

# Preface

5G is the new generation of the global telecommunication network. It is based on a cloud-native, softwarized, end-to-end architecture, encompassing the radio access, metro, and core network sections, as well as the edge, fog, and cloud computing resources within the network.

Aiming to become the new reference architecture for the global mobile and fixed telecommunication network, 5G is not only an evolution of 4G in terms of performance, but it also creates a breaking point with respect to previous generations: 5G will support diversified vertical services, targeting different types of users, and including services not exclusively dedicated to human users. Three classes of innovative service scenarios have been already defined:

- Enhanced Mobile Broadband: that is, services characterized by very high data rates and very high density of users, for instance virtual reality and augmented reality, requiring extremely high quality mobile video distribution, and, in general, support of the expected increases in video consumption.
- Ultra-reliable and low latency communications: that is, services related to scenarios with demanding requirements in terms of latency and reliability, such as automated driving, remote surgery, smart factories, smart grid, intelligent transportation systems.
- Massive IoT (or machine type) communications: that is, the plethora of services that will drive the advent of IoT, mainly characterized by a great number of devices, typically requiring small volumes of data, but with stringent constraints in terms of cost and energy.

To efficiently support end to end such diverse and demanding new applications and services, 5G is not limited to the cellular section, as previous generations, but encompasses the whole network, and introduces several innovations, among which:

- New Radio, a new air interface designed to greatly improve the performance of the access network;

- network softwarization, i.e., the virtualization of network services, obtained by means of three synergic solutions: i) a logically centralized control plane enabling a flexible and agile configuration of network resources (SDN); ii) the deployment of network functions as software components running on industry-standard commodity hardware platforms, instead of using specialized hardware (NFV); iii) the outsourcing to computing elements (edge, fog and cloud) not only of processing and storage functions but also of network services, control and management (cloud networking);
- network slicing: a softwarized network can be virtually divided in so-called slices, i.e., end-to-end virtual networks at the service of a class of applications; slices can be flexibly and quickly defined and setup, to support diversified vertical services;
- full exploitation of in-network computing, following the recent trend that is transforming the Internet in a network of data centres (or, more generally, computing resources) in which the prevailing communication paradigm is becoming device-to-computing-to-device, rather than device-to-device, and in which the smartphone is becoming more and more an instrument to access artificial intelligence services;
- a Service-Based Architecture, for which network control functions expose an Application Programming Interface (API) based on HTTP/2 and RESTful technologies, thus harmonizing the entire network control plane with Web technologies.

5G will constitute a larger ecosystem, including more stakeholders than in the past, with more complex relationships, more heterogeneity and more dynamicity. Applications sectors will be more and more actively involved in the creation and provision of services, taking full part in the 5G value chain. 5G will provide services not only to customers but also to industrial stakeholders, allowing both Business to Customers (B2C) and Business to Business (B2B) models. 5G is also an opportunity for network operators to return in the spotlight of the service creation and management arena.

5G is very important for Italy, therefore CNIT\* decided to organize on December 4-6, 2018 the 5G-Italy event (<https://www.5gitaly.eu/>), which provides a 360-degree vision about 5G. 5G Italy is a three days conference, where politics, regulatory authorities, research, businesses, economy and public administrations meet, addressing the challenges and opportunities of this technology. 5G Italy focuses on policy and research issues, but also, and significantly, on vertical applications in the most relevant sectors: Energy, Industry 4.0, Media and Tourism, Security, Public Administration, eHealth, Transports, Mobility and Automotive, and Infrastructure Protection. Another important aspect of the conference is the presentation of the 5G trials currently ongoing in 8 Italian cities.

As a companion initiative, CNIT also edited this white eBook, with the aim of overviewing the status of 5G and of documenting the Italian involvement in 5G research and experimentation. The eBook starts with basic definitions and

key characteristics of this game-changing technology, proceeds to present the work done up to now by the most significant research and industry players, including field trials, then focuses on applications and vertical exploitations and, last but not least, reports on regulatory and market/business issues. A final section of the eBook explores roadmaps and future work.

Importantly, this eBook will have a first version, printed, and presented at the 5G Italy event, but then it will continue to live and grow on the web, updated with contributions coming from the conference, including videos, demonstrations and interviews with leading actors of the field, so becoming a reference eBook on 5G (available here: <https://www.5gitaly.eu/white-ebook/>).

Finally, the eBook also incorporates key elements of the 5G PPP work and results to ensure compatibility between the emerging Italian 5G ecosystem and the pan-European 5G vision, as prepared by the 5G PPP (<https://5g-ppp.eu/>).

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\*CNIT (National, Inter-University Consortium for Telecommunications, <https://www.cnit.it/>) is a non-profit consortium established in 1995 and bringing together 37 public Italian universities to perform research, innovation and education/training activities in the field of Information and Communication Technology (ICT). CNIT also owns four National Laboratories: Multimedia Communications, Photonic Networks & Technologies; Radar & Surveillance Systems; Smart, Sustainable and Secure Internet Technologies and Infrastructures.

More than 1,300 professors and researchers, belonging to the member universities, collaborate within CNIT, together with more than 100 CNIT own employees. CNIT participated in hundreds of research projects, including EU coordinated projects, ERC grants and Italian nation-wide initiatives. In the EU H2020 program, CNIT has obtained 41 projects and coordinated 10 of them. CNIT has also a significant experience in the organization of scientific events. CNIT's funding comes from private companies and competitive programs. The innovation and technology transfer of research results from universities towards end-users and industry is a primary mission for CNIT. CNIT also facilitates the cooperation between member universities and promotes the collaboration of the same universities with other research institutes and with national and international industries.

CNIT is very active in 5G and related initiatives: i) CNIT participates in several EU projects on 5G and coordinates a number of them (four such projects ranked first in their respective calls); ii) CNIT is an elected member of the 5GPPP (<https://5g-ppp.eu/>), a 1.4 Billion Euro joint initiative including the European Commission and the European ICT industries and academia to rethink the network infrastructure and to create the next generation of communication networks and services; iii) CNIT participates in the 5G trials of the Italian Ministry of Economic Development in Milan; iv) CNIT participates in several EU projects on applications of 5G (e.g., for intelligent transport systems and autonomous vehicles) and in the Graphene and Quantum Information flagships projects.

# Acknowledgements

The Editors wish to thank all contributors, from many colleagues of Italian academia and industry, to some very relevant international actors of the 5G community. We are honoured to have so many high quality contributions in this collection, which will surely further stimulate interest in 5G, and simplify the work of many newcomers to such an exciting field.

The Editors also wish to thank Mario Alonzo, PhD student at the Università di Cassino e del Lazio Meridionale, for his precious help with the composition of the final book.

We hope you will enjoy reading this eBook, and possibly decide to add yet another contribution on aspects that we may have overlooked.