

# Mobile Communication Group (MCG)

## HEAD OF THE GROUP RESEARCH REPORT

The Mobile Communications Group (MCG) highlighted the leadership of Spain, in general, and Valencia, in particular, in the field of research and development in 5G technology. The MCG has about 40 researchers, including three senior researchers with outstanding biographies and global impact, seven post-doc and twelve pre-doc researchers. It is led by the current Director of iTEAM, Prof. Narcis Cardona.

Researchers from MCG have a consolidated experience in 5G due to their involvement with several international projects related to 5G. The group is now coordinating 6 European projects, all on 5G verticals and the initial stages of 6G, while participating in 8 more competitive projects of the H2020 and FP7 programs.

In addition, the group has a long tradition of cooperation with international companies and established contracts with the major players in the Mobile Networks area, from the Tier-1 operators to the technology vendors. The MCG has contracted with Huawei to create the iTEAM – Huawei Joint Research Center, which involves 12 projects, where the MCG participates in 8 of them.

This last academic year, the MCG has also obtained €8,562,000 in grants within the framework of the call for aid from the Universalization of Digital Infrastructures for Cohesion UNICO -5G I+D 2021 Plan de Recuperación, Transformación y Resiliencia del Gobierno de España, for the development of 3 projects, 12 subprojects in total, and the Plan for the Promotion of Telecommunications Engineering Studies at the UPV.

The group also collaborates with companies in the sector to develop 5G technology, applicable to industry 4.0 and the transfer of knowledge referring to measures in 5G networks and their optimization. The MCG members are very active in dissemination activities.

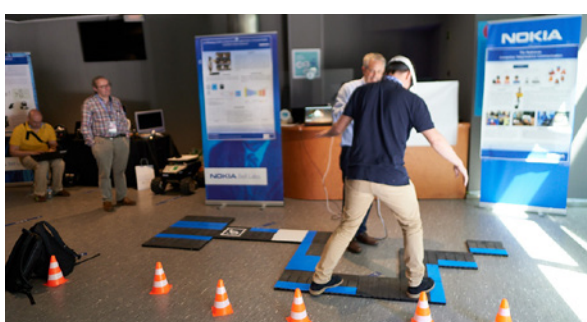
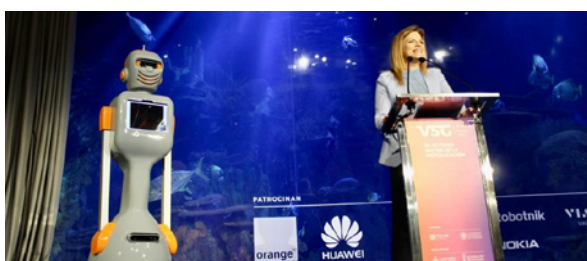
The main three lines in which the MCG is active are:

- ◆ Mobile Network Technologies beyond 5G, led by Prof. J. Monserrat.
- ◆ Broadcast Technologies and standardization, led by Prof. D. Gomez-Barquero.
- ◆ Body Environment Communications, led by Dr. Concepción García and Prof. Narcis Cardona.

## V5G Days 2022

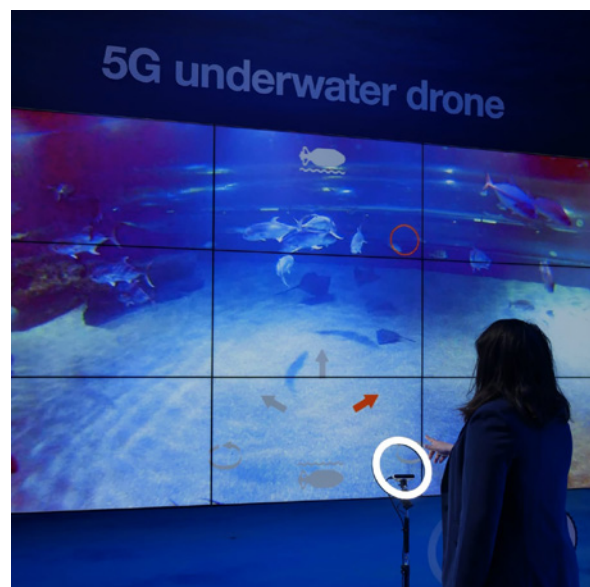
The second edition of V5G Days was held on May 30 and 31, 2022, in the Red Sea Auditorium of the Oceanogràfic de València, in hybrid format, giving continuity to the success achieved in the first edition, the event was extended to two days of duration and was opened to the international public. On this occasion, the V5G Days 2022 event brought together professionals from the telecommunications sector, national and international leaders in the field of 5G, to discuss and present the latest developments, achievements, and challenges of the application of this technology to the industrial field. The theme chosen for this second edition is “5G as a driver of digitization”, intending to expose, discuss and demonstrate how 5G technology is becoming a driving force for the modernization of our industry, presenting recent success stories of its implementation in Valencia and the rest of Spain. In total, more than 60 companies from the sector participated, making València the European capital of 5G. V5G Days 2022 was organized by the Mobile Communications Group of iTEAM of the UPV with the collaboration of Mobile World Capital, AMETIC and IEEE ComSoc Latam, and has the support of the València City Council and the Generalitat Valenciana (through the PROMETEO2020/040 project).

Also highlighted the leadership of Spain, in general, and Valencia, in particular, in the field of research and development in 5G technology. The demonstrations that stood out the most these days were those of connected robotics, virtual reality, autonomous driving... There were driving applications with Virtual Reality glasses, immersive mobile tourism experiences with 360° cameras and 5G, smart water meters equipped with 5G technology, and an immersive telepresence application, which allowed participants to feel as if they were teleported to another place (in this case nearby, in another part of the Oceanogràfic) and interact with people. At V5G Days, emphasis was placed on Valencian leadership in other disciplines, such as microelectronics.



V5G Days 2022.

In addition, for the second consecutive year, the iTEAM's MCG participated in the Mobile World Congress 2022 in Barcelona presenting the "5G underwater drone" demonstration from the Orange stand, together with the Oceanogràfic de València Huawei and Ender Ocean and Content Lab. Those attending the congress could live this immersive experience by controlling in real-time and only with their gestures a submerged robot (ROV) in the shark's aquarium of the Oceanogràfic de València (400 kilometers underwater), all thanks to 5G technology.



5G underwater drone demo at the MWC 2022.

## 1.- Project activities

### 1.1.- Ongoing projects

#### **VLC-CAMPUS-5G II (Pilot Test Campus, Development and Demonstration of 5G Mobile Technologies for the Internet of Things and Connected Machines Applied to Logistics)**

VLC-CAMPUS-5G II is the project to deploy an experimental field of 5G Mobile Technologies for the Internet of Things and Connected Machines that extends the current VLC-CAMPUS-5G infrastructure (from Release-15 to Release-16 standard).

The new equipment will include the mMTC (massive-Machine-Type Communications) and URLLC (Ultra-Reliable-Low-Latency Communications) functionalities that are fundamental for the Internet of Things and the connection of machines. Those will allow pioneering tests of 5G-IoT connected machines related to the world of Logistics and Industry 4.0 in general, with practical use cases applied to process and safety improvements in the port of Valencia.

During this year, the recruitment calls were launched for the acquisition of required equipment for the construction of the 5G-IoT test campus: Equipment with different types of mobile robots for indoor and outdoor industrial applications consisting of a fleet of mobile robots and a manipulator arm (MY21/ITEAM/S/95), 5G-IoT Release-16 end-to-end connectivity equipment in the frequency band below 6 GHz (MY21/ITEAM/S/96); Core network, radio access network; and 5G-IoT Release-16 devices emulation equipment (MY21/ITEAM/S/115); and 5G-IoT Release-16 end-to-end connectivity equipment in the millimeter wave frequency band (26-28 GHz) (MY22/ITEAM/S/28).

The purchased equipment will be used in the context of the current projects (iNGENIOUS, FUDGE-5G, 5G-TOURS, 5G-RECORDS, CROFT (PROMETEO 2020), ITN-5VC, 5G-INDUCE, 5G-IANA, Red.es 5G Pilots), among others, in which ITEAM participates. <https://vlc-campus5g.com/>

*This project is co-financed by the European Union through the operational program of the European Regional Development Fund (FEDER) of the Comunitat Valenciana 2021-2022, with reference IDIFEDER/2021/088, duration from January 2021 to December 2022.*

### **COREMAT-6G (Smart Radio 6G Communications using REconfigurable MATerials)**

COREMAT-6G aims at developing smart surfaces from an integral perspective, addressing from the design of the surface materials, their electromagnetic optimization, their influence on channel performance, their use for sensing and localization, as well as their management from the radio access network (RAN). The novelty of COREMAT-6G lays on the use of novel materials capable of changing their complex dielectric properties by adjusting their initial composition in combination with external control signals. These materials are in addition non-metallic, of lower cost and recyclable, so improving the

sustainability of the next generation networks deployment. All these concepts imply an interdisciplinary approach which accounts with highly specialized insight from different players, that will play a key role in the development, manufacturing and commercialization of these devices as 6G technology enablers.

Therefore, this project envisions involving the participation of both the scientific community in academia and research departments at companies, to succeed in the development of smart surfaces and their application.

Concretely, COREMAT 6G (Subproject A – RIS Implementation) will be focused on the research and development of both metallic and non-metallic RIS panels using novel dielectric materials to compare their performance. To achieve this goal, the engineering and design of both the materials of the panel as well as the design and optimization of the elements of the panel from the electromagnetic perspective will be also addressed. Besides, the physical implementation of the surface is also envisioned in the subproject, leading to a final manufactured prototype ready to be used in future applications in 6G networks (Subproject B - RIS Radio and Sensing) or to operate as an element of the network in future 6G systems (Subproject C - RIS Integration on 6G RAN).

*Call for applications for grants PRO-GRAMME FOR UNIVERSALIZATION OF DIGITAL INFRASTRUCTURES FOR UNICO-5G COHESION R&D 2021 published in BOE, on November 24, 2021 belonging to the Plan/Programme Plan for Recovery, Transformation and Resilience of the Government of Spain. From 29/11/2021 to 31/12/2024.*

### **Advancing-5G-Digital Twins (Real-time digital twin applications using advanced 5G and 6G technologies for industrial and logistics environments)**

The overall objective of the project is to create a flagship 6G application laboratory for real-time digital twins for industrial environments, which impose new requirements on the telecommunication network infrastructure in these vertical industries, and to progress beyond the current state of the art on new promising technological trends to enable the implementation of real-time digital twins, such as 5G-Advanced Internet-of-Things (IoT), edge and cloud computing, and real-time AI/ML (Artificial Intelligence/Machine Learning) analytics.

This project is divided in three subprojects: Advancing-5G-Digital Twins. 5G-IoT platform with edge and cloud computing (ADV5G-TWINS-CLOUD), Advancing-5G-Digital Twins for Industry 4.0 (ADV5G-TWINS-INDUSTRY), Advancing-5G-Digital Twins for Industry 4.0 (ADV5G-TWINS-INDUSTRY).

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#### **Advancing-5G-Immersive (Immersive and holographic advanced 5G laboratory)**

Advancing-5G-Immersive aims to create a cutting-edge immersive laboratory which will serve as one of the main Spanish testbeds for stakeholders and companies willing to validate their emerging 6G applications. The project is formed by three innovative types of communications: Haptic/Tactile, Holographic, and Telepresence. For each one of them, a subproject has been assigned, since the requirements, capabilities, technology enablers and use cases are different. These credible research proposals are completely aligned to the strategic research agenda of Smart Network and Services (SNS). The three subprojects will foster the creation of a highly-competitive beyond 5G ecosystem in Spain, which will strength the position and participation of Spain in the upcoming SNS work program in Horizon Europe, and therefore increase the reimbursement funding of Spain in this program.

This project will be carried out through the three subprojects: Advancing-5G-Immersive-Holographic (ADV5G-IMM-HOLOGR), Advancing-5G-Immersive-Telepresence (ADV5G-IMM-TELEP), Advancing-5G-Immersive-Haptic (ADV5G-IMM-HAPTICS).

The overall objective of Advancing-5G-Immersive project is twofold. On one side, the project aims to create a flagship 6G application laboratory for three emerging type of communications that impose new requirements on the telecommunication network infrastructure that cannot be met with existing 5G networks: emerging human-centric immersive applications (i.e. holographic, telepresence and haptics communications),

that are expected to revolutionize the work and everyday life of citizens. The three subprojects will pioneer the design and development of advanced 6G applications in Spain, increasing the Spanish competitiveness and sovereignty in future 6G “killer apps”. The laboratory will be also fundamental to define the Key Performance Indicators (KPI) and requirements for 5G-Advanced and 6G. On the other side, the three Advancing-5G-Immersive subprojects will research new promising technologies to optimize the delivery and implementation of the considered 6G applications, including: The combination of enhanced Mobile Broadband (eMBB) with the low-latency features of Ultra-Reliable Low Latency Communications (URLLC), 5G-Advanced broadcast with Non-Terrestrial Networks (NTN), and softwarized core and radio components for holographic, telepresence and haptic communications.

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#### **EMERGE-5G (Electromagnetic Fields Methodologies for 5G Use Cases)**

The Fifth Generation (5G) of mobile communication systems is expected to bring novel applications and business models. Its many enhanced capabilities are going to provide ultra-high speed, low latency and reliable communications never seen so far. These new features will be possible thanks to several innovations in their radio interface: massive MIMO (mMIMO) antennas and beamforming. These new features along with the intensive use of Time Division Duplexing multiplexing (TDD), will lead to a novel radio interface, called 5G New Radio (NR).

Exposure to electromagnetic (EM) fields have been a controversial issue during the last decades and years. The International Commission of Non-Ionizing Radiation Protection (ICNIPR) published in 1998 their guidelines for limiting exposure to EM fields, and in May 2020 has updated their recommendations in order to better adapt them to future 5G transmissions. The techniques for the assessment of human exposure to EM fields have been regulated y international organisms and can be performed by means of exposimeters and spectrum analysers. However, due to the

several novelties of the radio interface of 5G, it is not clear yet whether existing methodologies can evaluate properly the EMF in 5G.

The objective of EMERGE-5G project is the development of new methods and guidelines for the assessment of human exposure to the different novel used cases envisioned in 5G communication networks. To achieve this goal, firstly measurements in commercial and private 5G networks will be performed with different methodologies and equipment in order to compare them and obtain guidelines that can be translated to other use cases. Next, particular scenarios will be evaluated by means of software simulations or laboratory measurements with the aim of deducing recommendations for evaluating 5G exposure in such scenarios.

*This project has been funded by Agencia Estatal de Investigación MCIN/AEI/ 10.13039/501100011033. Duration: 01/12/2021 to 30/11/2024*

### **ITN-5VC (Integrated Telematics for Next Generation 5G Vehicular Communications)**

ITN-5VC aims to investigate how multi-band multi-antenna communications, including mmWave, could be integrated with radar heads and other wireless sensors into the same telematics unit so that transmission chains and radiation systems were reused opportunistically using the same spectrum. This idea has important implications for the design of the vehicle and its communications that will also be addressed in the project. With this premise, the project aims to investigate the future C-V2X systems based on 5G NR and how to integrate them with autonomous driving sensor systems. In the last year, three different training activities have been held: General Skills Training School (UPV), Vehicular Automation Seminar (Volkswagen), and V2X Communications/Simulations Training School (Bosch). These activities have provided high-quality interdisciplinary and cross-sector research training for a new generation of scientists. <https://itn5vc.eu/>

*This project has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No. 955629 Duration: 01/10/2020 - 30/09/2024.*

### **5G-INDUCE (Open cooperative 5G experimentation platforms for the industrial sector NetApps)**

The 5G-INDUCE project develops and open and cooperative 5G network platforms that will allow the showcasing and evaluation of advanced network applications, supporting emerging and innovative services related to the industry 4.0.

The goal is to provide an end-to-end orchestration platform over enabling experimentation infrastructures for advanced 5G network applications that can be applied for the realisation of extensive 5G UCs in the broader Industry 4.0 sector, leading to technological and business validation of 5G technologies by multiple collaborating tenants (e.g., manufacturing, logistics, maintenance power management, security/surveillance and more).

Focus is given on validation of the 5G-readiness of both telecom operators and applications providers. The 5G-INDUCE experimentation facilities (ExFas) are deployed with the goal to validate and showcase over a real industrial 5G environment the developed NetApps.

Three ExFas are envisioned Spain, Italy, and Greece, all linked with large industrial facilities (Ford, Whirlpool and PPC respectively) while being supported by advance 5G infrastructures.

The overall purpose of the adopted ExFa sites is to address actual Industry 4.0 needs in a diverse set of industrial environments, showcasing the beneficial use of 5G technology in terms of latency, optimized interoperability and management, security, and safety.

Following the evolution of Automated Guided Vehicles (AGVs) use in Ford three UCs will be tested to achieve a higher level of automation and increase human-machine interaction: Autonomous AGV fleet management, Smart operation of AGVs based on human gesture recognition and Virtual Reality (VR) immersion of AGVs control. <https://www.5g-induce.eu/>

*iTEAM is leading this project, which has received funding from the European Union's Horizon 2020, under grant agreement no.: 101016941, 36 months duration (January 2021 - December 2023).*

### **INGENIOUS (Next-GENeration IoT solutions for the Universal Supply chain)**

iNGENIOUS aims to design and evaluate the Next-Generation IoT (NG-IoT) solution, with emphasis on 5G and the development of Edge and Cloud computing extensions for IoT, as well as providing smart networking and data management solutions with Artificial Intelligence and Machine Learning.

For this purpose, the project will exploit some of the most innovative and emerging technologies in line with the standardised trend, contributing to the NG-IoT and proposing technical and business enablers to build a complete platform towards the future fully digitized supply chain management. iNGENIOUS embraces the 5G Infrastructure Association (5G IA) and Alliance for Internet of Things Innovation (AIOTI) vision for empowering smart manufacturing and smart mobility verticals. Following these references, the project proposes a cross-layer architecture including new smart 5G-based IoT functionalities, federated Multi-Access Edge Computing (MEC) nodes and smart orchestration, needed for enabling the projected real-time capable use cases of the supply chain. All this integrated under secure and trustworthy data management, thanks to a holistic security architecture for next-generation IoT built on neuromorphic sensors with security governed by Artificial Intelligence (AI) algorithms and tile-based hardware architectures based on security by design and isolation by default.

Project outcomes are validated into 4 large-scale Proof of Concept demonstration, covering 1 factory in the North of Spain, 2 ports, the port of Valencia in Spain and the port of Livorno in Italy, and 1 ship traveling from Valencia in Spain to Piraeus in Greece, encompassing 6 uses cases.

iNGENIOUS consortium is formed by 21 partners from eight countries, including telecom vendors and manufacturers, network operators, logistics partners, universities, research institutes and seven high-tech Small Medium Enterprises (SMEs) [www.ingenious-iot.eu](http://www.ingenious-iot.eu)

*iTEAM is leading this project, which has received funding from the European Union's Horizon 2020, under grant agreement no.: 957216. 30 months duration (October 2020 – March 2023).*

### **FUDGE-5G (FULLY Disintegrated private nEtworks for 5G verticals)**

FUDGE-5G will make a leap forward in realizing the notion of cloud-native 5G private networks by developing a further enhanced Service-Based Architecture (eSBA) for both control plane and user plane with “decomposed” players of the ecosystem divided into: New Radio (NR) access network infrastructure provider, eSBA platform provider, mobile 5G Core (5GC) provider, vertical application orchestration provider and vertical service provider. The forward-looking FUDGE-5G architecture will also feature “all-Ethernet” 5GLAN (Local Area Network), 5G-TSN (Time-Sensitive Networking), 5G-Multicast and intelligent vertical application orchestration features. The proposed framework enables highly customized cloud-native deployment of private 5G networks that can be deployed anywhere as micro-services (i.e., edge, on premises and cloud), while the access network is hosted over 5G, WiFi or wired Ethernet links. iTEAM is the coordinator of the project, and the leader of the Multimedia use case, divided into two sub-scenarios: an uplink focused Remote Production over 5G and a downlink intensive Media Showroom. iTEAM is also developing 5 Mobile Broadband System (5MBS) prototype to provide broadcast/multicast services over 5G. iTEAM also hosts one of the Interconnected NPN (Non Public Network) node, interworking with a Berlin and a London nodes. [www.fudge-5g.eu](http://www.fudge-5g.eu)

*iTEAM is leading this project, which has received funding from the European Union's Horizon 2020, under grant agreement no.: 957242., 30 months duration (September 2020 – Feb. 2023).*

### **eSCOPE (Early Diagnosis of Colorectal Cancer by using an Electromagnetic Probe)**

The project addresses clinical studies on patients with colorectal tumours who are going to undergo surgery, using both a commercial rigid probe already available to the research team and flexible probe prototypes that would form part of the final diagnostic device. This study will allow, on the one hand, to finally confirm that the differences in permittivity (dielectric constant and conductivity) between healthy and tumour tissue are as expected by our previous studies and that they can be used as a diagnostic criterion for colorectal cancer. On the other hand, measurements with the flexible probe prototype would allow further progress in the development of this device while comparing its performance and features with commercial rigid measuring

probes already available to the research team. At the same time, the project will improve the diagnostic algorithm to distinguish tumours from other types of pathologies, optimising its specificity and sensitivity.

*This project has been funded by Ayudas para el Desarrollo de Proyectos de Innovación Coordinados entre la Universitat Politècnica de València y el Hospital Universitario y Politécnico La Fe (call 2020). Duration: 01/11/2020 to 31/12/2022.*

### **HEPATOAXIAL (ElectroMagnetic prObe for early Tumour dEtection)**

The specific objective of this project is to find out how permittivity correlates with hepatic steatosis under in vivo conditions. To this end, an extensive measurement campaign is to be carried out throughout the duration of the project, which will provide a sufficient sample size to determine this correlation and confirm whether a greater presence of steatosis translates into a lower value of the permittivity typical of a healthy organ. Once this relationship has been determined, the overall objective of the final project is to design, implement and validate a measurement and diagnostic system based on the open coaxial method to determine the degree of steatosis in livers. The potential advantage of this method will lie in the possibility of making the diagnosis in just a few minutes, which can have a great impact when performed in situ during transplants. In addition, unlike liver biopsy, this system will have the ability to analyse several points and segments of the organ, not just a single point as is currently the case with biopsy.

*This project has been funded by Ayudas para el Desarrollo de Proyectos de Innovación Coordinados entre la Universitat Politècnica de València y el Hospital Universitario y Politécnico La Fe (call 2021). Duration: 01/10/2021 to 31/12/2022.*

### **5G-RECORDS (5G key technology enableRs for Emerging media Content pRoDuction Services)**

5G-RECORDS aims to explore the opportunities that new 5G technology components, including the core network (5GC), radio access network

(RAN) and end devices (UEs), can bring to the professional production of audiovisual content. The project targets the development, integration, validation, and demonstration of 5G components for professional content production, as part of an overall ecosystem integrating a subset of 5G network functions.

The project is using 5G key enabling technologies, such as NPNS, network slicing, millimeter waves, network function virtualization, among others, to bring these new 5G components to emerging markets and new market actors, while also addressing recent emerging remote and distributed production workflows where cloud technologies work hand in hand with 5G.

5G-RECORDS is structured around three real-world content production use cases: live audio production, a multicamera wireless studio and live immersive media production. The 5G project use cases testbeds are located in Sophia Antipolis (France), Aachen (Germany) and Segovia (Spain), respectively.

The first use case focuses on deploying a 5G private local network using open-source software and general-purpose processors as part of the overall infrastructure. To meet the challenges of live audio production, i.e., stringent requirements in terms of latency, availability and synchronization, ultra-reliable low-latency communications (URLLC) is key.

The second use case aims to develop a complete production system that takes advantage of 5G technology. This use case will deploy a studio with wireless 5G-enabled cameras for operation under remote production scenarios. This wireless scenario involves video, audio, and auxiliary data processing with strict requirements in terms of quality, data rate, latency, reliability, and synchronization between devices. Its main goal is to equip media equipment with external codecs and 5G modems that feed the media signals into the 5G network. A project-developed media gateway on the other end translates the 5G-IP transport protocols to the desired ones suited for media production networks, such as SMPTE-2110. The media equipment is managed through an also project-developed control gateway through the 5G network via Networked Media Open Specifications (NMOS) protocols.

The third use case aims to enable real-time immersive capture of sporting and cultural events through cameras connected via 5G millimeter waves. The key to this use case is to develop a high-definition free-viewpoint-video (FVV) solution to provide a new kind of experience to viewers in the location of the live event, as well as to remote viewers. Thanks to

the enhanced bandwidth, it will be possible to broadcast content both live and in replays, with different perspectives and shots, so that the live program director can move the viewpoint of the image freely. [www.5g-records.eu](http://www.5g-records.eu)

*iTEAM is leading this project, which has received funding from the European Union's Horizon 2020, under grant agreement no.: 957102, 26 months duration (September 2020 – October 2022).*

### **5G-TOURS (SmarT mObility, media and e-health for toURists and citizensS)**

5G-TOURS vision was to improve the life in the city for the citizens and tourists, making cities more attractive to visit, more efficient in terms of mobility and safer for everybody. 5G-TOURS builds on three themes: the touristic city (Turin), the mobility efficient city (Athens), and the safe city (Rennes). iTEAM was involved in the touristic city, where visitors of museums and outdoor attractions are provided with 5G-based applications to enhance their experience while visiting the city. This included VR/AR applications to complement the physical visit with additional content, involving interactive tactile communications. The experience of the visitors was also enhanced with robot-assisted services, telepresence to allow for remote visits, as well as live events enabled by mobile communications such as multi-party concerts. iTEAM was the leader of the broadcast use case. In this use case, a novel 5G Broadcast network was used to send high-quality multimedia content using a High Power High Tower architecture to the visitors of Palazzo Madama. UPV contributed directly to the development of equipment compatible with 5G Broadcast specifications, based on Software Defined Radio (SDR), as well as the implementation of the multicast interfaces of the 5G Core. [www.5gtours.eu](http://www.5gtours.eu)

*This project has received funding from the European Horizon 2020 under grant agreement no.: 856950, 36 months duration (June 2019 – May 2022).*

### **CROFT (Cloud Robotics and factories Of The FuTure)**

This project addresses the research required for the development of mobile robotics in the cloud

based on 5th generation mobile networks for the future IoT revolution.

The objective of the project is to research and optimize the operation of RAN architectures for 5G standards beyond NR phase 2, and to design reliable and realistic PHY and MAC procedures adapted to this new communication model composed of mesh networks and mobile nodes. The ultimate goal is to achieve an improvement in the latency, reliability and capacity of the large number of robots, drones, droids and humans that will work together in the factory of the future. In this context, the new communication paradigm of mmW and continuous UDNs together with the use of multihop cellular communications play a transversal role. During the project, the performance of the systems will be evaluated, simulations, RF measurements, and experiments with a large number of devices will be performed to validate the design principles used. For this purpose, the infrastructures of VLC-CAMPUS-5G I and II are being exploited. In addition, this project aims to attract the talent of women to the new job opportunities that 5G will generate and increase the visibility of the group in the definition of 5G, for this this year the second edition of V5G Days 22 has been organized. <https://vlc-croft5g.com/>

*This project has been funded by the Prometeo 2020 grant (PROMETEO2020/040) from the Generalitat Valenciana to carry out R & D & I projects for research groups of excellence, 36 months duration (01/01/2020 - 30/12/2022).*

### **5G-SMART (5G for smart manufacturing)**

5G-SMART unlocks the value of 5G for smart manufacturing through demonstrating, validating and evaluating its potential in real manufacturing environments. 5G-SMART trials will test the most advanced 5G integrated manufacturing applications such as digital twin, industrial robotics and machine vision based remote operations. 5G-SMART will undertake the first ever evaluation of ElectroMagnetic Compatibility (EMC), channel measurements and co-existence between public and private industrial networks in real manufacturing environments easing the integration of 5G. The new 5G features, developed in 5G-SMART such as time synchronisation and positioning for manufacturing use cases represent a technological leap.

5G-SMART lead by Ericsson brings together a strong consortium of partners involved in



every aspect of the manufacturing ecosystem. Prof. Jose F. Monserrat, member of the iTEAM, is the Innovation Manager of the Project. This project is funded by the European Commission. <https://5gsmart.eu/>

*This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no.: 857008. From June 2021 to May 2022.*

### 5G-CARMEN (5G for Connected and Automated Road Mobility in the European union)

This project, funded by the European Commission, has progressed with relevant impact on research community, being declared the most active project on autonomous driving by the European Commission.

The "Munich-Bologna corridor", which covers 600 km of roads across three countries (Italy, Austria and Germany), is one of the most important corridors identified by the European Union for an initiative to improve the mobility of people and goods throughout Europe. As part of the 5G-CARMEN project, 5G technologies have been deployed along selected stretches of the motorway in the border regions. First demos were experienced in June 2021, being the fall 2021 a new opportunity for testing real autonomous cars along European motorways. Final results in June 2022 showcased vehicles performing semi-autonomously, and equipped with communication technologies developed in 5G-CARMEN, which were demonstrated in the Austria-Italy border. Moreover, a centralized connected and automated lane change demo was tested at the Germany-Austria border. <https://5gcarmen.eu/>

*This project has received funding from the European Horizon 2020 Programme for research, technological development and demonstration under grant agreement no.: 825012. From November 2018 to July 2022.*

### 5G Valencia Pilots (5G Mobile Networks Pilot, Red.es Call 2019)

This is a Spanish national project, dedicated to study and experiment with 5G technology thanks to several real-world use cases performed

in the city of Valencia, Spain. The main objective of the project is to deploy real-world use cases using 5G technology to extract knowledge about technical aspects and viability of 5G applied to different verticals. iTEAM has participated in several use cases out of the 15 use cases proposed by the project: (1) Robotic Remote diagnostic, (2) Disaster Recovery, (3) Fleet management: Robotics Remote control of AGVs, (4) Robotics-Remote inspection and maintenance, (5) 5G Digital Contents, and (6) Massive IoT for smart meters in supplies.

The Disaster Recovery use case aims to study if 5G Millimetre Waves (mmW) connectivity can provide high bandwidth, reliable communications which can substitute fiber in disaster scenarios. In this use case, a backup system has been designed and tested to provide educational media content to the Universitat Politècnica de València (UPV) students and teachers in case of internal network failure or disaster. Through a real-world demo, the use case was demonstrated and the 5G mmW technology was presented as a future viable solution for wireless, high bandwidth communications solution.

The use case of 5G Digital Contents aims to study 5G and traffic prioritization as a viable solution for remote media content production. In this case, a media production system has been designed and tested to evaluate if 5G-enabled devices (cameras and microphones) which are covering a live event located remotely from the production center can provide the necessary performance and reliability to carry out a media content production, through network traffic prioritization. Through a real-world demo, the use case was demonstrated and the 5G technology was presented as a future viable solution for remote content production scenarios.



Use Case Demonstration of 5G Valencia Pilots (Red.es)

Some of 5G use cases demos, specifically in the field of telemedicine, remote inspection, and fleet management, were shown in front of senior officials from the national and local government, as well as managerial staff from Orange Spain, during the Red.es 5G pilots presentation event hosted by Orange Spain at the UPV on June 2021.

In addition, the use case of remote inspection and maintenance of electrical and railway infrastructures using Orange Spain's 5G network was demonstrated at the Universitat Politècnica de València on May 2022, thanks to the 5GBROAD from Fivecomm that successfully provided 5G connectivity to a Robotnik Automation robot. <https://5gpilotosvalencia.orange.es>

*This project has been funded by Red.es through European Regional Development Fund, 18 months duration (December 2020 – June 2022).*

### **5G Castilla La Mancha Pilots (5G Mobile Networks Pilot, Red.es Call 2019)**

The national project of Red.es in Castilla-La Mancha is based on the first real time demo of a live production and distribution of TV content by means of a 5G network in the city of Toledo, Spain. The project is made up of two use cases, the first that encompasses the multimedia content production through the use of 5G and the second use case is based on the content distribution using a 5G broadcast network. The first use case is based on the live production in the cloud of multimedia content from a live event in the Cortes of Castilla-La Mancha located in the city of Toledo. This requires reporters from the Corporación Radiotelevisión Española (RTVE), a 5G network arranged by Telefónica, which will be in charge of collecting information, in high-quality audio and video format. The objective is to transfer it in real time to the capture servers in the cloud of the WATCHITY.

For the second use case, this output signal is required from a web browser with professional rendering quality. This content will be modulated and transmitted using the 5G Broadcast network, by means of the integration of the iTEAM software-defined radio (SDR)-based 5G Broadcast network together with the high-power RF equipment of BTESA, getting a 5G Broadcast transmitter with enough radio frequency power to cover the city of Toledo completely. TelecomCLM will provide the high power High Tower (HPHT) infrastructure, in which Digital Terrestrial Televisión (DTT, Cerro de los Palos broadcasting center) is currently being broadcast.

*This project has been funded by Red.es through European Regional Development Fund, from June 2020 – to December 2022.*

### **AUDERE (Advanced Urban Delivery and Refuse Recovery)**

The AUDERE project aims to design and develop an intelligent automated system for urban waste collection as well as last-mile parcel delivery. The AUDERE platform coordinates robots (autonomous vehicles) and smart containers that are connected to a 5G network. The project has been included as a use case within the 5G Pilots project in the Comunitat Valenciana where Orange participates as an infrastructure provider. The system has been validated at the VLC-CAMPUS-5G of the Universitat Politècnica de València, a closed and controlled environment, which could be considered a small city due to its infrastructure, commercial and sports places, banks, parks, and where more than 20,000 people move daily. The second validation scenario is the La Pinada District, which is an eco-district, the first in Spain, that will integrate the principles of sustainable urban development, creating an attractive environment for family living, work, and enjoyment of nature. The results of this project will define new technological products that can be deployed in Smart Cities or Smart Quarters.

*This project has been funded by The Agència Valenciana de la Innovació (AVI), 21 months duration (April 2020 – December 2021).*

### **6G Evaluation Methodologies (SOW 1, SOW12)**

In this project, work continues on an exploratory research towards the definition of the 6G developing the required models and making a specific proposal of scenarios, assumptions and KPI. Considering that the frequency range will exceed the 100 GHz limit, and the propagation will be highly dependent on the details, new channel models are required, while a more accurate characterization of the obstacles is a must. In this way, the project is focused on the set up of an advanced E2E simulation platform in which new channels models light-oriented will be integrated. Accurate modelling of the channels and the obstacles are being included, while a first set of scenarios for simulation are being analysed as a prospective analysis.

*This project was funded by Huawei as a part of our iTEAM – Huawei Joint Research Center. It's original duration of 12 months, has been extended until 30/03/2023.*

### Quantum Machine Learning for the AI Integration in 6G (SOW2, SOW10)

The project was planned as exploratory and aimed to use the advantages of quantum information theory to improve classical machine learning. Quantum machine learning met high expectations of providing a solution to the analysis of large volumes of data using the power of quantum computing “parallelism”. Specifically, aims at meeting the Grover algorithm for the identification of matches in an exploratory search among big data. A clear example is to identify a face image pattern through the cameras and thus be able to locate the person among millions of images captured instantly. This could be used in a subsequent phase of the project to elaborate in a collaborative manner the hologram of a person for the holographic moving call.

*This project was funded by iTEAM – Huawei Joint Research Center and its original duration of 12 months, from 01/04/2021 to 30/03/2022 has been extended until next April.*

### Customized materials for EM communications in the GHz and THz band (SOW6)

The project aims to develop full-spectrum phantoms, i.e., liquids and semisolids (gels) components with tailor-made electromagnetic properties fully adjustable in the range above 26GHz and up to 100MHz for a range of applications in 6G new devices and interfaces. This “custom EM materials” can be used in many areas like the physical interface between antennas and surfaces, the better impedance adaptation in wearables or implants, to develop “liquid” antennas, to build physical EM filters for certain bands, to improve human brain interfaces, and to explore the possibility of integrating these materials (in its gel configuration) in printed electronics or Reconfigurable Intelligent Surfaces (RIS). The scope of the project is to develop novel composite materials, on the basis of iTEAM’s expertise, that can replicate the behavior of different human body tissues in an ultra-large frequency band.

*Huawei as a part of our iTEAM – Huawei Joint Research Center funds this project. Duration: 18 months, from 01/04/2021 to 30/09/2022.*

### AI Video-Assisted Radio Communications (SOW7, SOW11)

The project combines Artificial Intelligence video tracking algorithms with reconfigurable radiating systems, to improve beamforming performance and vehicle’s location. Current systems rely on the detection of sensing radio signals and their quality. These solutions are reactive, meaning that the system responds to the radio channel behaviour and changes accordingly. Many scenarios in which the future communication systems will be deployed, or are deployed nowadays, can be assisted by video information, to feed the reconfiguration algorithms of the radio systems and even to anticipate such configuration on the basis of predictive video analytics. The aim of this project is to develop a prototype of a video-assisted beamforming panel, as a first proof of concept of the AI applied to the Physical Layer of beyond 5G radio, as well as to explore the application to reinforce the location and tracking of moving objects in indoor (industrial) environments, to define a potential follow-up of the work on that direction.

*Huawei as a part of our iTEAM – Huawei Joint Research Center funds this project. Original duration: 12 months, from 01/04/2021 to 31/03/2022. Extended until next April.*

## 2.- Research results

### 2.1.- Featured publications

**“5G key technology enablers for emerging media content production services”**  
**Universitat Politècnica de València, Nokia Spain S.A., Ericsson GmbH., Telefonica Investigación y Desarrollo SA, Cumucore OY, RED Technologies, Image Matters, Radiotelevisione Italiana Spa, Accelleran, LiveU Ltd., 5G Communications for Future Industry Vertical S.L., Eurecom, Sennheiser Electronic GmbH & Co. KG, Red Bee Media, Union Européenne de Radio Télévision, British Broadcasting Corporation, Universidad Politécnica de Madrid, TV 2 Denmark AS, doi: 10.3030/957102**

This paper explores the possibilities that 5G technologies and innovations may bring to the content production industry. The project targets the integration and validation of 5G technologies as part of an overall infrastructure in order to meet the requirements of the emerging market players in Europe, especially in the context of

professional content production. Three use cases will be deployed in professional environments, enabling performance measurements and evaluation, aiming to explore and demonstrate the feasibility of using 5G in the context of professional content production, opening new horizons for the industry and generating new business models that will help to deliver value.

**“A Disaggregated 5G Testbed for Professional Live Audio Production” J. Dürre, N. Werner, P. Matzakos, R. Knopp, A. Garcia and C. Avellan, “A Disaggregated 5G Testbed for Professional Live Audio Production,” 2022 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB), 2022, pp. 1-6, doi: 10.1109/BMSB55706.2022.9828613.**

Professional wireless audio equipment such as microphones and in-ear-monitoring systems are popular among live musicians and performers due to their beneficial flexibility and mobility. At the same time, artists have very high technical requirements for these devices e.g., regarding transmission delay, reliability, and battery runtime. In addition, cost, efficient use of scarcely available spectrum, and related scaling factors play a major role in professional audio productions. As of today, the entirety of technical requirements under given constraints can only be met with highly optimized custom RF technology. The new generation of cellular technology 5G is targeted to deliver new ultra-reliable low latency communication (URLLC) use cases similar to fore mentioned audio scenarios. Within the H2020 project 5G-RECORDS, a consortium of relevant actors from the media and mobile industry are exploring and evaluating 5G technology and related eco systems in the context of professional audio productions. Key element of the consortiums holistic approach of answering the question if requirements can be met and understanding relevant economic trade-offs, is the setup and optimization of a disaggregated 5G testbed. This work describes the testbed in detail and presents first results of the technical evaluation.

**“A Multiple Camera 5G Wireless Studio for Professional Content Production Scenarios” P. Sunna et al., 2022 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB), 2022, pp. 1-6, doi: 10.1109/BMSB55706.2022.9828740.**

In this paper, a detailed overview of the H2020 European 5G-RECORDS project Use Case 2 (UC2) is presented. Currently, the project is in its 20th month of 26 and it is in the final stages of integration, tests and trials. The project devised three use cases focused around exploring 5G technologies for content production scenarios.

Use Case 2 is “Multiple Camera Wireless Studio” and has two main objectives: exploring how 5G can help create an IP studio environment in which wired and wireless equipment can be used for media content production; and how 5G can help for remote contribution scenarios. The paper outlines the envisioned scenarios, describes the components of the use case (a detailed description of two of the components is given: the Media Gateway and the Media Orchestration and Control Gateway), the results obtained via a series of tests performed to demonstrate the validity of multiple production scenarios are presented and finally work remaining, expected outcomes and future beyond the project are discussed.

**“5G Broadcast SDR Open Source Platforms”, A. Ibanez, J. Sanchez, D. Gomez-Barquero, J. Mika, S. Babel and K. Kuehnhammer, 2022 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB), 2022, pp. 01-06, doi: 10.1109/BMSB55706.2022.9828570.**

SDR stands for Software Defined Radio. This term encompasses programmable transceiver which supports various wireless technologies with low dependence of hardware. The main advantage of the SDR is the capability of the migration during prototypes developments from one standard based device to the other, support for many technologies (such as WiFi, LTE, 5G NR), the easy introduction of new releases with minimum hardware updates and also it deals with many software defined wireless communication protocols (e.g. PHY, MAC) rather than hardware based solutions. One of the technologies that have benefited from SDR is the mobile communications, being LTE and 5G NR technologies that are currently available, under Open Source solutions in SDR for a laboratory tests. The deployment of a SDR prototype could be key for the emerging 5G Broadcast solutions. In this article we will perform an analysis of the SDR open source platforms which offers 5G Broadcast solutions. For instance, the current OAI SDR broadcast solution and the 5G broadcast solution, recently developed by UPV and ORS, will be evaluated.

**“Received power modelling in ultra-dense networks” D Prado-Alvarez, A Antón, D Calabuig, JF Monserrat, S Bazzi, W Xu. Electronics Letters 58 (11), 448-450**

This paper studies the impact of accounting or not accounting for receiver antenna gain in ultra-dense indoor environments with ceiling-mounted antennas. A simple approach to account for this gain using the effective antenna area is provided. Finally, this approach is compared with that based on antenna radiation patterns.

**“Effect of Breathing on UWB Propagation Characteristics for Ingestible and Implantable Devices”. Concepcion Garcia-Pardo, Alejandro Fornes-Leal, Matteo Frasson, Vicente Pons-Beltrán, Narcis Cardona. IEEE Transactions on Antennas and Propagation, Pages 3118 - 3122, 14 October 2021. DOI: 10.1109/TAP.2021.3118724**

Wireless in-body devices are those in which a medical sensor is introduced–implanted or ingested– inside the human body and communicates with a remote node. Some in-body applications demand high data rates, so ultrawideband (UWB) spectrum has been proposed as a good candidate because of its large bandwidth available. Besides, breathing can lead to internal movement of the torso and consequently, of devices installed in this area. Thus, the radio channel performance can be affected by such movement leading to a malfunction of the radio interface of the medical device. This work aims at analyzing the effect of breathing on the propagation channel by means of in vivo measurements in living animal models. Continuous wave (CW) measurements have been carried out for five different frequencies in the lower part of the UWB band, and the effects of breathing on the relative received power (module and phase) are analyzed and discussed.

## 2.2.- Awards.

- ◆ **Best Final Work of Degree award** at the Valencian Telecommunications Night (NTV) and 1st prize in the Telecommunication Systems category at the XV edition of the Future of Telecommunications Awards organized by the Official College and Spanish Association of Graduates and Technical Telecommunications Engineers. “Colorectal Cancer Diagnosis Using Electromagnetic Tissue Characterization and Video Endoscopic Analysis.” (Sergio Morell)
- ◆ **Best Master’s thesis award** at the Valencian Telecommunications Night (NTV). “5G mobile robotics: Implementation of a control platform for robotic systems.” (Miriam Ortiz).