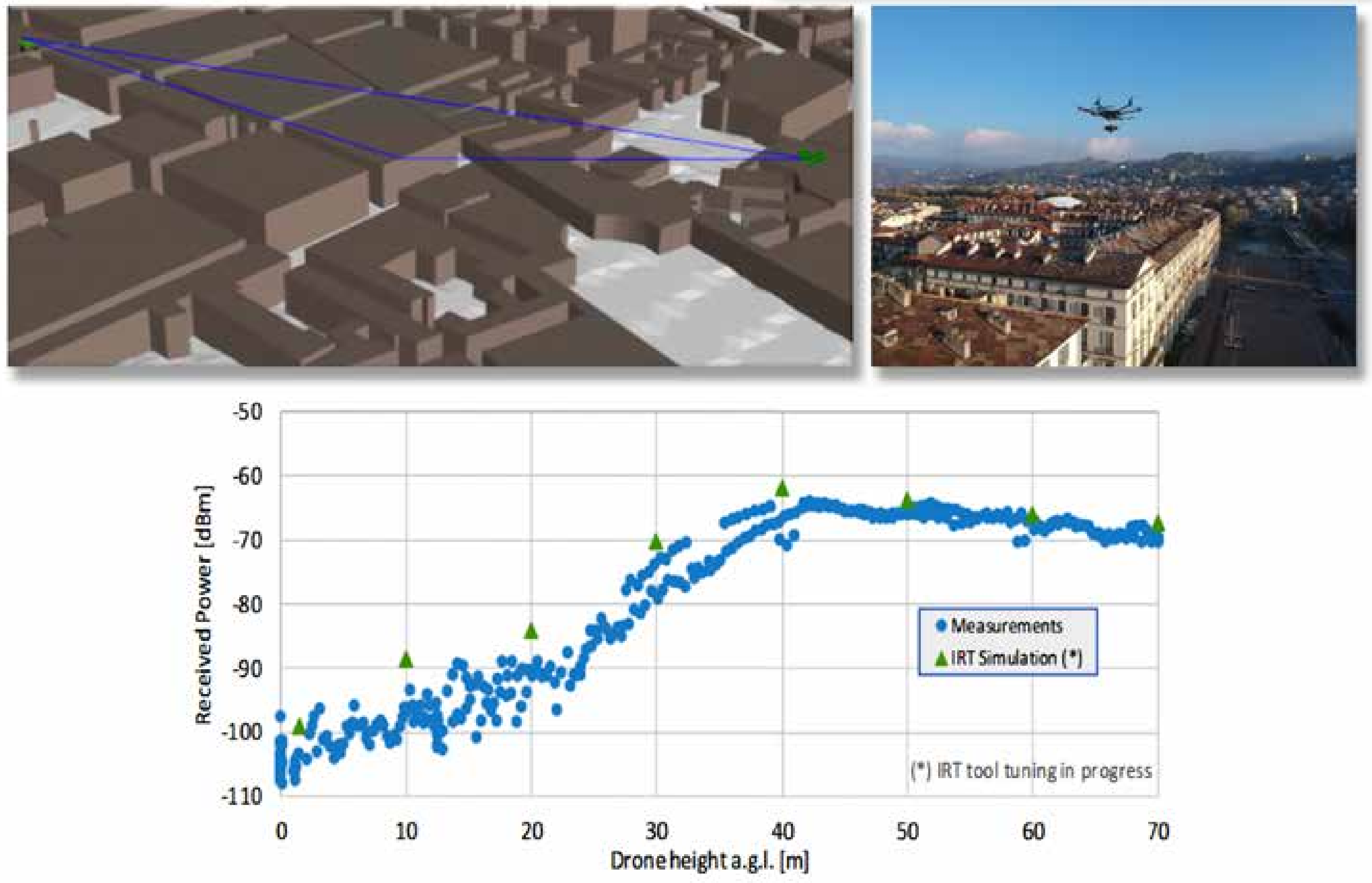
Ad hoc *measurement campaigns* were performed to validate and tune the UAV models in various propagation scenarios, focusing on urban areas where drones operations are more challenging. Good agreement between measurements and simulation was experimented.

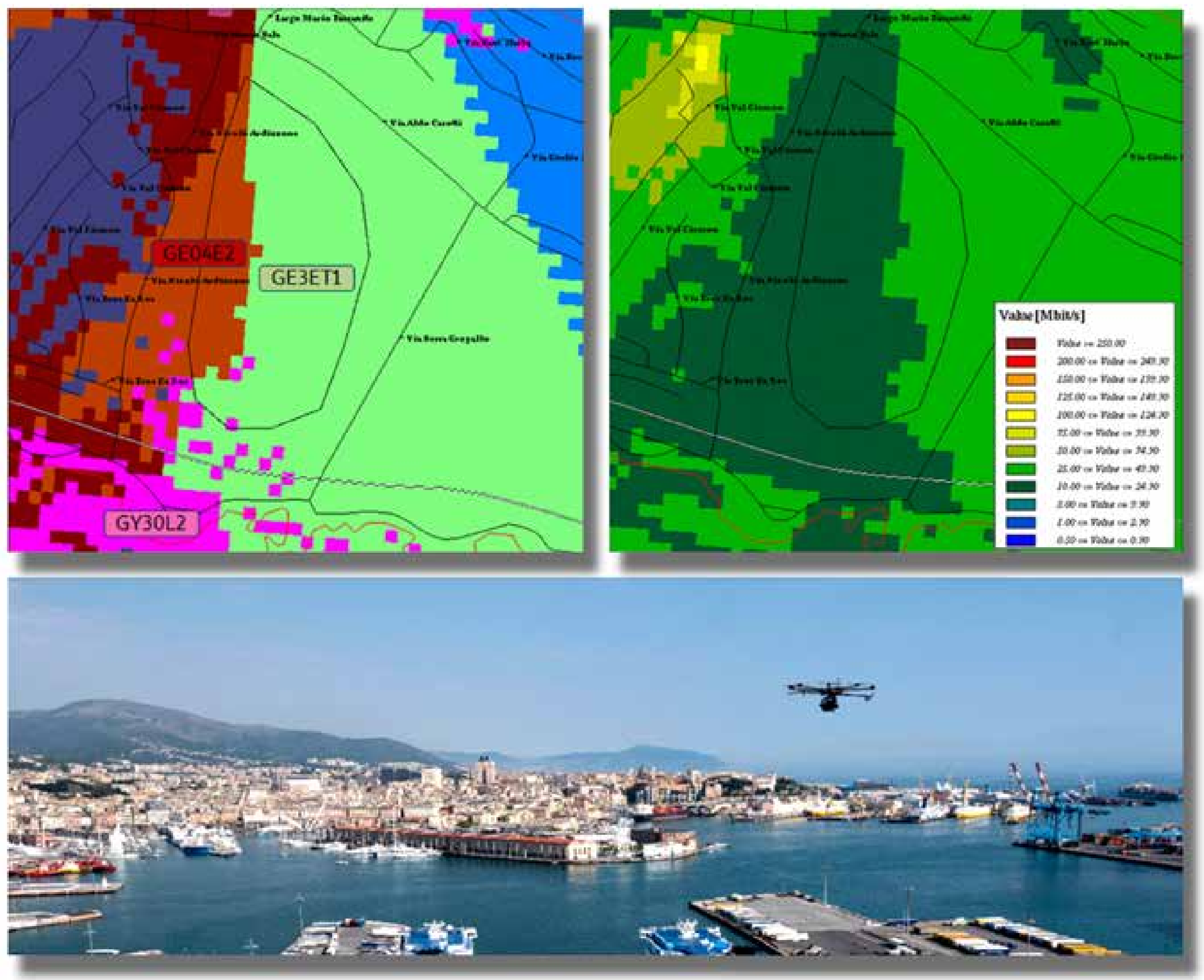
On the other hand, *Interference analysis* identified some potential issues in case of *massive connected-UAV’s* scenario: significant uplink interference increase for “*mobile ground users*”, due to drone-to-ground transmissions impacting over wide areas.

For such a reason, overall *network performance analysis* focused on aerial users (e.g. in terms of up-link and down-link user throughput estimation) has to be

Continua→

A
DRNet ray tracing simulations and measurements campaign in Turin – November 2018





B

Liguria Digitale feasibility study and simulations: best server and throughput map @ 30 m a.g.l – May 2019

carried out, exploiting both simulations and measurements, including MDT (*Minimization of Drive Tests*) features, able to collect geo-referenced measurements directly form the drones. Active antennas will play an important role in this context, with the possibility of automatically generating specific beams directed towards aerial users.

The above summarized process was efficiently applied on a *RT HD Environmental Monitoring UAV demo*, into the framework of *Liguria Digitale*, as proof-of-concept for the incoming 5G use cases applicable in the future *smart cities*. Coverages and throughput maps both at ground and aerial levels were provided for preliminary feasibility study and localization of demo trial site ■

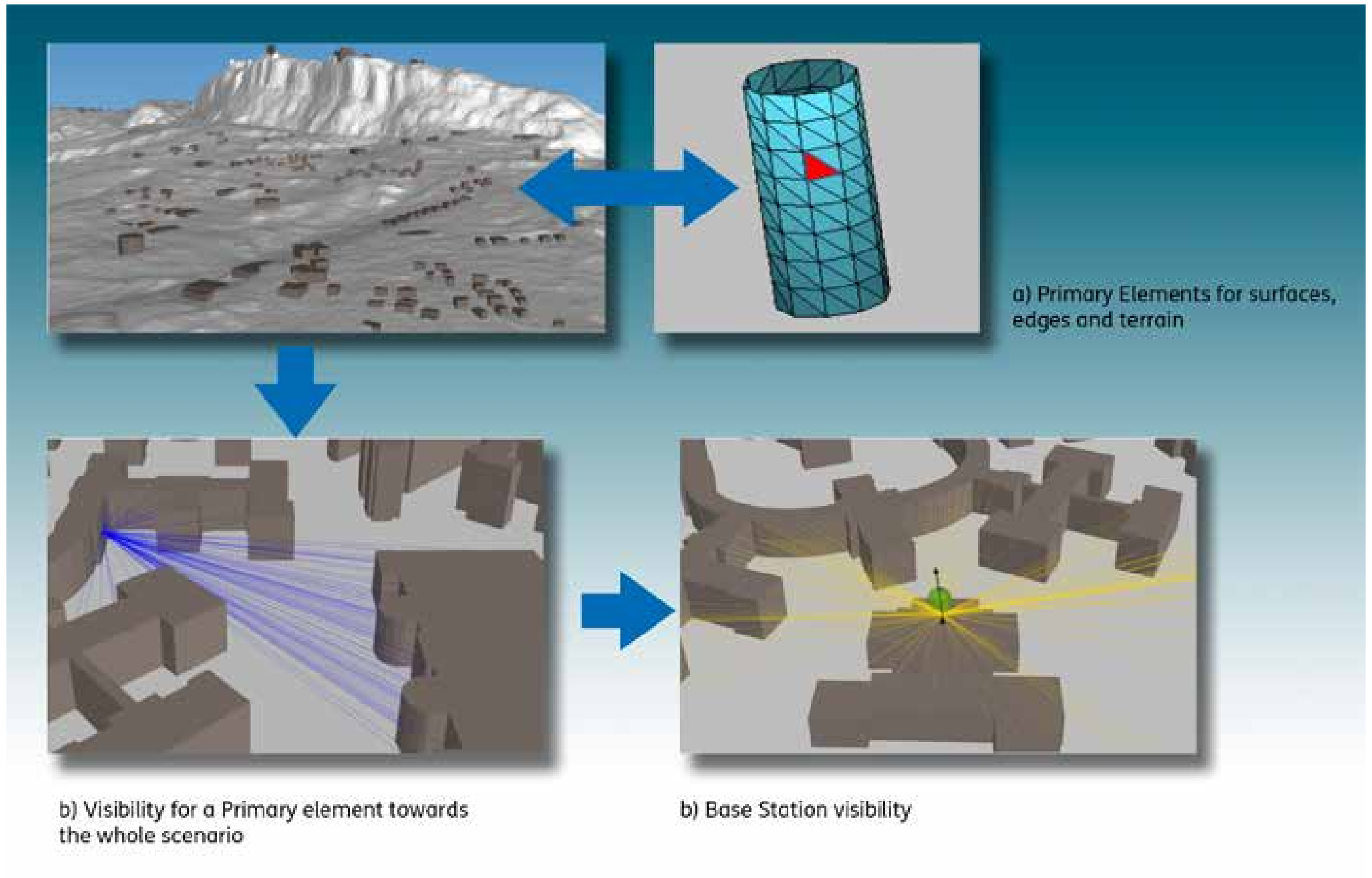
complexity), *deterministic approach* to field estimation has to be preferred, capable of characterizing the propagation on the base of the physical laws describing the interaction of the electromagnetic fields with materials, which represent a stable basis for analyzing the heterogeneous 5G scenarios. As a consequence, *ray-tracing* techniques have to be considered. Ray tracing is based on the characterization of the electromagnetic wave by mean of rays, namely the unit vector normal to the surface wavefront, that interacts with the environment by the basic electromagnetic mechanisms: reflection, rifraction and diffraction. This approach requires a 3D representation of each object inside the scenario such as building, urban furniture, vegetation areas, terrain, etc, including permittivity and conductivity of each material. In general, the number of possible geometrically identifiable electromagnetic paths is very high. This is the reason why the ray-tracing approach is very reliable in terms of accuracy of the result at the cost of increasing computational resources as a function of the size of the scenario and its spatial definition. As a matter of fact, application of ray tracing to wide area scenarios with acceptable computational times is still a challenge for state-of-the art propagation modelling tools.

To cope with this complexity, TIM has developed internally a *full 3D ray tracer* based on the *IRT* (*Intelligent Ray Tracing*) *approach* [5], able to operate accurately for any base station configuration, i.e. macro, micro, indoor, including outdoor-to-indoor propagation and considering also receiver characteristics on the user side. Computational time has been optimized using innovative optimization algorithms and approaches, some of those patented, which allow reasonable execution time even in large scenarios (in the order of some hundreds of square kilometers). The IRT approach can be described with three steps:

1. **Creation of the environmental model**: the whole area is divided into PE (*Primary Elements*), with proper dimensions (related to frequency) and shape, that are rectangles, triangles and segments, *Figure 3a*. Result of the process is a 3D discretized representation of the scenario. The process can manage also different size primary elements to increase flexibility in the representation of each object.
2. **Generation of the Optical Visibility Database**: Once the whole scenario has been discretized, the visibility relations among all couples of PE is determined, *Figure 3b*, only once. Until the scenario does not change, the visibility relations among paired tiles do not change, thus representing a geometrical invariant, that can be stored and re-used for analyzing different radio network configurations.
3. **Base Station Positioning and field computation**: only the visibility relationships of the base station versus each PE must be calculated, since when a primary element is in view of the base station, the graph computed in the previous step can be used. The term visibility indicates the determination of all the paths, pre-determined in the previous step, that are in relationship according to the electromagnetic mechanisms of interaction (even for refraction) with the Base Station. Field level is then computed in each observation point by surfing on the visibility tree up to the base station, considering all the possible available paths. The electric field vectors related to each path are composed to derive the total field level in the point. Thanks to the information previously stored in the database, a reasonably low amount of computational resources are required for this step, leading to acceptable computational burden also in case of relevant areas under analysis (e.g. a major city). *Figure 3c* shows the rays originated by the base station towards all the primary elements in its visibility.

Validation and calibration of the computational tools with measurement campaigns are fundamental to get the required and necessary reliability for the design of the radio access network.

Figure 4 shows the comparison between simulations and measurements in terms of the absolute received power as a function of floor



a) Primary Elements for surfaces, edges and terrain

b) Visibility for a Primary element towards the whole scenario

b) Base Station visibility

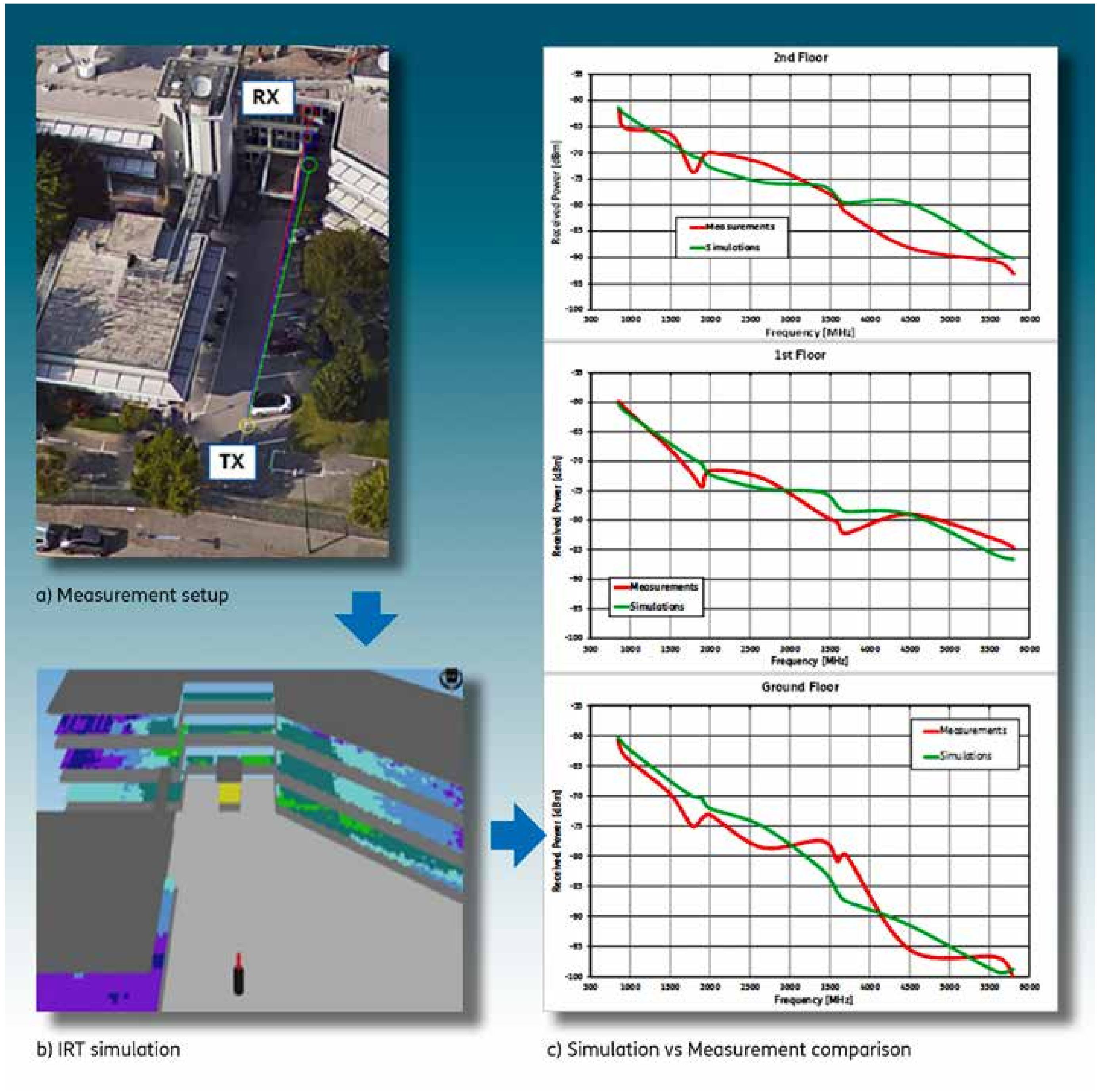
3
The three phases of Intelligent Ray Tracing (IRT) approach

height and frequency for the analyzed scenario. It can be noted that the difference between computations and measurement is very limited and even the sharp changes on the received power because of the stratified glasses have been correctly modelled and represented. The accurate characterization of the electromagnetic properties to the materials present in the scenario is a fundamental aspect when assessing the reliability of the simulations.

5G Radio access design examples

Thanks to the flexibility and the effectiveness of the adopted approach, IRT model was integrated in TIMplan radio design tool, developed in house by TIM and exploited during 5G TIM trials, assessing both LTE Advanced and NR (*New Radio*) coverage, both contributing to the 5G service, when considering NSA (*Non Stand Alone*) options defined by 3GPP. *Figure 5* show different examples of field estimation related to TIM Trials in Torino, San Marino and Matera, addressing scenarios with complex orography.

Figure 6 shows simulation examples related to FWA (*Fixed Wireless Access*) applications at 3.7 GHz in urban scenario: IRT model can estimates SINR levels also inside buildings, considering refraction and material properties. Different hypothesis for CPE (*Customer Premises Equipment*) are compared through simulations: indoor installation with omnidirectional antenna, considering outdoor-to-indoor propagation; outdoor installation with omnidirectional antenna and with directive antenna optimized considering base station position, the latter case showing the best performance in term of user throughput, directly related to SINR level.



a) Measurement setup

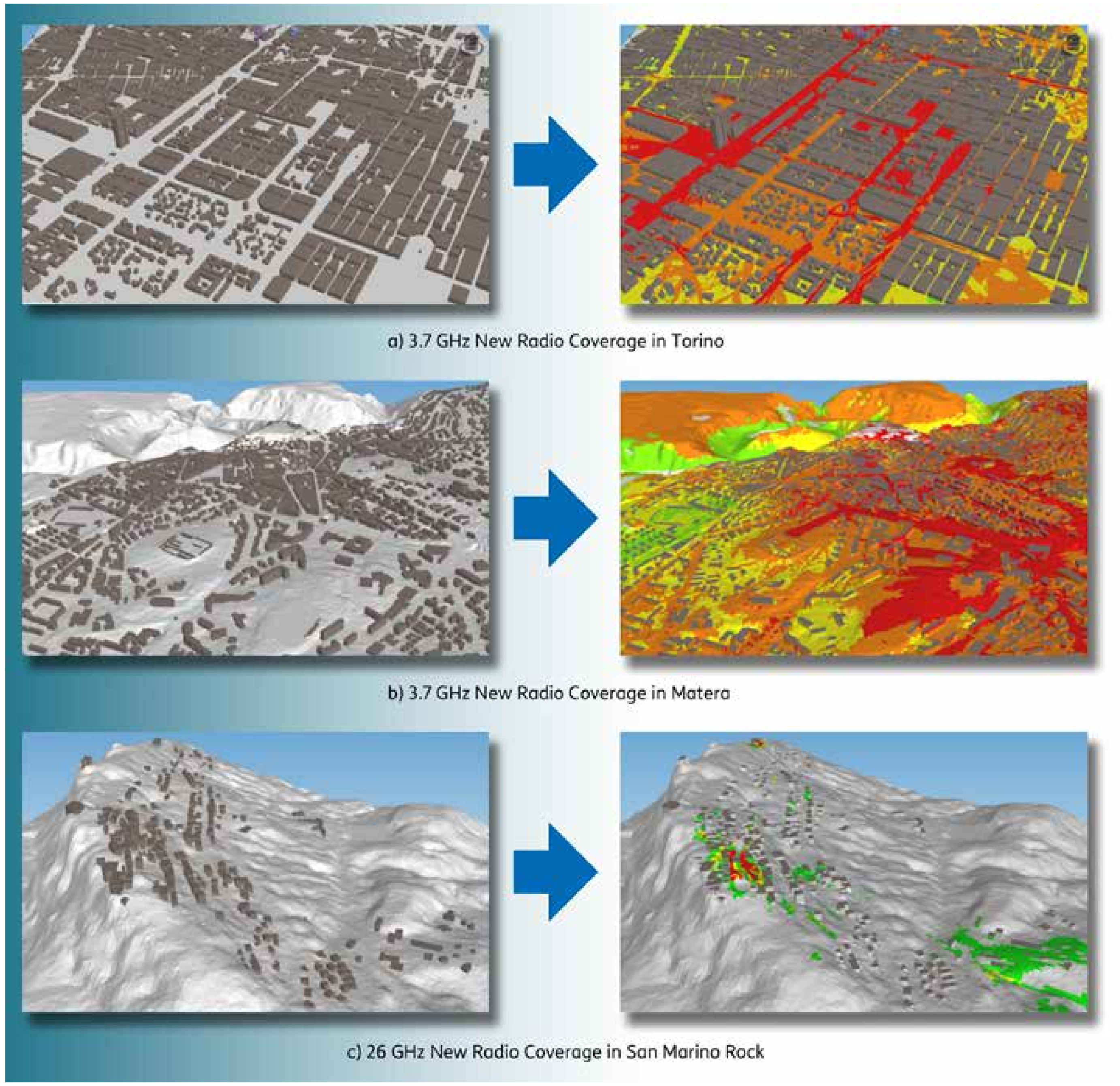
b) IRT simulation

c) Simulation vs Measurement comparison

4
Verification of IRT model with outdoor-to-indoor measurements: simulations and measurements as a function of floor and frequency

5G radio access automation and optimization: towards AI

As already mentioned in the introduction, one of the most impacting technologies charactering 5G is the usage of TVA (*Time Variant Antennas*) able to change, in real time, the radiation performances and, consequently, the coverage. This kind of capability requires active antenna arrays with a relevant number of


a) 3.7 GHz New Radio Coverage in Torino

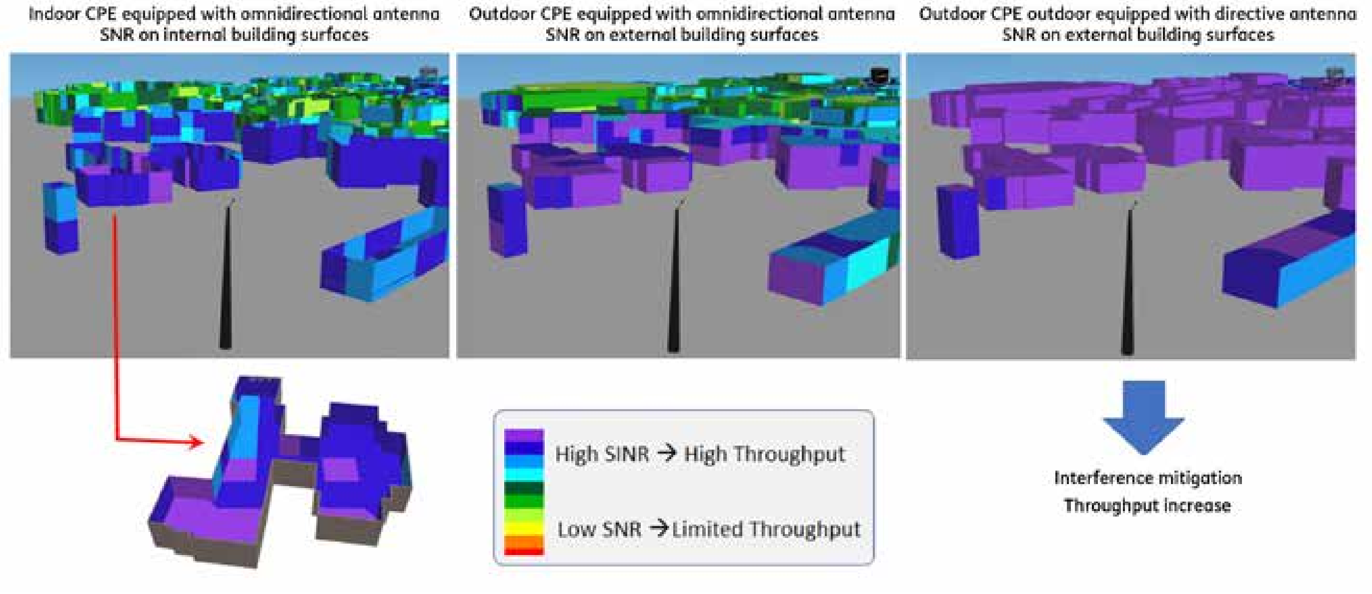
b) 3.7 GHz New Radio Coverage in Matera

c) 26 GHz New Radio Coverage in San Marino Rock

5
5G Radio access design examples exploiting IRT modelling

Transmitters (T) and Receivers (R): antennas with 64 T and 64 R, as an example, are being exploited in TIM Trials. Antenna arrays enables MU-MIMO (*Multi User Multiple Input Multiple Output*), where each antenna element transmits a portion of the payload that is recomposed at receiver level, making use of the spatial diversity.

An example of coverage generated at 3.7 GHz by two dedicated traffic beams of a Time Variant Antenna is depicted in *Figure 7*.



6
Coverage for NR 3.7 GHz for Fixed Wireless Access Scenario in urban area

7
Coverage at 3.7 GHz generated by two dedicated traffic beams of a Time Variant Antenna in Turin downtown

ENABLING SOFTWARE INTELLIGENCE ALL OVER THE WIRELESS ACCESS: THE O-RAN INITIATIVE

andrea.buldorini@telecomitalia.it
marco.caretti@telecomitalia.it
gianmichele.dellaera@telecomitalia.it
salvatore.scarpina@telecomitalia.it

Open RAN Alliance (http://www.o-ran.org) is an industry initiative resulting from the merging between xRAN Forum with the C-RAN Alliance, with the objective to form a world-wide, 'carrier-led' effort to push more openness into the radio access network of the next-generation wireless systems. It is supported by AT&T, China Mobile, Deutsche Telekom, NTT DOCOMO, Orange, Verizon and TIM and other telco operators.

The openness of network architecture and interfaces is carried out in two main tracks:

1. Defining implementation requirements by means of "profiles" defined on top of Specifications provided by the relevant Standard Development Organizations, like 3GPP, so that multi-vendor interoperability of RAN functions is ensured. This aspect involves both functional interfaces and management interfaces
2. Introducing new functions and interfaces to centralize the key radio resource management functions in a RIC (*RAN Intelligent Controller*) interworking with the existing RAN functions (e.g. gNB-CU and DU) where customized algorithms, empowered by the adoption of Artificial Intelligence / Machine Learning techniques, can be designed and implemented as Cloud Native Applications.

Near Real Time RIC exposes RAN capability and resources towards the Management and Orchestration layer over A1, an "intent-based" interface used to instruct RAN with performance targets and Radio Resource Management policies. The new A1 interface will complement Network Management and Orchestration O1 interface providing fault-management, configuration, accounting, performance, and security (see figure).

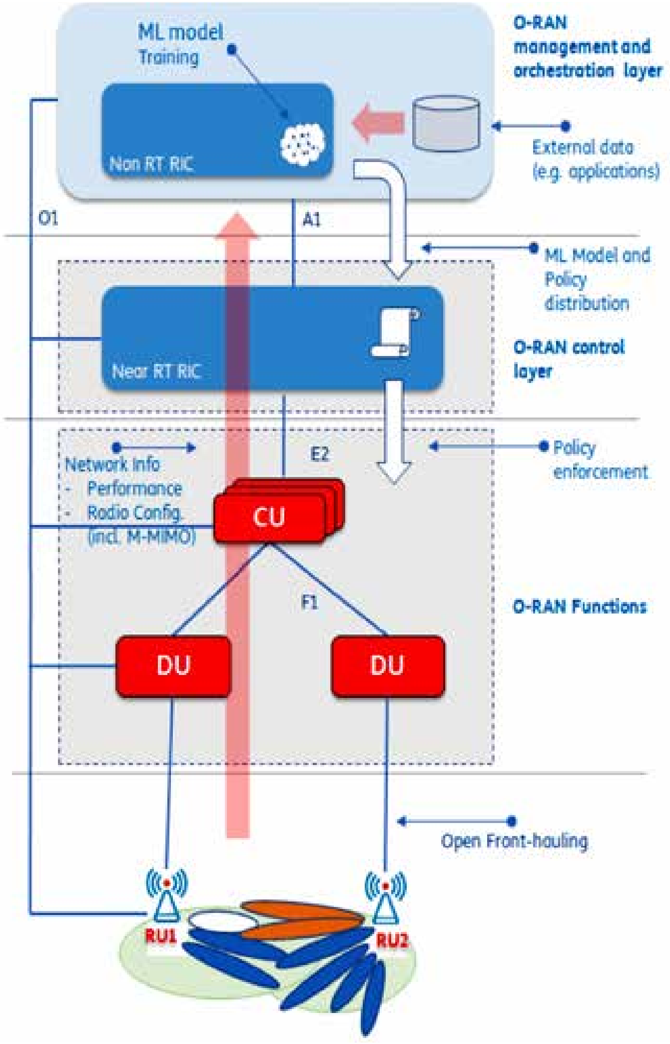
The enforcement of RAN policies is then performed by coordinating resources and algorithms in the RAN functions as defined in the 3GPP RAN Architecture, i.e. CU-CP, CU-UP and DU. In addition to 3GPP architecture, O-RAN architecture introduced a further functional split of the Layer 1 protocol stack in the DU over an Open Fronthaul interface, resulting in the separate O-DU and O-RU functions.

The modular, open, intelligent, efficient, and agile disaggregated radio access network resulting from the O-RAN reference architecture is expected to facilitate the exploitation of Hardware/ Software separation and the adoption of open source solutions.

With this aim, the "O-RAN Software Community (SC)" (www.o-ran-sc.org) was created as a collaboration between the O-RAN Alliance and Linux Foundation with the mission to support the creation of software for the RAN (*Radio Access Network*). The O-RAN SC plans to leverage other LF network projects, while addressing the challenges in performance, scale, and 3GPP alignment. Coordination and synergic effort is also expected towards ONAP and 3GPP with particular focus on Network Management and Orchestration architectures and platforms.

The use case "3D MIMO Beamforming Optimization", proposed in O-RAN by TIM, Orange and CMCC is an example of how 5G M-MIMO capability can be exploited to adapt the network coverage and capacity based on service requirements and traffic distribution (see figure):

- a dedicated function (Non Real Time RIC) in the management layer retrieves necessary configurations, performance indicators, measurement reports and other data from Configuration and Performance Management for the purpose of constructing/training relevant AI/ML models. Moreover other information from the application layer (e.g. GPS location of users) and mobility pattern predictions can be used to enrich the model;
- the trained AI/ML model is transferred to the near-Real Time RIC and may be used to infer the user distribution of multiple cells, and predict the optimal configuration of radio resources and M-MIMO parameters for each cell according to a global optimization objective designed by the operator;



O-RAN Architecture: Example Use Case "3D MIMO Beamforming Optimization"

- optimal beam pattern configuration and/or policy are then applied by changing the configuration in the affected CU/DU/RU;
- the fulfillment of the network performance is checked against the new targets and the adopted configurations. Periodic model retraining and policy adjustment is then performed to cope with the dynamic nature of the traffic and the user distribution ■

TVA and MU-MIMO are significant examples of the complexity behind 5G mobile network and corresponding functionalities, where configuration parameters increased compared to 4G and to previous mobile generation, making more and more challenging the identification of optimal parameters' set.

In this field, ML (*Machine Learning*) approach can play a relevant role in defining optimization methodologies and algorithms: ML applications provide systems the ability to automatically "learn and improve from experience without being explicitly programmed" (as stated by Arthur Samuel, pioneer in the field of artificial intelligence), and this could really become beneficial in contexts where many degrees of freedom lead to huge number of combinations, like the one of selecting e.g. the optimal beam(s) and power level(s) configuration of a 5G cell at each transmission interval.

As represented in *Figure 8*, training of ML-based models can based on the collection of several network configurations together with corresponding network performances and traffic distribution on the territory, in order to predict network behavior. Once trained, ML-based models can be deployed in the network in order to derive the optimal antenna and radio resource configuration, starting from the observation of the status of relevant network variables (in closed loop and in near real time).

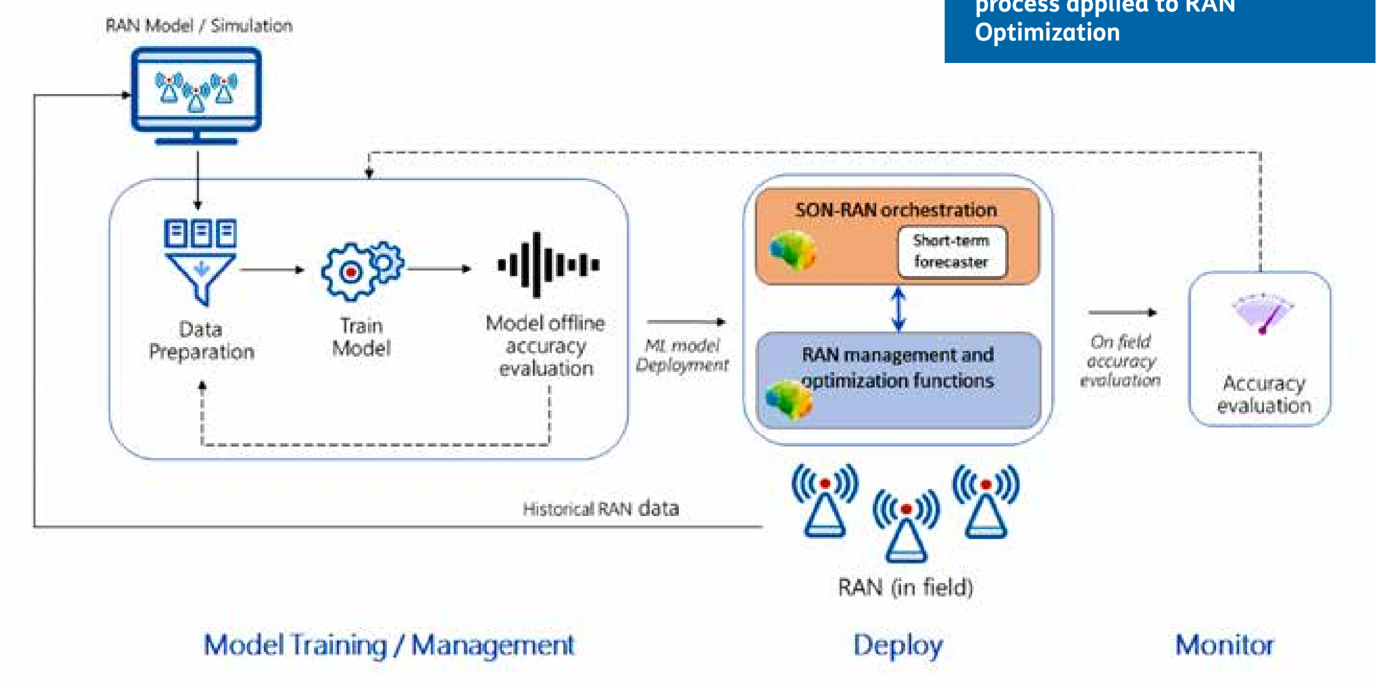
In particular, Deep Neural Networks (DNN) and deep reinforcement learning techniques might become the basis for defining both prediction and optimization functionalities. Adoption of ML-based algorithms lead to the necessity of dedicated monitoring functions able control the level of ML performance (accuracy). In case of accuracy degradation detection, a re-training process can be activated, in order to align the model with the new scenario characteristics.

An exemplary flow diagram for exploitation of ML in radio network optimization is shown in *Figure 8*.

Considering the exemplary flow diagram in *Figure 8*, the ML-based model is built using network modelling, e.g. based on the models described in the previous sections, as an input. Once the model is available, it is deployed in the network and exploited by the SON-RAN Orchestrator functionality SON-RAN Orchestrator is a key building block of TIM RAN automation architecture, exploiting open interface, through network management systems, to enable closed-loop operation towards the network nodes.

8

Machine Learning exemplary process applied to RAN Optimization



The need for smarter optimization capabilities, together the continuous increase and extension of mobile traffic to be served by the networks, make necessary that mobile networks and related equipment become more software-driven, virtualized, flexible, intelligent and energy efficient, towards a fully automated radio access network.

More in particular, the introduction of virtualized network elements, based on software able to run on generic COTS (*Commercial Off-the-Shelf*) hardware with open and standardized interfaces and, will enable a more cost-effective and agile RAN operations. In this scenario, real-time analytics driving ML modules, embedded both in the access network and in the operator's management systems, will empower network intelligence.

All these pillars are addressed by the O-RAN (*Open RAN*) Alliance (see dedicated box), that is committed to lead the evolution of radio access networks making them more open and smarter than previous generations:

- **Openness in both interfaces and software**: O-RAN defines open interfaces between any component and layer in access network, enabling multivendor deployments - that increase competition in the supplier ecosystem - and allowing quick introduction of new services and functionalities or specific network customizations; in addition, open source software and hardware reference designs enable faster innovation.
- **Intelligence everywhere**: in O-RAN architecture intelligence is embedded in every layer and element, leveraging new ML-based technologies to automate operational network functions and, thus, enabling both dynamic local radio resource allocation and networkwide optimization, towards a real optimized closed-loop automation for network operations.

Referring to the TVA and MU-MIMO exemplary case, O-RAN open interfaces, up to front-hauling (i.e. link between antenna and radio signal processor), enable a flexible multi-vendor software architecture where ML-based optimization logics can be provided by specialized companies or event developed by the operator itself. Considering the exemplary scheme of Figure 8, the role of SON-RAN Orchestrator in the figure can be associated to the RIC (*RAN Intelligent Controller*) defined by O-RAN (see specific box).

In this context, the active antenna itself can evolve into "a sensing device" able to analyze the dynamicity of the service requirements for the specific scenario where the antenna is deployed. The capability of changing the radiation pattern and tracking users allows the system to generate a distribution map, over the time, of the service requests that can be used to understand, analyze and optimize the service over that specific territory in the time, automatically. The antenna itself becomes "able to learn" from the territory over the time: new KPIs (Key Performance Indicators) can be defined able to support innovative optimization algorithms for e.g. interference management, peak performance management, cooperation with neighboring cells. An example of intelligent network node is described in [6].

The capability of the TVA in shaping the beam and to direct the field can be also exploit to mitigate electromagnetic field exposure. The antenna can be instructed to limit and to prevent exposure in defined sensible directions, while maintaining the capability of beam shaping and performances, by making use of SON algorithms, exploiting Machine Learning.

In general, ML techniques in order to provide good models and algorithms require that input data used for training models are carefully identified and reinforcement criteria are appropriately defined and weighted. In this context, TIM is currently involving radio optimization experts on the definition of ML-based optimization algorithms: the "knowledge mix" between digital skills (data science, agile software development, cybersecurity) and wireless communication skills (radio-propagation, antenna systems, radio resource management) is fundamental to unleash the potential of ML for the evolution of 5G radio optimization and automation. «Augmented intelligence is designed to augment the intelligence and knowledge of the individual and assist decision making and further knowledge acquisition, not to replace the person with an artificial system” [7] ■

References

[1] Okumura Y, Ohmori E., Kawano T., Fukuda K., “*Field Strength and its Variabilità in VHF and UHF Land-Mobile Radio Service*”, Rev. of the Electrical Communication Laboratory, Vol. 16, N.9-10, pp. 825-873, 1968

[2] Hata M., “*Empirical Formula for Propagation Loss in Land Mobile Radio Service*”, IEEE Transactions on Vehicular Technology, Vol. 29, N. 3, 1980

[3] Yun Z., Iskander F. I., “*Ray Tracing for Radio Propagation Modeling: Principles and Applications*”, Digital Object Identifier 10.1109/ACCESS.2015.2453991

[4] Bastonero S., Brunello F., Disco D., Gambin D., Gianola P., Scotti R., “*Tool for Electromagnetic Field Computation in Proximity of Radio Base Stations*”, IV Int. Symp. On EMC and Electromagnetic Ecology (EMC-2001), St. Petersburg, Russia, June 2001

[5] Wolfle G., Gschwendtner B.E., Landstorfer F.M., “*Intelligent ray tracing-a new approach for field strength prediction in microcells*”, 1997 IEEE 47th Vehicular Technology Conference. Technology in Motion

[6] WO2017/178038, Radio access network node for a telecommunication network, 19/10/2017

[7] The Future X Network, Bell Labs

Simone Bizzarri *simone.bizzarri@telecomitalia.it*

ingegnere elettronico entra in Azienda nel 1993 occupandosi di comunicazioni via satellite. In questo ambito partecipa, nel 1995, al progetto Iridium. Dal 2001 fa parte dell’area di Radio Planning Innovation della funzione Wireless Network. In questo contesto si è occupato degli aspetti di QoS in ambito radiomobile collaborando alla realizzazione di un sistema prototipale per il monitoring della QoS di utente tramite l’uso di agent installati sui terminali radiomobili; da tale attività ne è derivata la produzione di alcune domande di brevetto. Sempre in ambito QoS ha seguito l’attività finalizzata alla definizione e al calcolo di KPI di rete di accesso radiomobile. Dal 2007 si occupa delle problematiche relative alle Self Organizing Networks in ambito radiomobile e partecipa alle attività del working group 3GPP SA5 (gruppo di lavoro che, in ambito 3GPP, è responsabile delle procedure di Operation and Maintenance) ■

Paolo Goria *paolo.goria@telecomitalia.it*

ingegnere delle telecomunicazioni, entra in Azienda nel 2000. Ha focalizzato le proprie attività sulle metodologie di ottimizzazione e gestione dell’accesso radio, la valutazione delle performance mobili e l’evoluzione verso l’automazione e virtualizzazione di rete, partecipando anche a progetti finanziati Italiani ed Europei relativi a tali tematiche (es. ARROWS, EVEREST, E2ER, E2ER-II, E3). E’ stato delegato TIM nei gruppi di standard ITU-R WP8A/WP5A (2007-2010) e 3GPP RAN WG4 (2009-2017) ed è coautore di diversi articoli e brevetti nell’area delle comunicazioni mobili e dell’ottimizzazione radio. Attualmente guida il progetto “Open SON and Access evolution” focalizzato al dispiegamento ed alla evoluzione del SON e degli Element Manager di accesso nella rete TIM ■

Roberto Lanzo *roberto.lanzo@telecomitalia.it*

laureato in Ingegneria Elettronica ho iniziato a lavorare in Azienda nel 1991. Mi sono occupato da subito di temi inerenti la progettazione di reti cellulari e lo sviluppo di modelli e metodologie per la previsione di copertura, utilizzati sia in Italia sia all'estero. A partire dagli anni 2000 ho guidato l’evoluzione di TIMplan, lo strumento di progettazione della rete di accesso radio di TIM, seguendo l’evoluzione delle tecnologie dal 2G al 5G. Attualmente ho la responsabilità del progetto “Network Management Tools & Methodologies Coordination” e della valorizzazione e crescita delle relative risorse ■

Andrea Schiavoni *andrea.schiavoni@telecomitalia.it*

laureato in Ingegneria Elettronica e dottorato di Ricerca in Compatibilità Elettromagnetica entra in Azienda nel 1993. Sin dall’inizio si è occupato di esposizione al campo elettromagnetico dei terminali del servizio radiomobile attraverso metodologie computazionali e con lo sviluppo ed accreditamento del laboratorio di qualifica SAR. È stato responsabile del progetto di qualifica radio dei terminali mobili. Attualmente si occupa di aspetti relativi alle antenne tempo varianti e all’esposizione al campo elettromagnetico da stazioni radio base. È co-chair di IEEE P.1528.7 - Guide to Assess the Electromagnetic Field Exposure of IoT Technologies. È membro di IEC TC106 e IEEE ICES TC34 ■