



5TONIC

A Look into Future Networks
by 5TONIC

October 3rd
2023



5TONIC

A CONSOLIDATED AND REPUTED
OPEN CO-CREATION LABORATORY
FOCUSED ON 5G AND BEYOND TECHNOLOGIES

5TONIC Objectives

5TONIC is an **open co-creation laboratory** focusing in **5G and beyond-5G technologies**, founded by Telefónica and IMDEA Networks in 2015 and based in Madrid

Technology development through EU Projects
Standardization activities (ETSI, 3GPP, IETF, IEEE...)

Joint ventures and start-ups.
Advanced training (Master in NFV/SDN)
Multilateral trials and interoperability (ONF POC...)

CORE RESEARCH

Pilot services to large vertical customers of technology trends.
Access to a superb academic environment.

Demonstration of H2020 projects.
Exchange of 5G technologies.
Joint actions with administration.

5TONIC Members & Collaborators

MEMBERS

5TONIC members steer the activities of the lab and contribute to its maintenance



COLLABORATORS

Collaborators are involved in specific 5TONIC activities, but do not take part in lab decisions



5TONIC activities

- 5TONIC activities can be classified into different sets:

Development and testing of 5G use cases	<p>Objective: _____</p> <p>Cooperate with verticals in the development of services and applications that may benefit from 5G innovations and may constitute new revenue streams for operators</p>	<p>Examples: _____</p> <ul style="list-style-type: none">• Autonomous vehicles in industrial environments, with ABB/• Emergency services in cooperation with SAMUR• Augmented reality services for fairs in cooperation with YBVR• REMOTIS project with Capgemini Engineering
Test and evaluation of 5G components	<p>Objective: _____</p> <p>Test and evaluate the new technical solutions proposed by 5TONIC members and collaborators, to identify those that may prove valuable for the evolution of 5G and beyond 5G in areas like new radio technologies and virtualization and network slicing</p>	<p>Examples: _____</p> <ul style="list-style-type: none">• New waveform OTFS trials with Cohere and Telefónica• Cell-less RAN architecture OneCell with CommScope• High throughput E-band link between UC3M and IMDEA Networks• End-to-end automated network slicing with Ericsson and Telefónica
Technology exploration via European projects	<p>Objective: _____</p> <p>Provide support for the 5TONIC members in their activities in current projects, as well as become one of the main European testbeds for future 5G SNS projects</p>	<p>Examples: _____</p> <ul style="list-style-type: none">• Hosting of the review, both final and intermediate, of several projects, like CrossHaul, 5G-Ex, 5GInFire, 5Growth or 5G Drive• Involved in the 3 large end-to-end trial projects of the EU ICT-17: 5G-EVE, 5G-VINNI and 5GENESIS• Involved in Hexa-X and HEXA-X-II, flagship projects for 6G definition
Dissemination and other activities	<p>Objective: _____</p> <p>Contribute to the dissemination of 5G capabilities to support new applications and use cases</p>	<p>Examples: _____</p> <ul style="list-style-type: none">• 1st ETSI NFV plugtests• Cooperation in the UC3M's Master on NFV and SDN in 5G Networks

5TONIC Follows a Pragmatical Way of Working

5TONIC main technical activities are structured around **projects/trials**

- The projects/trials should be **approved by** the 5TONIC governing body, the **Steering Board**
- Each trial involves **at least one 5TONIC member** and may include also **one or more collaborators**
- The **work plan, resources** committed (human and material), **location** and **dissemination** policy are agreed by the participants of the trial
 - There is a project manager in charge of coordinating each trial
 - The results from the trials may be kept confidential to those involved in them
 - Infrastructure not available at 5TONIC for the support of the trials should be provided by those involved in them
- The trial may be related to a **potential 5G use case** (which is the preferred option) or to the testing of a **5G technological component**
- 5TONIC provides **dedicated resources** (not only the lab infrastructure, but also two people with full dedication) for the support of the trials
- 5TONIC trials may be also **associated to European projects** the members participate in

Beyond technical activities, 5TONIC is also involved in **academic activities** (like the *NFV/SDN for 5G Networks* master program of University Carlos III Madrid), as well as **5G promotion and standardization activities**

5TONIC Activity Is Organized in Collaborative Projects

Current use cases

Nº	Project	Project Leader in 5TONIC	5TONIC members	5TONIC Collaborators	New results
1	Industry 4.0 in collaboration with ASTI Mobile Robotics	Marc Molla	Ericsson, Telefónica, UC3M, CommScope, Intel	ASTI, Saguna Networks	Migrating the demo to 5G NSA (E2E latency 10 ms)
2	Altran's REMOTIS connected car project	José Soriano	Altran, Ericsson		Altran EPC and MEC deployed at 5TONIC. Two connection options supported
3	Health emergency services with SAMUR	Carlos Bernardos	UC3M	SAMUR	Demo carried out to the Madrid regional government and Madrid City council
4	Enhanced fair experience with SEGITTUR & YBVR	Marc Molla	Ericsson,	YBVR, Segittur	Initial tests carried out by YBVR at 5TONIC
5	Small cell deployment with Celling5G Solutions	Ignacio Berberana	Ericsson, Telefónica, CommScope	Celling5G	Small cells measured, pending processing the results
6	Unmanned vessels control with UTEK	Marc Molla	Ericsson	UTEK	Trial carried out at Pantano de San Juan
7	Use of 5G technologies in the context of Metrology 4.0 Zero Defect manufacturing (ZDM) services and solutions for Industry 4.0 with Innovalia	Manuel Lorenzo	Ericsson, Telefónica	Innovalia	
8	Multimedia services for Telefónica Movistar with Nokia Bell Labs	Juan Rodríguez	Telefónica	Nokia, Spirent	5G network deployed at 5TONIC
9	New generation data center in a box with Adam Data Center	Ignacio Berberana	IMDEA Networks, Intel	Adam Data Center, UPM	Abandoned project.
10	Image recognition from drones with Visiona-IP	Manuel Lorenzo	Ericsson, UC3M, Intel		Abandoned project.
11	Small cell planning with Siradel	Ignacio Berberana	Ericsson, Telefónica, CommScope	Celling5G, Siradel	Abandoned project.
12	5G technologies in escalator/lift control applications with Thyssen	Mario Buritica	Ericsson, Telefónica, UC3M, CommScope, Intel	Thyssen	Abandoned project.
13	Telefónica's LUDICO on line games	Jesús Folgueira	Telefónica, Ericsson	Nvidia	First phase of tests completed. Second phase with Nvidia scheduled in Q2
14	Real-time 360-based robotic navigation over 5G	Alain Mourand	Interdigital, UC3M, Ericsson		Deployment at 5TONIC delayed due to Covid-19 situation
15	SANNA: neuro rehabilitation	Jose Soriano	Capgemini, UC3M, Telefónica		UC associated to the 5G Vinni project
16	Quantum cryptography for 5G networks	Jesús Folgueira	Telefónica		Initial deployment of equipment at the lab
17	Integration of MEC in the 5G Core SA. 5G-based security system with facial recognition	Marc Molla	Telefónica, Ericsson, Intel, Capgemini	DeepSight AI Labs	PR published
18	Cooperation with TI in the support of 5G IA use case with MEC roaming	Alex Harmand	Telefónica, Intel, Altran		5TONIC was not finally involved in the project
19	360 degrees augmented assistance	Miguel Ángel Arjona	Altran	CDTI	Activities continue
20	Lime E2E network slicing testing	Alex Harmand	Ericsson Telefonica	ASTI, Google, TCL, YBVR, Xiaomi, Samsung	Activities under final phase, PR under definition
21	Lime NEF capabilities validation	Alex Harmand	Ericsson Telefonica		Activity finalised, PR under definition
22	Lime for gaming	Alex Harmand	Ericsson Telefonica		Activity to be started

Mature/completed, demo available for show
 Intermediate, equipment available and/or initial tests
 Project not started or abandoned

5TONIC Has Demonstrated Use Cases in Many Verticals

- 5TONIC is focusing on **use cases with potential short/medium term commercial applications**
- The main elements of the strategy adopted are:
 - **Involving final users** in the development of the applications and services that make use of the 5G technology, to ensure that they provide real value for them
 - Ensuring that the implementation is based, whenever feasible, on **commercial/pre-commercial equipment** (rather than experimental one), so the economic viability of the solutions is more likely
 - Trying to involve **different partners** in the implementation of the use cases, rather than a single one
 - Emulating, as much as possible, **realistic operational conditions**
 - Adopting a **phased approach** for the development of 5G based services and applications, adapted to the evolution of the technology
 - Trying to find **synergies with other 5TONIC activities**, like the participation in European projects

Vertical screened

Gaming	
Emergencies	 
Manufacturing	 
Tourism	  
Smart Agro	 
Utilities/Energy	 
Financial	
Education	
Retail	 
Automotive	 

5TONIC - Some Use Cases

Virtualization in the network of the controller of an autonomous industrial vehicle (AGV)

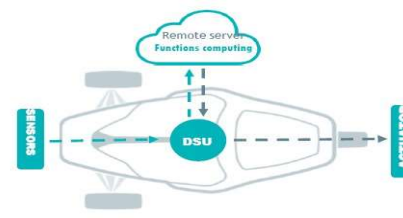


ASTI
ABB

5G-based fast-response emergency service



Remotis: Connected vehicle prototype



Capgemini

5G support for Zero Defect Manufacturing (ZDM)



Remote control of unmanned vessels



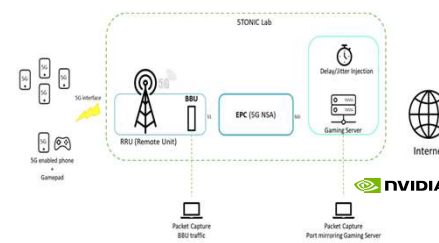
utek

Virtual and augmented reality for tourist applications



ybvr

5G access to Lúdico online gaming platform



nvidia

innovalia
METROLOGY

5TONIC Approach to Technology Evaluation Trials

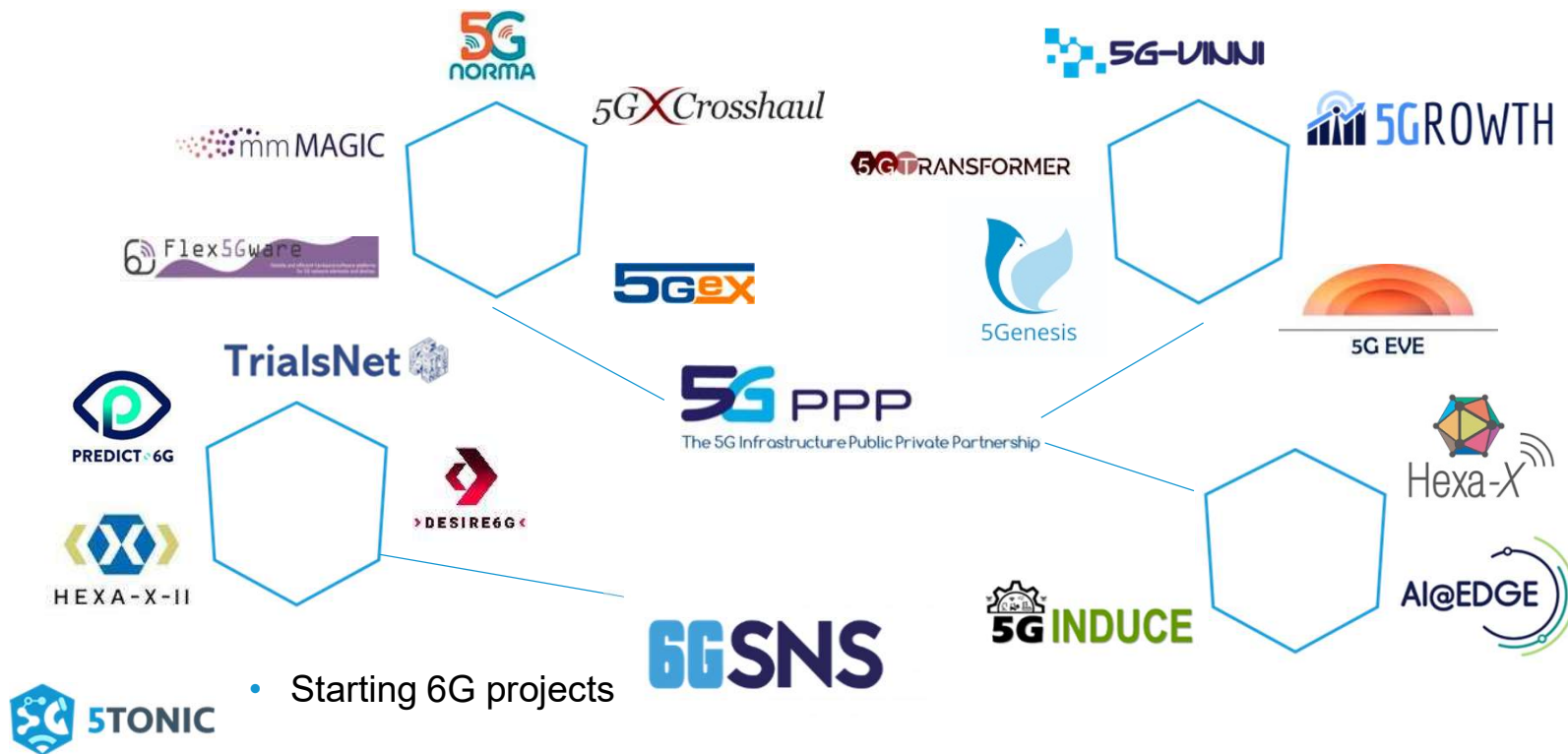
- The objective of the technology trials is to develop and validate the main enablers that will make 5G use cases **feasible from a techno-economic viewpoint**
- Main focus has been put on:
 - **Virtualization of the different network functions**, for both core and access
 - **Network slicing** for greater flexibility in the support of the requirements associated to different use cases
 - **Integrated transport** for both backhaul and fronthaul
 - Use of **high frequency bands**
 - **5G SA Core**
- 5TONIC is also looking at potentially **disruptive technologies** that may be part of 5G evolution:
 - **OTFS**, a new wave form that provides more than 50 bit/s/Hz of spectral efficiency measured in live tests carried out at Telefónica head quarters
 - **New antenna technologies** for high frequency bands: LCD antennas, lens antennas
 - New signal generation technology based in **optical processing**



5TONIC Explores 5G Technology via European Projects

- Providing support for the 5TONIC members in their activities in current projects
- Involved in the 3 large end-to-end 5G trial labs funded by the EU ICT-17

- Participating in other relevant projects and calls:



- EU-Brasil:



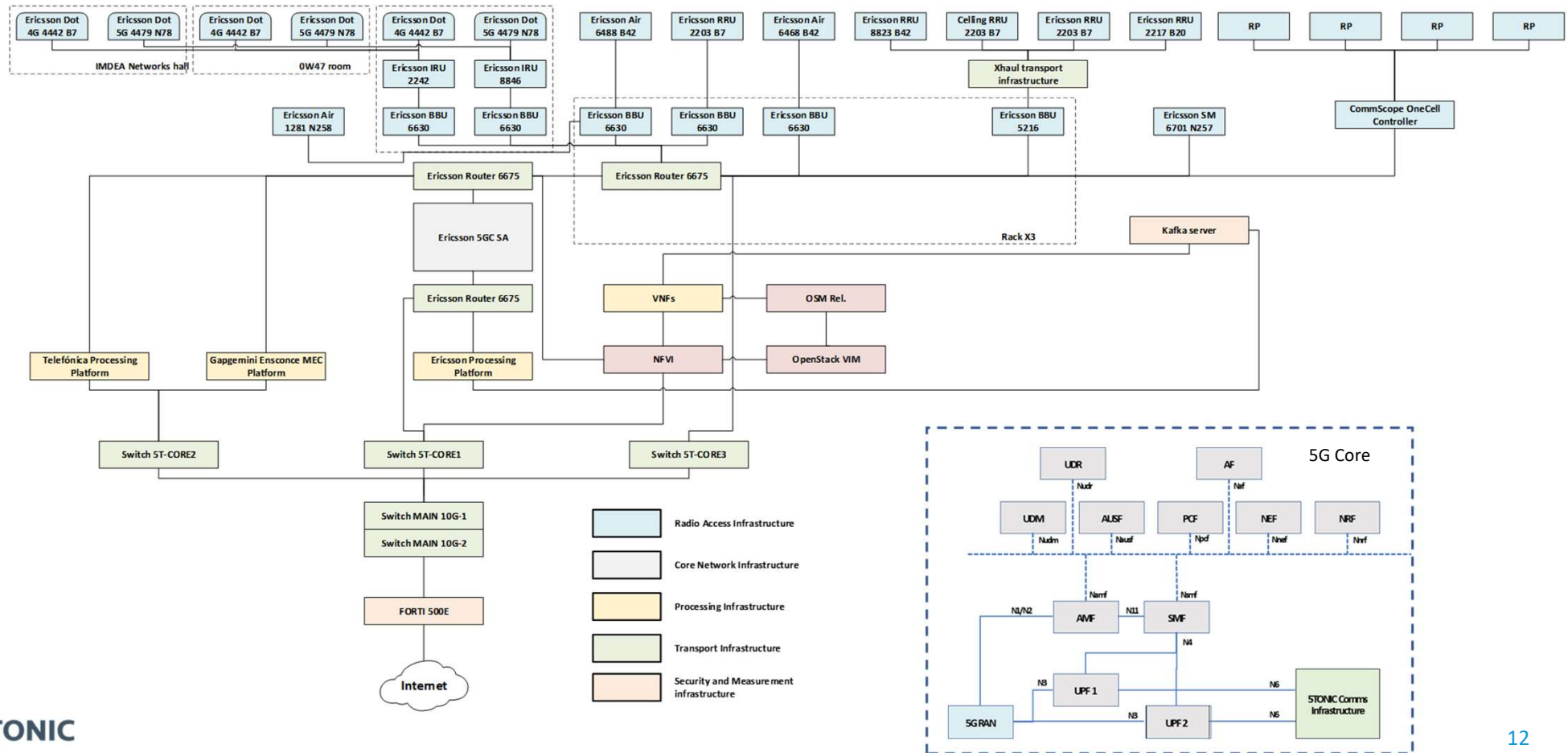
- EU-Taiwan:



- EU-China:



5TONIC Has a Complete 5G Infrastructure



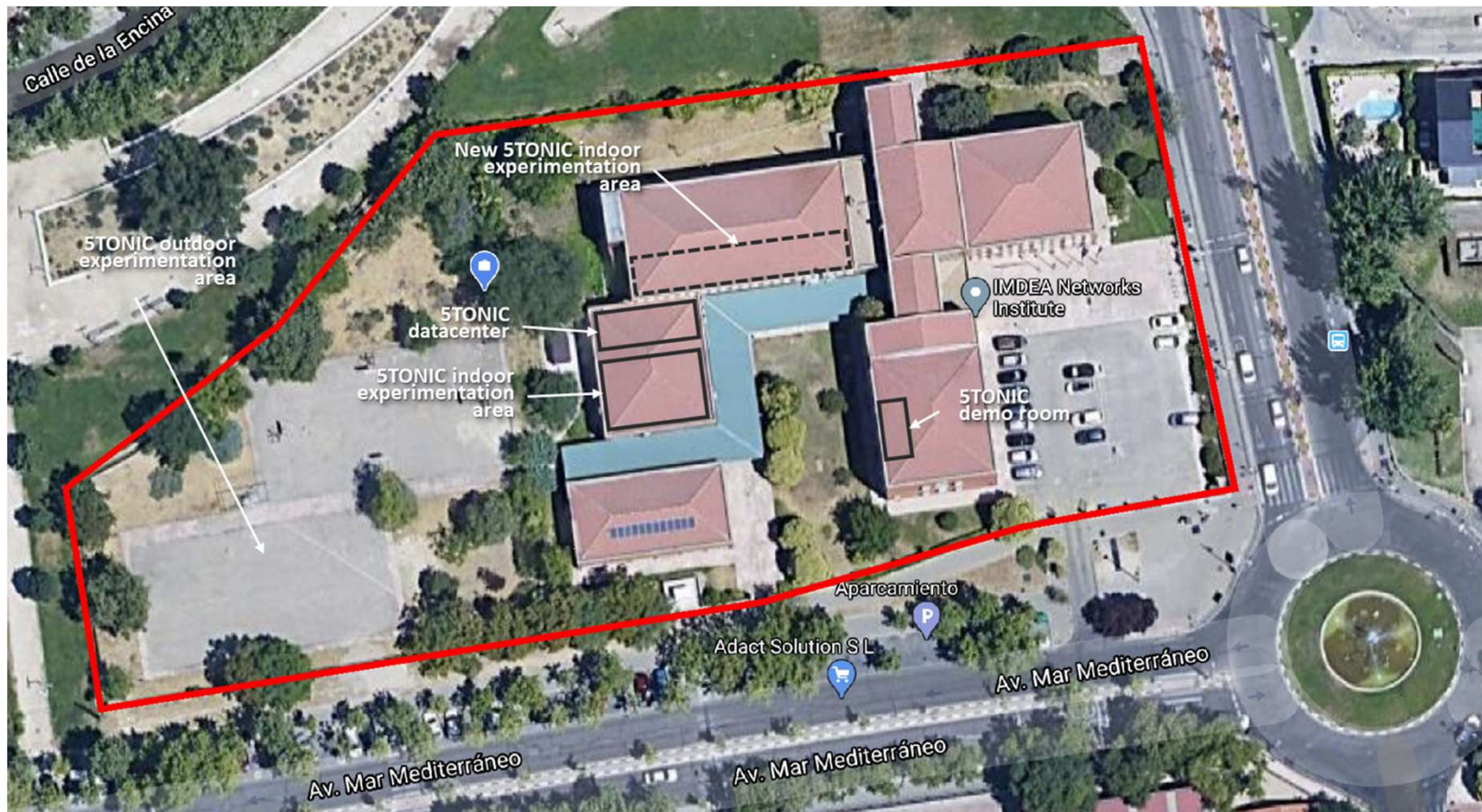
5TONIC Provides a Rich Set of Testing Tools

Currently, in order to facilitate the testing of different use cases or specific tests, we are using in the lab different tools:

- **Throughput and latency** measured with **off the shelf tools**:
 - SpeedTest, iPerf, ping, Fast.com,...
- **Protocol analysis** with Wireshark
- **Latency, jitter and packet error distribution control** with Linux Traffic Controller
- **Monitoring and drive test tools**: G-Nettrack, LTE Discovery,...
- Access to network elements' counters
- **Traffic generation**: based on MAMI European project tool *traffic*
 - Virtualized traffic mix generator based on iperf3
- **Visualization dashboard** based in Grafana
- For specific tests we have had the access to more **advanced testing tools** (e.g., spectrum and network analyzers) on loan from vendors like R&S and Anritsu

A **measurement framework**, developed in the context of the 5G EVE project and based on the use of open sources tools (Kafka with ELK stack, Robot Framework, Ansible Automation Platform,...), as well as tools developed by the project, is available

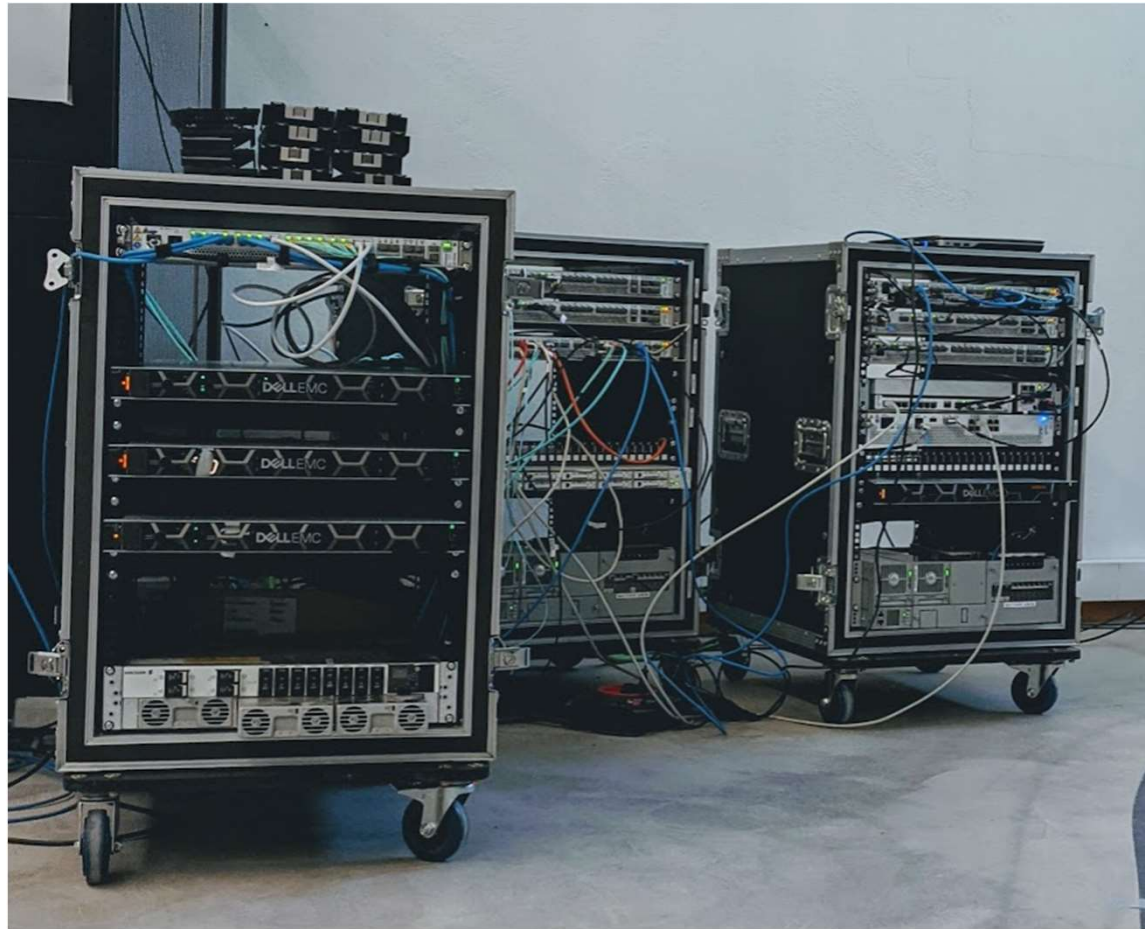
5TONIC Is Hosted at IMDEA Networks Premises



5TONIC Indoor Experimentation Area



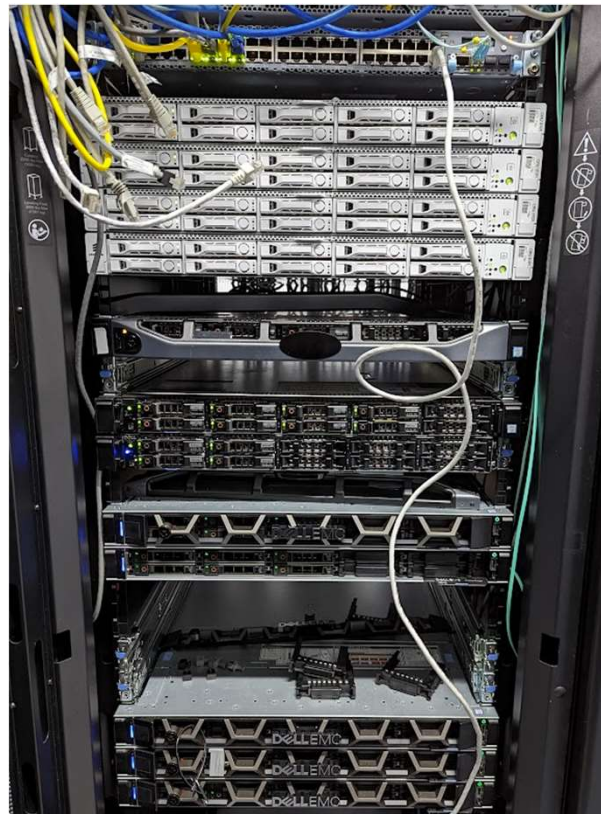
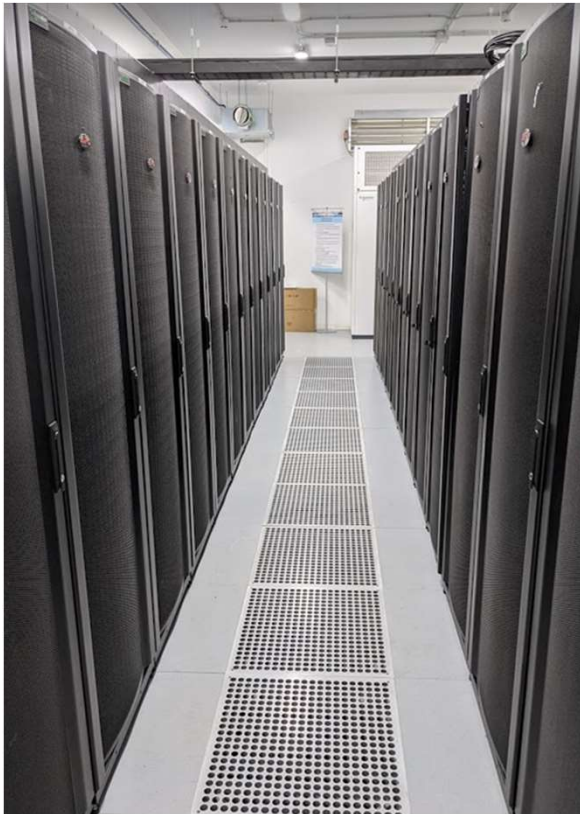
5TONIC Portable Infrastructure



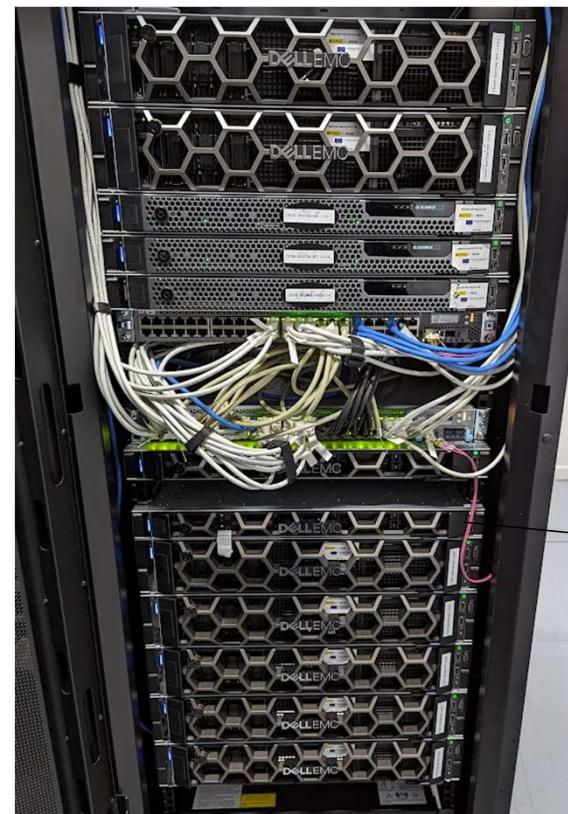
ASTI/ABB Experimentation Area



5TONIC Data Center

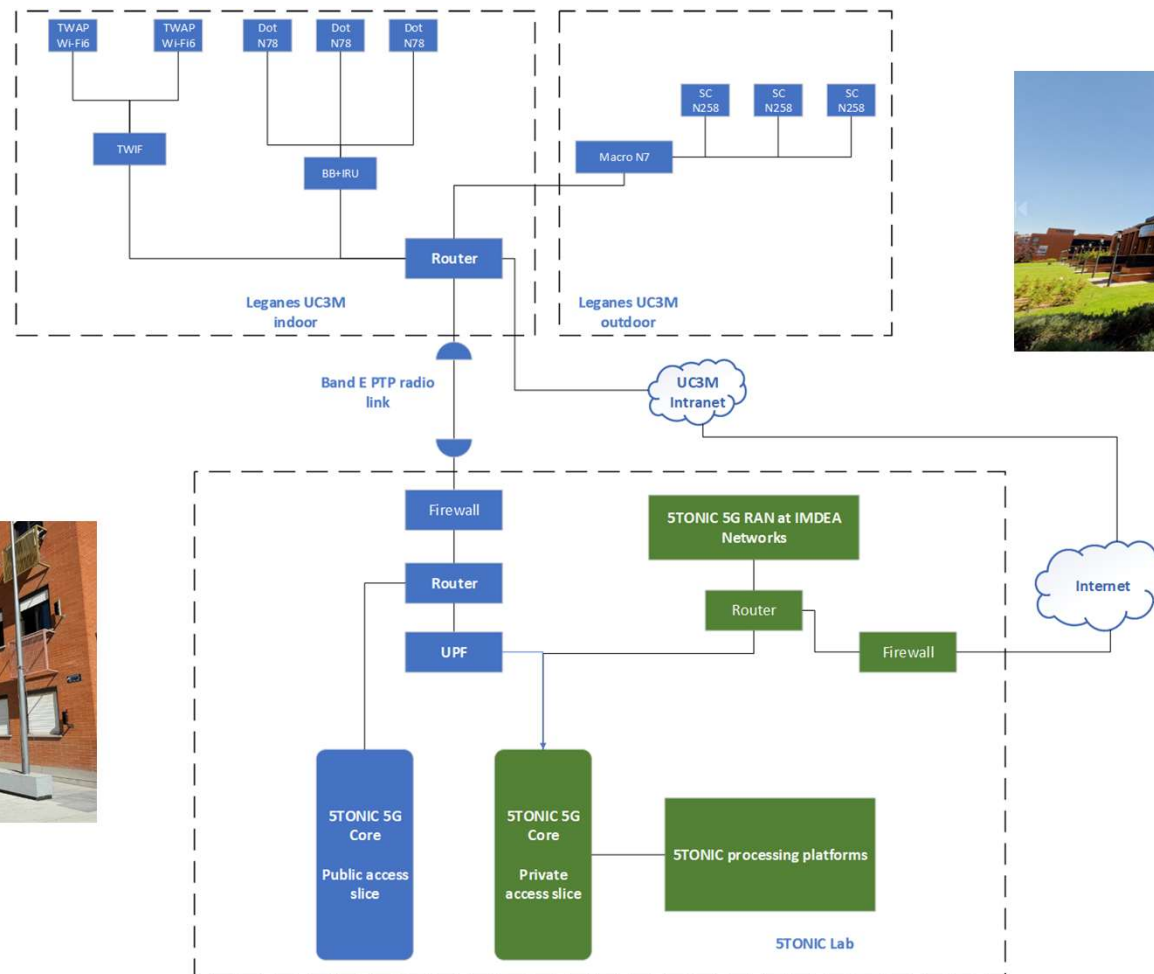


5GC



Processing platform

5TONIC Expansion at UC3M








5TONIC

LOOKING AT THE FUTURE




Evolution beyond 5G towards 6G

As any new generation, 6G will bring never seen KPIs...

	UNIT	 lte	 5G	 6G
Peak Data Rate	<i>bps</i>	100 M	20 G	>1 T
Experienced Data Rate	<i>bps</i>	10 M	100 M	1 G
Spectrum Efficiency	<i>X</i>	1x	3x	5-10x vs 5G
Network Energy Efficiency	<i>X</i>	1x	10-100x	10-100x vs 5G
Area Traffic Capacity	<i>bps/m²</i>	0.1 M	10 M	1 G
Connectivity Density	<i>devices/km²</i>	10 ⁵	10 ⁶	10 ⁷
Latency	<i>ms</i>	>10	<10	<1
Mobility	<i>Km/h</i>	350	500	>1000

Evolution beyond 5G towards 6G

...based on new technologies and network architectures...

			
TECHNOLOGY	OFDM MIMO Turbo Code Carrier Aggregation Hetnet ICIC D2D communications Unlicensed spectrum	mmWaves Massive MIMO LDPC & Polar codes Flexible Frame structures Ultradense Networks NOMA Cloud/Fog/Edge Computing SDN/NFV/Network Slicing	THz frequencies SM-MIMO LIS & HBF OAM multiplexing Laser & VLC DLT-based spectrum sharing Quantum Comms&Compute AI/ML
ARCHITECTURE	Flat and All-IP	Virtualized Software-based Sliceable	Intelligent Cloud-native Software-based APIfied Sliceable

The evolution Beyond 5G and 6G brings a new set of technological components to test at 5TONIC

Evolution beyond 5G towards 6G

...opening opportunities for new ways of communication



PURPOSE

Connecting people



Connecting people and things (massively)



People interacting with physical and virtual worlds

APPLICATIONS

HD video streaming
2D Social Media
Rich Voice
Mobile TV
Mobile Internet
Mobile Pay

VR/AR/360/UHD video
V2X
Massive IOT
Smart City/Factory/Home
Telemedicine
Wearables

Holographic video
Tactile/Haptic Internet
Industrial Internet
Full-Sensory Digital Sensing and Reality
Fully Automated Driving
Internet of Bio/Nano things



These new B5G/6G capabilities and use cases will be the target for our new phase of exploration and experimentation following our collaborative co-creation approach

5TONIC Exploration on B5G & 6G

5TONIC will host activities around a number of national and European B5G/6G projects that have been granted to its members...

National projects within  UNICO

6G-DATADRIVEN: B5G/6G as driver of the [r]evolution of industry 4.0, allowing for full automation and context-awareness

6G-EDGEDT: Network Digital Twin (NDT) technologies focused on massive deployments at the network edge

6G-INTEGRATION: O-RAN enabled integration of B5G/6G, supporting network slicing



European projects within



5G/6G networks and vertical applications reducing their carbon footprint by a factor >10



End-to-end service deployment and management based on a highly-distributed grid of orchestrators



Orchestration platform, with native integration of AI, to support extreme URLLC application requirements



Second stage of the European flagship project on 6G technologies



Provisioning of deterministic network paths to support time sensitive services as requested by end-customers



Privacy-sensitive security enablers for 6G networks



Full large-scale trials to implement a comprehensive set of innovative 6G applications based on various technologies

...and is open to any other collaboration initiatives!

5TONIC New Use Cases

The consolidation of the 5G technology in the networks worldwide and the evolution to 5G Advanced (3GPP Rel 17-20) open opportunities for new breakthrough applications in different sectors. As example:



Industrial sector use cases enabled by TSN, DetNet, RedCap and advanced IOT devices (cameras, microphones and other sophisticated sensors)



Video analytics-based applications like zero-default manufacturing, video surveillance, remote drone-based inspection of critical infrastructures, etc.



Metaverse for: **consumer** (video, gaming), **enterprise** (conferencing, retail) and **industry** (mobile AR for technicians), based on volumetric video immersive interoperable XR.



Autonomous Networks, zero-touch network operations supported by Data, AI/ML and Digital Twins, from reaction to prediction, from repair to prevent.



Safe Networks for the **Post-Quantum** Era, new levels of security in preparation for the arrival of quantum computing.

A future of **pervasive sensing** (Internet of Senses), with machines that can see **-computer vision-** and **augmented humans** with ergonomic untethered **XR** glasses and connected **bio-sensors** and **exoskeletons**, industry processes supported on a **fusion of digital and physical** worlds using extensively interactive **3D digital twins**.



5TONIC Extending Lab Capabilities

SHORT-TERM

Edge Computing service, offering a hybrid multicloud environment

Extension of **high capacity 5G Radio** (5G-NR, mmWave), new **antennas** (mid-band 8T8R FDD, FDD massiveMIMO), **features** like precise location, DC/CA, 5GA enhanced uplink

Cloud-native network (vRAN/vOLT, open IP/Optical, SDN-C, 5G SA Core...), an open digital architecture with standard APIs to facilitate network component integration, and horizontal tools for O&M

NaaS API platform that offers developers access to telco capabilities (NEF/SCEF, NWDAF, PCF, RAN-RIC, SDN-C, Edge) via open standards (like CAMARA)

Network Slicing, initially static and based on 5G SA, a major capability to be exposed and monetized.

Extensive use of Data, AI/ML in all verticals and business processes, extensive application in the analysis of video data (**video analytics**) and in **Digital Twins** of objects, assets and even processes

Dataspaces will also be a fundamental tool for a secure and controlled data sharing for improvement of processes across value chains in different sectors.

Time synchronization and **real-time** support (TSN, DetNets) for media content production and industry. **RedCap** features to facilitate massive penetration of IOT sensors and actuators.



These capabilities are progressively incorporated to the 5TONIC lab environment as use cases and research projects demand them

5TONIC Extending Lab Capabilities

LONG-TERM

New bands like FR3 (7.125 GHz to 24.25 GHz) and THz for 6G (~300 GHz)

New radio innovations for 6G like giga-MIMO, Reconfigurable Intelligent Surfaces (RIS), Integrated Sensing and Communication (ISAC)...

Multicloud orchestration solutions will facilitate the use and management of the complex hybrid multiprovider edge to cloud continuum

Quantum Safe communications, improving encryption (Post Quantum Cryptography) and key management (Quantum Key Distribution, Quantum Random Number Generation).

Decentralized internet, Web 3.0, blockchain/DLT technology

Highly specialized networks: in-vehicle, in-body, in-factory... with specific frequencies, antennas, devices, computing and security requirements and space and power limitations, and connected between them and with the public network.

Composable networks: with tools to develop services based on the combination of elements from different networks (and even different providers), by enriched APIfication (NaaS), codification (Network as Code) and AI/ML-based orchestration to simplify the management of network assets and operations.

Federation and Roaming services that will facilitate our interconnection with other labs

Spatial Computing, that will allow to augment the physical reality with virtual objects/persons correctly positioned.

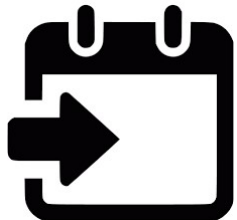


5TONIC Prepares for the Future



A present we are proud of...

- In its first 8 years, 5TONIC has got to consolidate a **complete 5G lab and ecosystems** with all the technological components required to showcase all the opportunity 5G brings.
- The set of **use cases and trials** performed so far in many different sectors have helped to bring the technology to life working with the customers that will consume it and validating its maturity and readiness for the different applications.
- 5TONIC has become a **reference lab in Europe** (Digital Innovation Hub and part of all European 5G Infrastructure projects).



...and a bright future we are starting to build:

- **A new phase** comes in which new features will be introduced to progressively transition 5G into the next generation of cellular network.
- 5TONIC has now **the challenge to evolve its capabilities and continuing to demonstrate its value** as a catalyser for the development and adoption of 5G/6G technologies in the different industry, agriculture and service verticals.

SLICES-RI, as a large research infrastructure, will be a great complement to 5TONIC lab in its technology exploration, development and testing process



5TONIC