Beyond 5G Multi-Tenant Private Networks Integrating Cellular, Wi-Fi, and LiFi, Powered by Artificial Intelligence and Intent Based Policy

5G-CLARITY Deliverable D6.3

Mid-Term Report on Disseminations and Communications Activities

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List of Acronyms

3GPP	3rd Generation Partnership Project
5GC	5G Core
5GNR	5G New Radio
ACL	Access Control Lists
AGV	Automatic Guided Vehicle
AI	Artificial Intelligence
AoA	Angle-of-Arrival
API	Application Programming Interface
AT3S	Access Traffic Steering, Switching and Splitting
B5G	Beyond 5G
CBRS	Citizen Broadband Radio Service
CP	Control Plane
eAT3S	Enhanced AT3S
IP	Internet Protocol
KPI	Key Performance Indicator
L2	Layer 2
LiFi	Light Fidelity
LoS	Line-of-Sight
LTE	Long Term Evolution
ML	Machine Learning
mmWave	Millimetre Wave
MP3S	Multi-Path Steering, Switching and Splitting
MPTCP	Multi-Path TCP
NFV	Network Function Virtualisation
NPN	Non-Public Network
O-RAN	Open RAN
RAN	Radio Access Network
RAN	Radio Access Network
RIC	Radio Interface Controller
RU	Radio Unit
SAS	Spectrum Access System
SLA	Service Level Assurance
SSID	Service Set Identifier
SSS	Switching, Steering and Splitting
TCP	Transmission Control Protocol
ToF	Time-of-Flight
UC	Use Case
UE	User Equipment
UL	Uplink
UP	User Plane
UPF	User Plane Function
VM	Virtual Machine
VNF	Virtual Networking Function
WAT	Wireless Access Technology
WP	Work Package

Executive Summary

This document corresponds to deliverable D6.3, entitled 'Mid-term report on dissemination and communication activities', achieved in the framework of 5G-CLARITY's Work Package 6 (WP6).

Particularly, it includes all the dissemination and communication activities related with the promotion of the 5G-CLARITY project and its results beyond the project own community along the mid-term project execution.

According to deliverable D6.1 [1], in this document, all 5G-CLARITY's WP6 achieved activities are clustered in three main sections: Communication, Dissemination, and Exploitation activities.

The Communication Section reports on activities carried out that impact project stakeholders and audiences that go beyond the project's own community, including the general public and the media. The Dissemination Section includes activities related with boosting awareness of 5G-CLARITY results in a technical community working on the same research field. In general, this has been done through publications in high impact journals/magazines, international conferences and participation in technical events. Finally, the Exploitation Section covers activities aiming at using the results in further research activities other than those covered by the project, such as developing, creating and marketing products or processes, creating and providing a service.

As part of WP6, the plan included here will be complemented by the following deliverables. For each document, the delivery date is also provided:

- D6.4 Mid-term report on standards engagements: Month 18.
- D6.5 Final report on innovation management, exploitation and Intellectual Property (IPR): Month 27.
- D6.6 Final report on dissemination and communication: Month 30.

1 Introduction

The main purpose of deliverable D6.3 is to report on the 5G-CLARITY's communication and dissemination activities achieved in the first 15 months of the project (from November 2019 to April 2021), including 3 months extension due to the COVID-19 pandemic. All reported activities aim at the promotion of the 5G-CLARITY project and its outcomes to the target audience (defined in Table 2-1 of 5G-CLARITY D6.1, 'Plan for Exploitation and Dissemination of the Project Results' [1]).

In regard to the Innovation Management activities, the summarised overview of the first and second workshops on effective innovation management among the 5G-CLARITY project partners, reporting on the held workshops content, output and feedbacks received from each participant was included in 5G-CLARITY D6.2, 'Interim Report on Innovation Management' [2], submitted on the 31st of October 2020.

Following 5G-CLARITY D6.1, 'Plan for Exploitation and Dissemination of the Project Results' [1], the current deliverable provides a detailed report of the work carried out by 5G-CLARITY in this domain, with particular emphasis on the fulfilment of the Key Performance Indicators (KPIs).

1.1 Organisation of the document

This document is structured in 5 Sections. Following the Introduction, Section 2 reports on the Communications Activities. Section 3 describes the 5G-CLARITY Dissemination Activities. It includes scientific publications (papers in indexed journals and international conferences) and other dissemination actions as well (workshops and panels among others). Section 4 provides some insights regarding exploitation activities. Finally, Section 5 concludes this mid-term report.

2 Communications Activities

The 5G-CLARITY communications plan was detailed in 5G-CLARITY D6.1, Section 3 [1]. Here a report on the updates related to the project identifier, the communication activities and the external/internal communication channel and social media are provided.

2.1 Project identifier

The project identifier, 5G-CLARITY logo, as Figure 2-1 shows, has been used across project communication channels, on project deliverables, reports, newsletters, presentations, and anywhere suits.

Figure 2-1: 5G-CLARITY project logo

2.2 Communication channels

The communication activities are performed based on the guidelines sketched in [1] in terms of the targeted audience, as well as the employed channels and tools. All project partners have been so far actively involved in the corresponding activities, *a)* using internal communication channels, *b)* using and promoting external communication channels, and *c)* promoting social media posts. Further details on the communications activities are provided in the following subsections.

2.2.1 Project repository and collaboration tool

For internal communications between partners, originally the Basic Support for Cooperative Work (BSCW) workspace server was used as a repository. However, since there were requests from partners to employ a tool equipped with software version control, which suits well for the preparation of collaborative documents and reports, a Microsoft (MS) Teams account was made available for the consortium.

The 5G-CLARITY MS Teams has around 50 active members from 12 partners. It is used to store and share all project documents, reports, deliverables, and presentations, and has served the purpose well. Figure 2-2 shows how the 5G-CLARITY Teams is organised into several channels and folders.

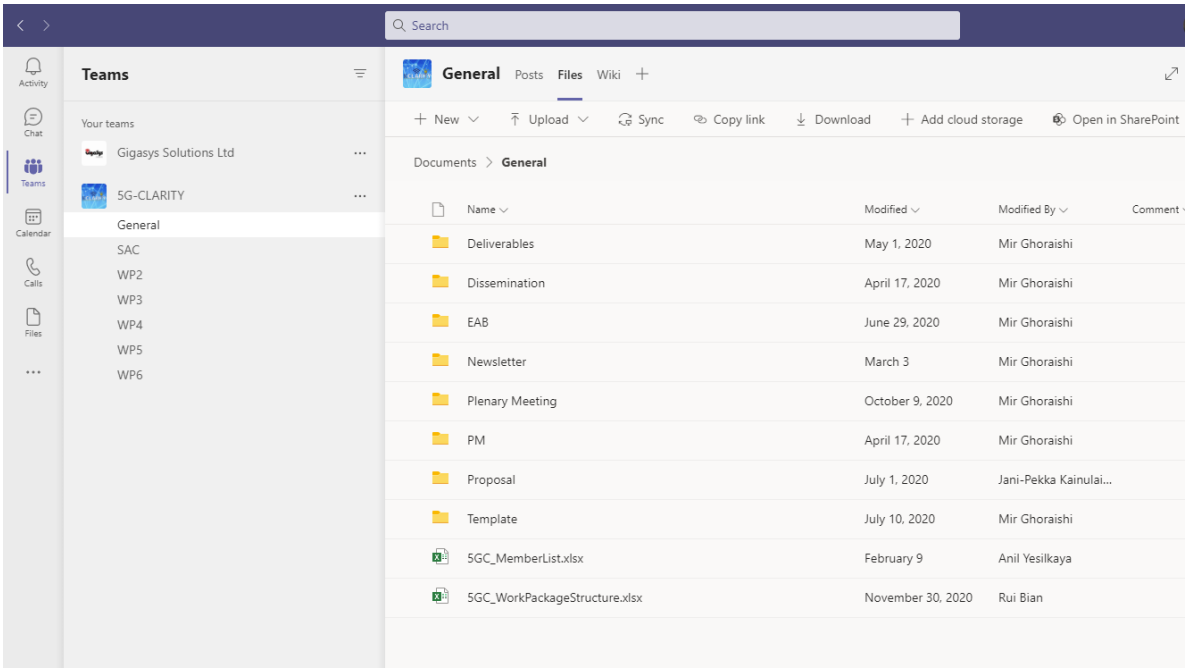

Figure 2-2: 5G-CLARITY MS Teams repository and collaboration tool

2.2.2 Project website

The most important communication tool for external communications is the official project website, which is up and running on http://www.5gclarity.eu/ and http://www.5gclarity.com/ addresses. The website was established immediately after the project was setup, and then significantly improved during the first months of the project. Figure 2-3 shows the main page of the website while Figure 2-4 presents the menu of the website subpages and the latest blog posts.

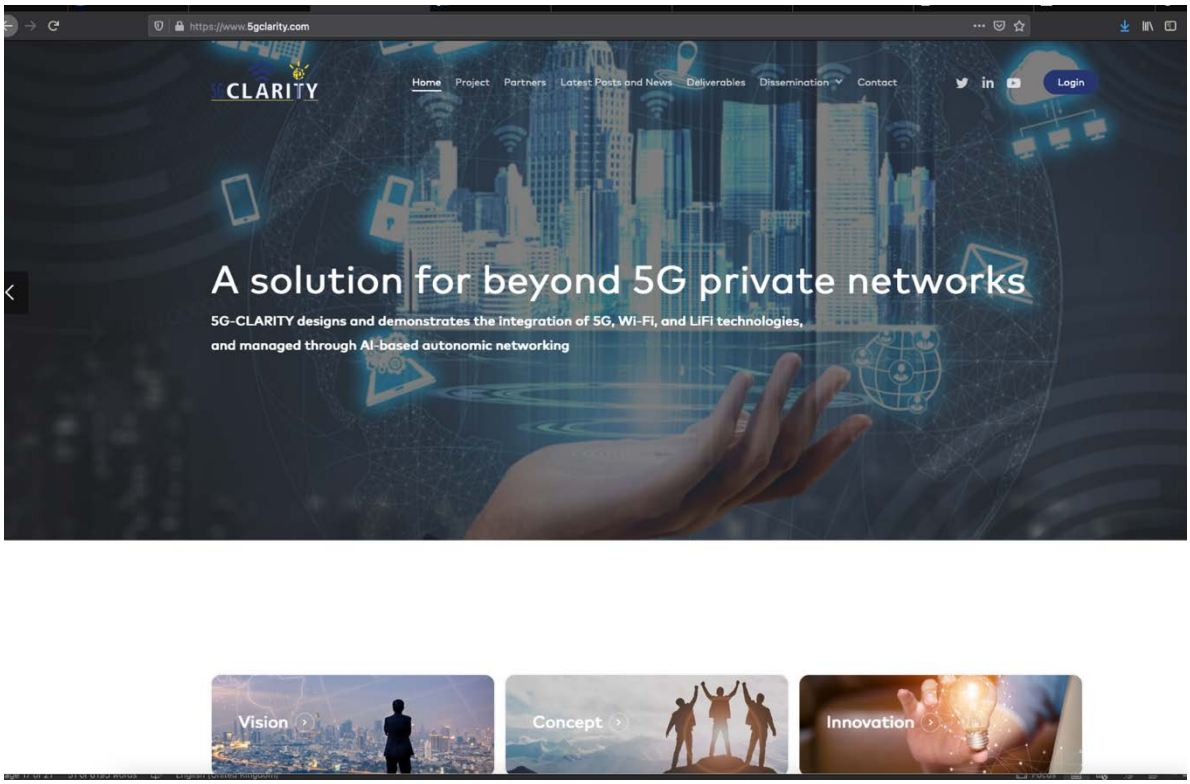

Figure 2-3: 5G-CLARITY project website main page

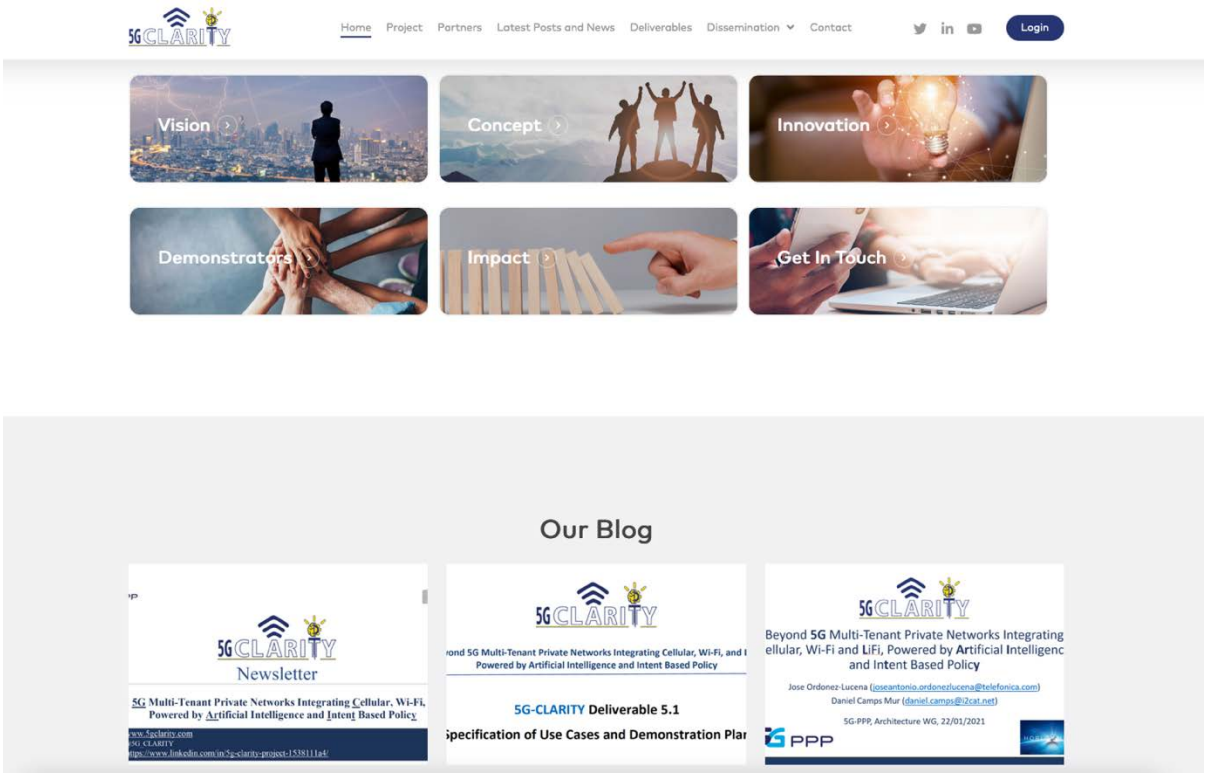

Figure 2-4 5G-CLARITY website lead to its subpages and its blog posts

The website contents are regularly updated and maintained by the project manager. To ease accessibility, the website contents are split in the following sections:

- Home: the main page of 5G-CLARITY website. It enables an easier browsing of the website content, and contains links to the social media channels.
- Project: contains an overall description of the project, gathering the 5G-CLARITY vision, concept, innovation, demonstrators and impact. Moreover, each of these items are linked from the main page via separate links (as shown in Figure 2-4).
- Partners: provides a description of each partner of 5G-CLARITY consortium.
- News and Latest Posts: includes relevant news about 5G-CLARITY activities and results, which will also be spread through the 5G-CLARITY social media channels to increase the project visibility. For each case a blog post is prepared, while the latest blogs are linked from the main page (as shown in Figure 2-4).
- Deliverables: provides the list of all submitted deliverables, plus its PDF if the document is public, as is indicated in Figure 2-5.
- Dissemination: includes 'Publications', 'Talks and Panels', 'Workshops', and any 'Other' disseminations. Figure 2-6 shows the publication page which includes all accepted academic papers by project partners during the last period.
- Contact: It contains a contact form to send a message to the project management team for all relevant communications with the 5G-CLARITY consortium.

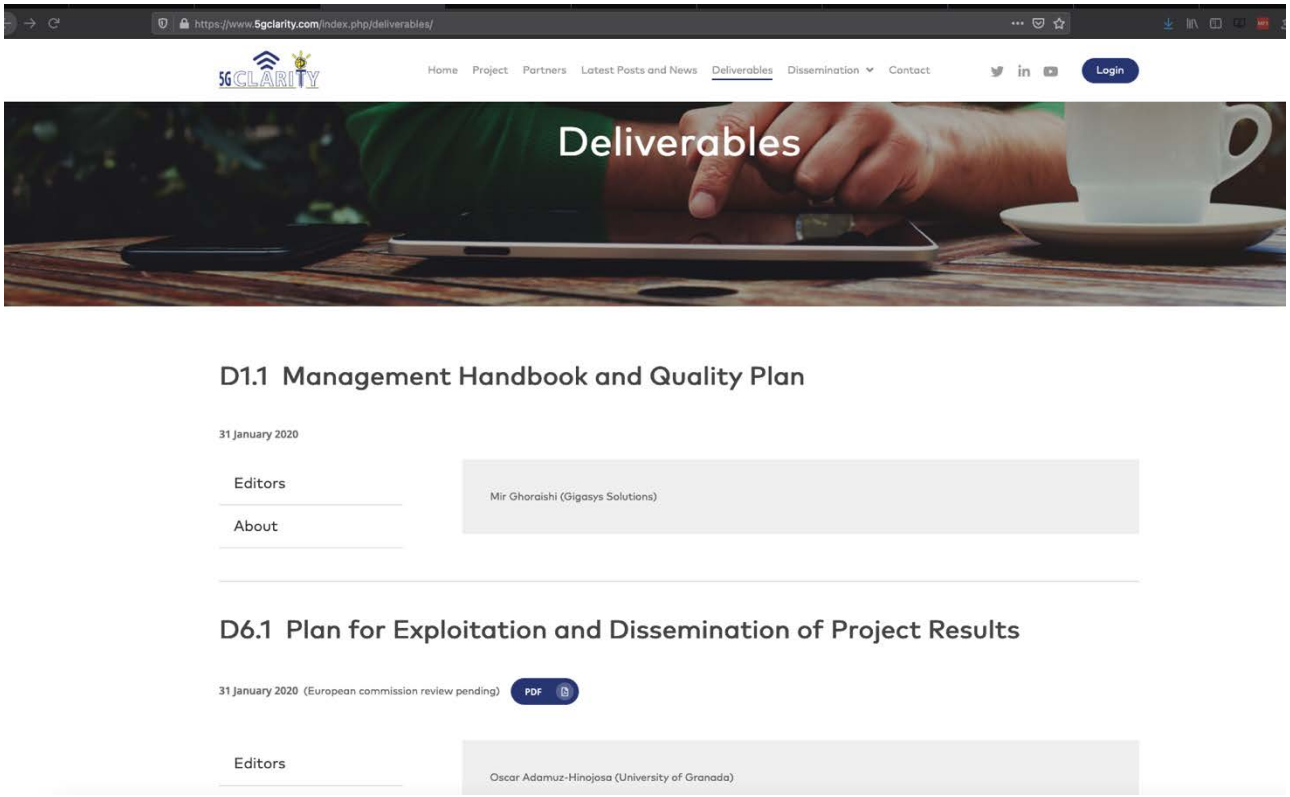

Figure 2-5 5G-CLARITY website 'Deliverables' page

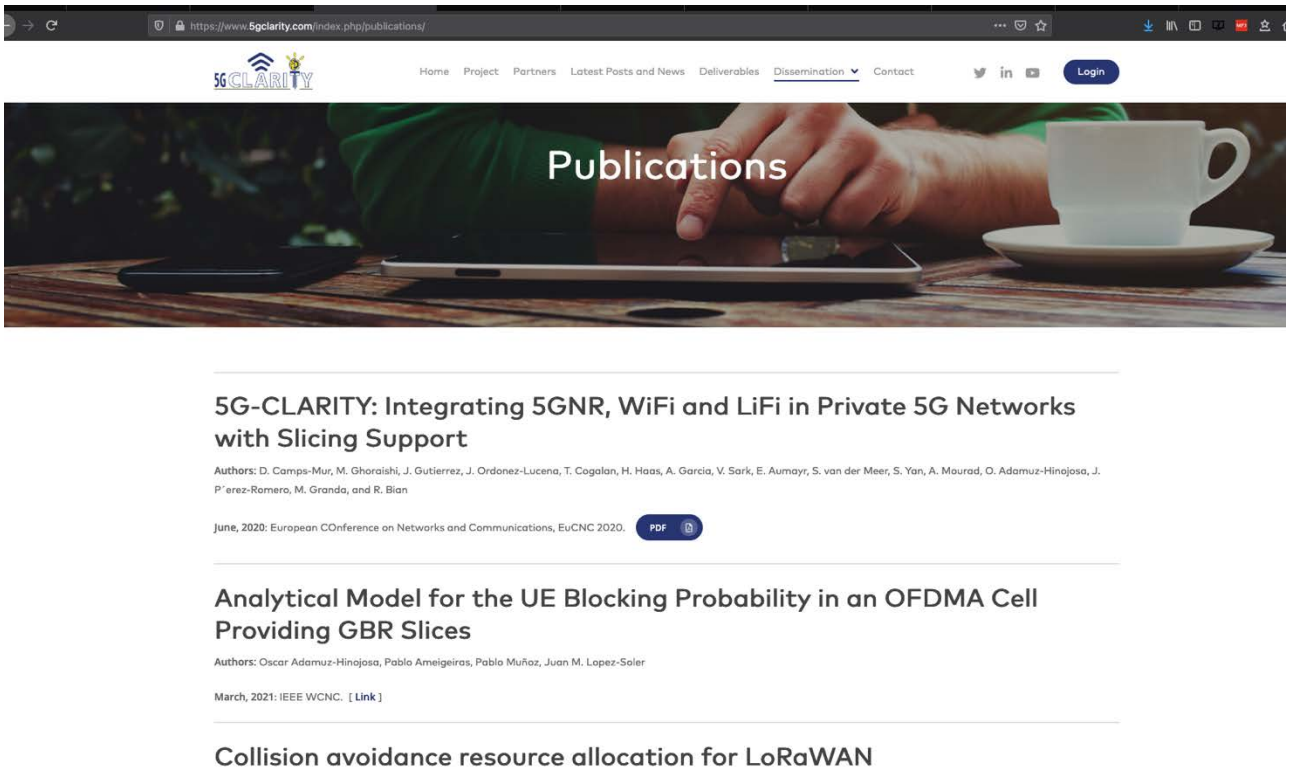

Figure 2-6 5G-CLARITY website 'Publications' page

2.2.3 Social media tools

5G-CLARITY exploits relevant social media such as Twitter, LinkedIn and YouTube to promote the potential benefits of the solutions proposed in the project. All the project social media accounts can be accessed from the project website and target to have at least 100-200 followers by the end of the project. The actions carried out in each social media account are briefly described in the following sections.

2.2.3.1 Twitter

5G-CLARITY Twitter account (https://twitter.com/5G_CLARITY) was setup on 8th of November 2019 with the aim of providing information about the ongoing activities throughout the project lifetime. Since then, the account has been actively tweeting project related news, information and posts. Figure 2-7 shows a screenshot of the main 5G-CLARITY Twitter page, with 362 followers. Figure 2-8 shows 5G-CLARITY twitter account's statistics for March 2021. It is observed the tweets during this period alone have earned 6.6 K impressions.

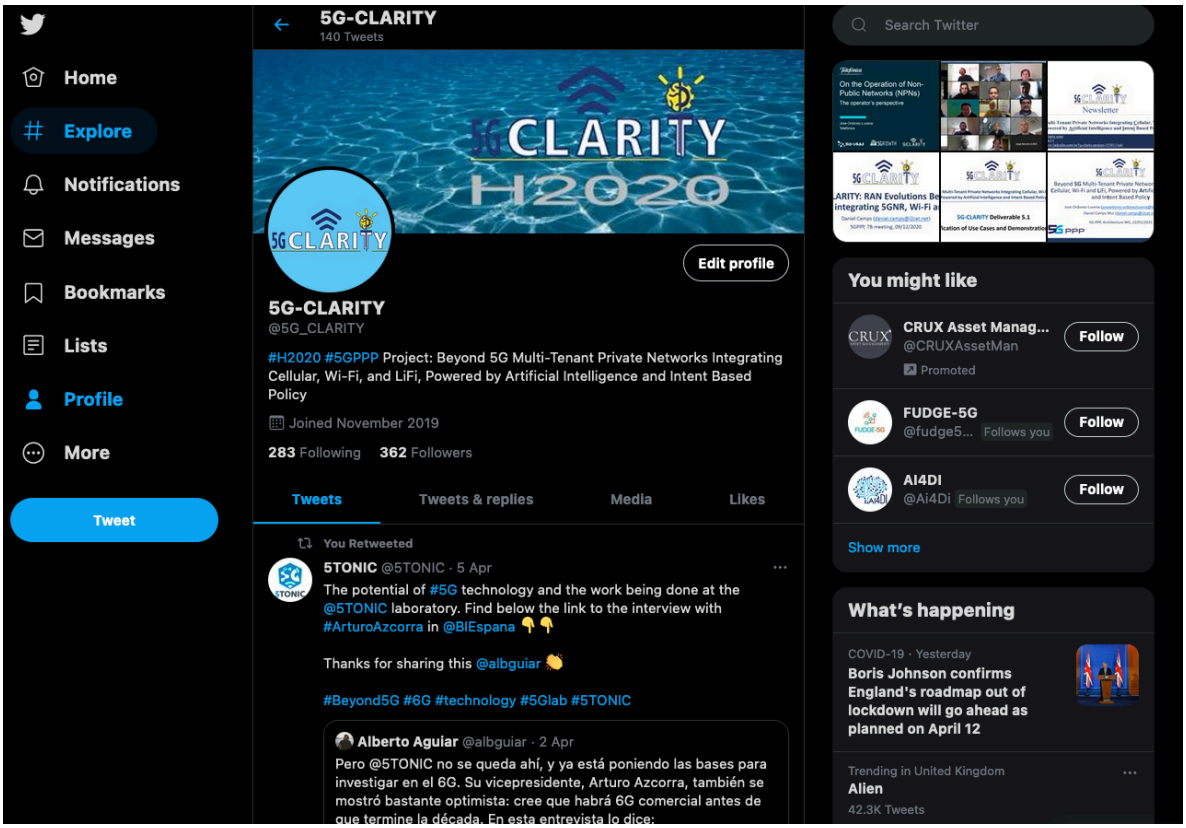

Figure 2-7: 5G-CLARITY project Twitter account

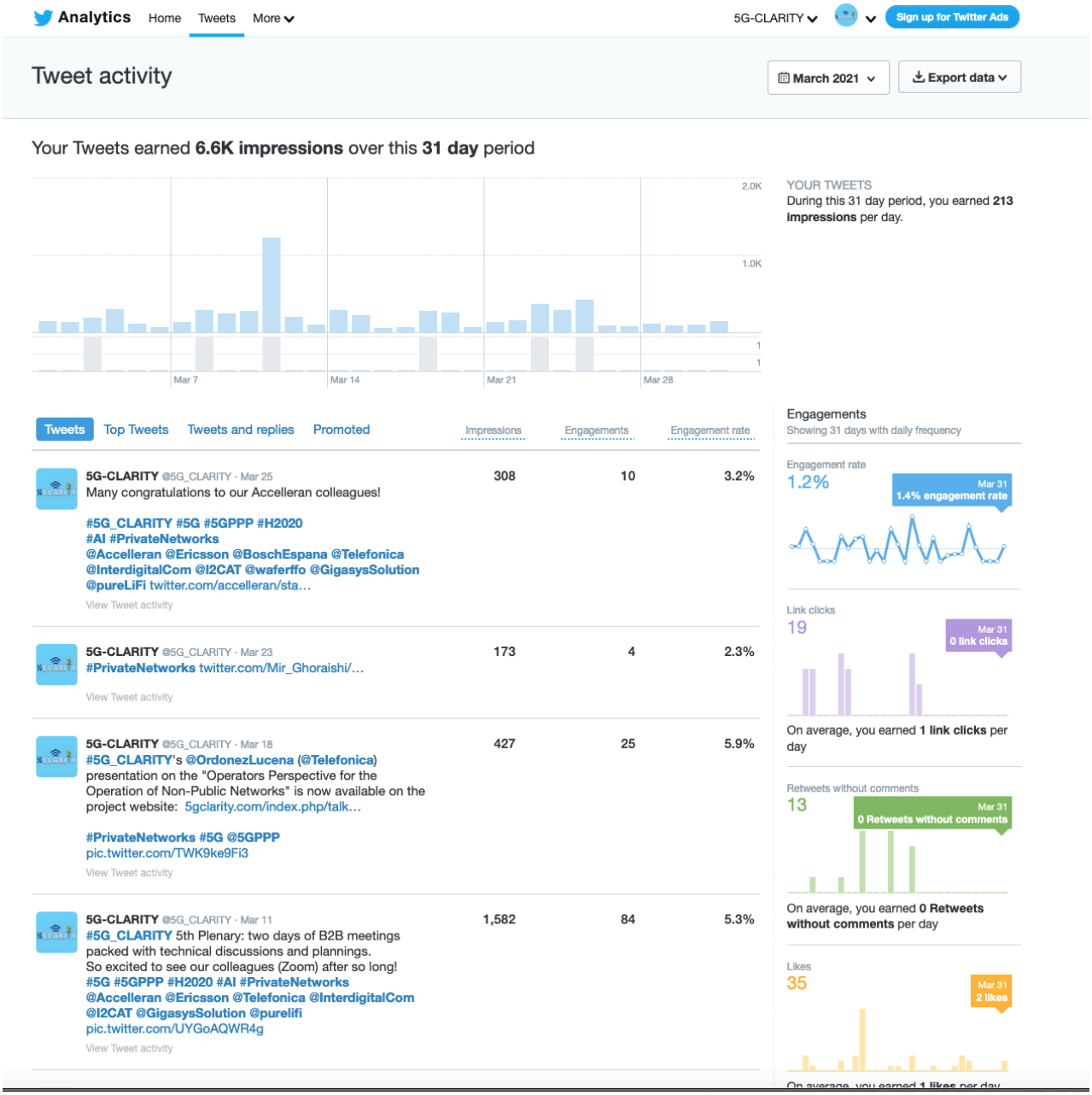

Figure 2-8 5G-CLARITY twitter account analytics for March 2021.

2.2.3.2 LinkedIn

LinkedIn is a business and employment-oriented social network. Since LinkedIn is tailored for professionals, it is well suited to communicate the activities and contributions carried out in 5G-CLARITY project. To that end, 5G-CLARITY consortium has created a LinkedIn group (https://www.linkedin.com/groups/12331231/) in December 2019. Later on the profile migrated to a LinkedIn profile (https://www.linkedin.com/in/5g-clarity-project-1538111a4/), since a profile is open to all LinkedIn members, and also the posts can be shared and reshared, hence more publicity is possible. The project news and events are regularly posted on the LinkedIn page and currently has 191 followers (but all posts are visible to ALL LinkedIn members), Figure 2-9 shows a screenshot of 5G-CLARITY LinkedIn profile, and a recent post which has earned 441 views.

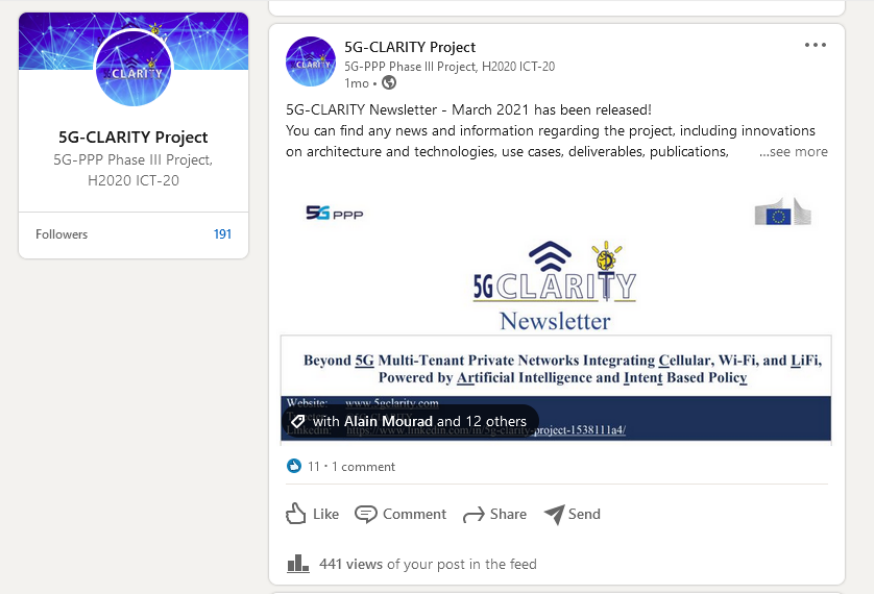

Figure 2-9: 5G-CLARITY project LInkedIn account

2.2.3.3 YouTube

YouTube is the most popular video-sharing platform in the world, thus it is the perfect social channel to broadcast the main activities carried out in the project. For that reason, 5G-CLARITY hosts a YouTube channel (https://www.youtube.com/channel/UCtAZgpXA-Ud-l8TMfTBPxxw/about) that provides video content produced by the project to stakeholders. Figure 2-10 presents a screenshot of the YouTube channel.

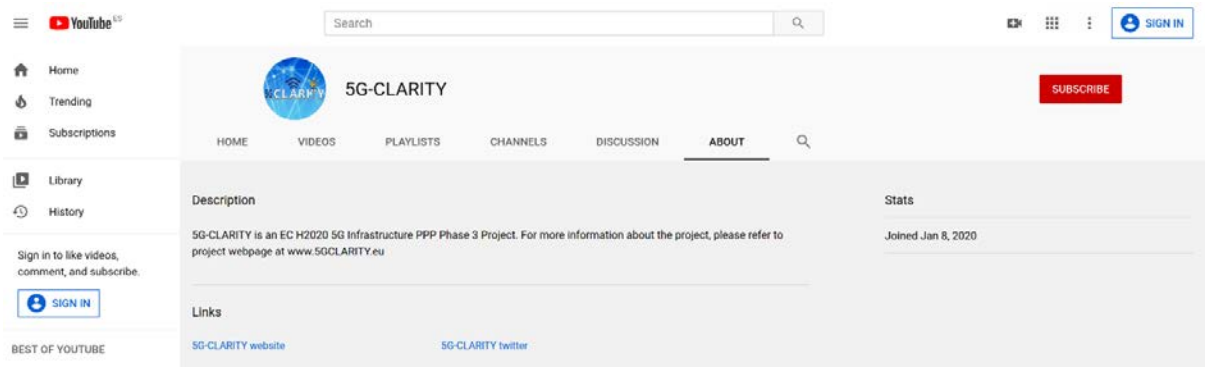

Figure 2-10: 5G-CLARITY project YouTube channel

2.2.3.4 Others

In addition to the social media channels set up by the 5G-CLARITY consortium, the 5G-PPP channels (i.e. 5G-PPP website, 5G-PPP channels for Twitter, LinkedIn, YouTube) also announce the most relevant achievements of 5G-CLARITY project as well as its main news and events. As an example, Figure 2-11 shows the 5G-PPP communication of the starting of 5G-CLARITY project within the 5G-PPP Phase 3 projects (see https://5g-ppp.eu/5g-ppp-phase-3-projects/).

Moreover, 5G-CLARITY activities, news, and posts on social media are shared with partners, and within 5G-PPP community and each time they are encouraged to share project disseminations within their own channels and media.

Figure 2-11: News about the 5G-CLARITY project kick-off within the 5G-PPP Phase 3 projects.

3 Dissemination Activities

5G-CLARITY dissemination activities involve providing project's information, news, findings, and achievements to the academic and industrial communities, as well as to the public. The plan for such activities was outlined in 5G-CLARITY D6.1 [1].

For the abovementioned goal, this Section reports the 5G-CLARITY mid-term dissemination actions. In particular, for different partners Table 3-1 shows the total number of 5G-CLARITY scientific publications. It includes accepted and currently under review papers in indexed journals (Journal Citation Reports, JCR) and international conferences for the mid-term period of the project´s time life. Details about all these actions are provided in following subsections.

Table 3-1: Mid-term scientific publications from 5G-CLARITY partners.

PARTNER	SCIENTIFIC PUBLICATIONS
IHP	2
I2CAT/UPC	8
UGR	9
TOTAL	19

In addition, Table 3-2 shows the mid-term number of 5G-CLARITY dissemination activities for different types of action considered.

Table 3-2: Mid-term 5G-CLARITY dissemination actions.

DISSEMINATION ACTION	TOTAL NUMBER
Published papers in JCR journals	8
Submitted papers in JCR journals under review	2
Accepted international conferences and posters	9
Submitted international conferences under review	0
Workshops/Talks/Panels/Special Issues	5
Newsletters	1
Press releases	10
TOTAL	35

According to the Plan for Exploitation and Dissemination [1] and the project proposal, Table 3-1 shows the summary of 5G-CLARITY´s dissemination KPIs for the whole project duration.

Table 3-3: 5G-CLARITY dissemination activities KPIs.

DISSEMINATION ACTION	KPI
Open source and Standards	At least 5 accepted contributions in SDOs/open-source bodies
Organization of 5G-CLARITY workshops	At least 2 technical project workshops
Participation in Industry exhibitions	At least participation in 3 industry event per year
Publications of Industry-related White Papers, magazines, technology roadmaps, and industry-led journals	At least 5
Scientific Publications in leading conferences and journals	At least 22

Presentation of 5G-CLARITY results, research and innovation activities in EU events	At least 1 participation in EU events per year
Participation in 5G initiatives	At least 2 participation in EU events per year
Web site, social networks, press releases	Public website; At least 2 newsletters per year; at least 1 social networking tool utilized

3.1 Scientific Publications

One of the activities envisioned in the 5G-CLARITY dissemination plan [1] is the scientific publication in leading conferences and journals.

3.1.1 5G-CLARITY papers in indexed journals

During this period, the following papers were published. For each item, it includes the quality evidence and impact:

1. M. Goodarzi, D. Cvetkovski, N. Maletic, J. Gutierrez Teran, E. Grass, "**Synchronization in 5G Networks: A Hybrid Bayesian Approach Towards Clock Offset/Skew Estimation and its Impact on Localization**," accepted in *EURASIP Journal on Wireless Communications and Networking*, Article number: 91 (2021) . DOI: https://doi.org/10.1186/s13638-021-01963-x

   Abstract: Clock synchronization has always been a major challenge when designing wireless networks. This work focuses on tackling the time synchronization problem in 5G networks by adopting a hybrid Bayesian approach for clock offset and skew estimation. Furthermore, we provide an in-depth analysis of the impact of the proposed approach on a synchronization-sensitive service, i.e. localization. Specifically, we expose the substantial benefit of Belief Propagation (BP) running on Factor Graphs (FGs) in achieving precise network-wide synchronization. Moreover, we take advantage of Bayesian Recursive Filtering (BRF) to mitigate the time-stamping error in pairwise synchronization. Finally, we reveal the merit of hybrid synchronization by dividing a large-scale network into local synchronization domains and applying the most suitable synchronization algorithm (BP- or BRF-based) on each domain. The performance of the hybrid approach is then evaluated in terms of the Root Mean Square Errors (RMSEs) of the clock offset, clock skew, and the position estimation. According to the simulations, in spite of the simplifications in the hybrid approach, RMSEs of clock offset, clock skew, and position estimation remain below 10 ns, 1 ppm, and 1.5 m, respectively.

   Impact Factor: 1.408

   JCR Rank: 190/266, Quartile: Q3, Category: Computer Science, Information Systems

2. J. Prados-Garzon, P. Ameigeiras, J. J. Ramos-Munoz, J. Navarro-Ortiz, P. Andres-Maldonado and J. M. Lopez-Soler, "**Performance Modeling of Softwarized Network Services Based on Queuing Theory With Experimental Validation**," in *IEEE Transactions on Mobile Computing*, vol. 20, no. 4, pp. 1558-1573, 1 April 2021.
   DOI: 10.1109/TMC.2019.2962488.

   Abstract: Network Functions Virtualization facilitates the automation of the scaling of softwarized

network services (SNSs). However, the realization of such a scenario requires a way to determine the needed amount of resources so that the SNSs performance requisites are met for a given workload. This problem is known as resource dimensioning, and it can be efficiently tackled by performance modeling. In this vein, this paper describes an analytical model based on an open queuing network of G/G/m queues to evaluate the response time of SNSs. We validate our model experimentally for a virtualized Mobility Management Entity (vMME) with a three-tiered architecture running on a testbed that resembles a typical data center virtualization environment. We detail the description of our experimental setup and procedures. We solve our resulting queueing network by using the Queueing Networks Analyzer (QNA), Jackson's networks, and Mean Value Analysis methodologies, and compare them in terms of estimation error. Results show that, for medium and high workloads, the QNA method achieves less than half of error compared to the standard techniques. For low workloads, the three methods produce an error lower than 10 percent. Finally, we show the usefulness of the model for performing the dynamic resource provisioning of the vMME experimentally.

Impact Factor: 5.112

JCR Rank: 18/156, Quartile: Q1, Category: Computer Science, Information Systems

Number of *IEEEXplore* full text views: 182 (Date: April 6, 2021)

3. J. Navarro-Ortiz, P. Romero-Diaz, S. Sendra, P. Ameigeiras, J. J. Ramos-Munoz and J. M. Lopez-Soler, "**A Survey on 5G Usage Scenarios and Traffic Models**," in *IEEE Communications Surveys & Tutorials*, vol. 22, no. 2, pp. 905-929, Second quarter 2020.
DOI: 10.1109/COMST.2020.2971781.

Abstract: The fifth-generation mobile initiative, 5G, is a tremendous and collective effort to specify, standardize, design, manufacture, and deploy the next cellular network generation. 5G networks will support demanding services such as enhanced Mobile Broadband, Ultra-Reliable and Low Latency Communications and massive Machine-Type Communications, which will require data rates of tens of Gbps, latencies of few milliseconds and connection densities of millions of devices per square kilometre. This survey presents the most significant use cases expected for 5G including their corresponding scenarios and traffic models. First, the paper analyzes the characteristics and requirements for 5G communications, considering aspects such as traffic volume, network deployments, and main performance targets. Secondly, emphasizing the definition of performance evaluation criteria for 5G technologies, the paper reviews related proposals from principal standards development organizations and industry alliances. Finally, well-defined and significant 5G use cases are provided. As a result, these guidelines will help and ease the performance evaluation of current and future 5G innovations, as well as the dimensioning of 5G future deployments.

Impact Factor: 23.700

JCR Rank: 1/156, Quartile: Q1, Category: Computer Science, Information Systems

Number of citations in Google Scholar: 62

Number of citations in Scopus: 30

Number of *IEEEXplore* full text views: 3117 (Date: April 6, 2021)

4. P. Muñoz, O. Adamuz-Hinojosa, J. Navarro-Ortiz, O. Sallent and J. Pérez-Romero, "**Radio Access Network Slicing Strategies at Spectrum Planning Level in 5G and Beyond**," in *IEEE Access*, vol. 8, pp.

79604-79618, 2020.
DOI: 10.1109/ACCESS.2020.2990802.

Abstract: The new fifth generation (5G) era has transformed previous mobile generations into fast, smart networks that will be more responsive and customizable. With network slicing, 5G networks can be dynamically adapted to the different needs of specific vertical industries. This capability has opened the opportunity to new business models whereby infrastructure owners can monetize their investment by leasing resources to third parties (i.e. tenants). In this respect, a challenging task for the owner of the radio access network infrastructure (i.e. the network provider) is the spectrum planning of multi-tenant scenarios. This paper proposes different alternatives of hiring capacity to the provider as well as a set of spectrum planning strategies, each giving a certain degree of flexibility to allocate resources per tenant. These strategies are evaluated in a 5G small cell multi-tenant network through snapshot-based simulations. The performance of the strategies is assessed in terms of scalability, spectrum isolation, utilization and efficiency.

Impact Factor: 3.745

JCR Rank: 35/156, Quartile: Q1, Category: Computer Science, Information Systems

Number of ieeexplore Full Text Views: 852 (Date: April 6, 2021)

5. P. Muñoz, O. Adamuz-Hinojosa, P. Ameigeiras, J. Navarro-Ortiz, and J. J. Ramos-Muñoz, "**Backhaul-Aware Dimensioning and Planning of Millimeter-Wave Small Cell Networks**," *Electronics*, vol. 9, no. 9, p. 1429, Sep. 2020.
DOI: 10.3390/electronics9091429.

Abstract: The massive deployment of Small Cells (SCs) is increasingly being adopted by mobile operators to face the exponentially growing traffic demand. Using the millimetre-wave (mmWave) band in the access and backhaul networks will be key to provide the capacity that meets such demand. However, dimensioning and planning have become complex tasks, because the capacity requirements for mmWave links can significantly vary with the SC location. In this work, we address the problem of SC planning considering the backhaul constraints, assuming that a line-of-sight (LOS) between the nodes is required to reliably support the traffic demand. Such a LOS condition reduces the set of potential site locations. Simulation results show that, under certain conditions, the proposed algorithm is effective in finding solutions and strongly efficient in computational cost when compared to exhaustive search approaches.

Impact Factor: 2.412

JCR Rank: 125/266, Quartile: Q2, Category: Engineering, Electrical & Electronic

Number of Full Text Views: 560 (Date: April 6, 2021)

6. N. Chinchilla-Romero, J. Navarro-Ortiz, P. Muñoz, and P. Ameigeiras, "**Collision Avoidance Resource Allocation for LoRaWAN**," *Sensors*, vol. 21, no. 4, p. 1218, Feb. 2021.
DOI: doi.org/10.3390/s21041218

Abstract: The number of connected IoT devices is significantly increasing and it is expected to reach more than two dozens of billions of IoT connections in the coming years. Low Power Wide Area Networks (LPWAN) have become very relevant for this new paradigm due to features such as large

coverage and low power consumption. One of the most appealing technologies among these networks is LoRaWAN. Although it may be considered as one of the most mature LPWAN platforms, there are still open gaps such as its capacity limitations. For this reason, this work proposes a collision avoidance resource allocation algorithm named the Collision Avoidance Resource Allocation (CARA) algorithm with the objective of significantly increase system capacity. CARA leverages the multichannel structure and the orthogonality of spreading factors in LoRaWAN networks to avoid collisions among devices. Simulation results show that, assuming ideal radio link conditions, our proposal outperforms in 95.2% the capacity of a standard LoRaWAN network and increases the capacity by almost 40% assuming a realistic propagation model. In addition, it has been verified that CARA devices can coexist with LoRaWAN traditional devices, thus allowing the simultaneous transmissions of both types of devices. Moreover, a proof-of-concept has been implemented using commercial equipment in order to check the feasibility and the correct operation of our solution.

Impact Factor: 3.275

JCR Rank: 77/266, Quartile: Q2, Category: Engineering, Electrical & Electronic

Number of Full Text Views: 693 (Date: April 6, 2021)

7. S. Wang and R. Ferrús, "**Extracting Cell Patterns From High-Dimensional Radio Network Performance Datasets Using Self-Organizing Maps and K-Means Clustering**," in *IEEE Access*, vol. 9, pp. 42045-42058, 2021.
DOI: 10.1109/ACCESS.2021.3065820.

Abstract: Mobile Radio Networks produces many of Operations, Administration, and Maintenance (OAM) data used by operators for network operational assurance. These data include multiple and diverse performance measurements and indicators that characterize the behavior of the radio cells. Being able to properly cluster the apparently dissimilar behaviors exhibited by a large number of individual cells into a reduced set of prototype patterns constitutes a valuable tool to support multiple processes such as cell configuration optimization or fault performance root cause analysis. While powerful clustering methods such as Self Organized Maps (SOM) exist, there is practically no literature showing the applicability of these methods of OAM datasets with a high number of attributes (>20) collected from live network deployments. Moreover, the applicability of the clustering methods does not come free of open questions since, for instance, when using SOM there is no explicitly obtained information about clusters after the SOM training in the underlying data, so the k -means technique for grouping SOM units has to be applied afterward. In this context, this paper describes a methodology to cluster radio cells based on a combination of SOM and K-means methods. The methodology is applied to extract cell patterns of the characterization of the long-term behavior (15 days' observation period) and short-term behavior (hourly observation periods) of mobile cells. OAM datasets collected from a live 4G/LTE network deployed in a major European city are used in the analysis.

Impact Factor: 3.745

JCR Rank: 35/156, Quartile: Q1, Category: Computer Science, Information Systems

Number of Full Text Views: 49 (Date: April 6, 2021)

8. August Betzler, Daniel Camps-Mur, Miguel Catalan, " **G-ADRR: Slicing distributed Wi-Fi networks with variable loads in space and time**," in *IEEE Transactions on Mobile Computing*, accepted for publication, 2021.

Abstract: As part of 3GPP releases 15 and 16 Wi-Fi networks have been integrated with the 5G Core, which is a key feature in private network scenarios. Another important feature for private networks is multi-tenancy, whereby an infrastructure provider shares a common radio access network among several tenants subject to Service Level Agreements (SLAs). 3GPP has defined network slicing on the radio access segment supporting multi-tenancy for 5GNR, but a similar feature is lacking in Wi-Fi networks. In this paper we present G-ADRR, which, to be best of our knowledge, is the first global slicing policy for Wi-Fi that delivers per-tenant radio level SLAs over a given geographical area. We extensively evaluate the performance of G-ADRR by means of an experimental prototype and packet level simulations, and demonstrate its advantages as compared to two alternative global scheduling strategies and a static slice configuration policy commonly used in the state of the art.

Impact Factor: 5.112

JCR Rank: 18/156, Quartile: Q1, Category: Computer Science, Information Systems

In addition, during this period the following papers were submitted and are currently under review:

1. Oscar Adamuz-Hinojosa, Pablo Muñoz, Pablo Ameigeiras, Juan M. Lopez-Soler, "**Potential-Game-Based 5G RAN Slice Planning for GBR Services**," in *IEEE Transactions on Vehicular Technology*, submitted in March 2021.

Abstract: In the dynamic resource provisioning, the amount of reassigned radio resources in each cell for a Radio Access Network (RAN) slice must be in compliance with upper and lower bounds. Established during the planning procedure, these bounds aim to ensure the Service Level Agreement (SLA) is met throughout a planning window. Assuming the MNO periodically performs in advance a planning procedure, we propose a mathematical framework for planning the radio resources of RAN slices offering Guaranteed Bit Rate (GBR) services. The proposed framework provides the minimum amount of radio resources for each requested RAN slice in each cell, while guaranteeing the User Equipment (UE) blocking probability is below a certain upper bound, given the worst-case inter-cell interference levels at the highest aggregated traffic load. To model the RAN slice planning, we use multiple ordinal potential games and demonstrate the existence of a Nash Equilibrium (NE) solution which minimize the average UE blocking probability for all the RAN slices. To reach this solution, we design novel strategies based on better response dynamics. Finally, we perform detail simulations to demonstrate the effectiveness of the proposed solution in terms of performance, adaptability and renegotiation capability.

Impact Factor: 5.379

JCR Rank: 34/266, Quartile: Q1, Category: Engineering, Electrical & Electronic

2. Jonathan Prados-Garzon, Pablo Ameigeiras, Jose Ordonez-Lucena, Pablo Muñoz, Oscar Adamuz-Hinojosa, Daniel Camps-Mur, "**5G Non-Public Networks: Enablers, Requirements and Architectures**," in *IEEE Communications Magazine*, submitted in December 2020 under Major revision.

Abstract: Fifth Generation (5G) is here to accelerate the digitalization of economies and society, and open up innovation opportunities for verticals. A myriad of 5G-enabled use cases has been

identified across disparate sectors like tourism, retail industry, and manufacturing. Many of the networks of these use cases are expected to be private networks, that is, networks intended for the exclusive use of a business-to-business (B2B) customer. This article provides a comprehensive overview of the technical aspects for realizing private 5G networks while motivating them with illustrative examples. We first identify the key requirements of private 5G networks and the respective enabling solutions. Then, we follow an overview of the latest3GPP specifications capabilities to support private 5G networks. Finally, we address the realization of five worthwhile scenarios that cover single site, multi-site, radio access network (RAN) sharing, and mobility use cases in private 5G networks.

Impact Factor: 11.052

JCR Rank: 7/266, Quartile: Q1, Category: Engineering, Electrical & Electronic

3.1.2 5G-CLARITY Publications in International Conferences

During the concerned period, the following 5G-CLARITY publications were accepted in international conferences.

1. Timo Kellermann, Ferran Cañellas, Ricardo Gonzalez, Daniel Camps: "**vL2-WIM: Flexible Virtual Layer 2 Connectivity Services in Distributed 5G MANO Domains**," accepted in EuCNC, Network Softwarisation Symposium, Porto, Portugal, 8-11 June 2021. DOI: TBD

   Abstract: Future 5G networks will be implemented as distributed clouds where virtual network functions and services are instantiated on demand. To support the required flexibility and automation, novel data center interconnect technology must support stringent data plane requirements brought along by 5G Radio Access Networks (RANs), while delivering the necessary flexibility in the service definition and enabling automation in the service provisioning. In this paper we present vL2-WIM, a novel WAN Infrastructure Manager (WIM) that enables virtual layer 2 services across data centers in distributed 5G MANO deployments. We provide a detailed evaluation of vL2-WIM showing how complex connectivity services composed of up to 30 Virtual Network Functions (VNFs) in different compute domains can be provisioned in less than 15 seconds.

2. Jonathan Prados-Garzon, Lorena Chinchilla-Romero, Pablo Ameigeiras, Pablo Muñoz, Juan M. Lopez-Soler: "**Asynchronous Time-Sensitive Networking for Industrial Networks**," accepted in EuCNC, Porto, Portugal, 8-11 June 2021. DOI: TBD

   Abstract: Time-Sensitive Networking (TSN) is expected to be a cornerstone in tomorrow's industrial networks. That is because of its ability to provide deterministic quality-of-service in terms of delay, jitter, and scalability. Moreover, it enables more scalable, more affordable, and easier to manage and operate networks compared to current industrial networks, which are based on Industrial Ethernet. In this article, we evaluate the maximum capacity of the asynchronous TSN networks to accommodate industrial traffic flows. To that end, we formally formulate the flow allocation problem in the mentioned networks as a convex mixed-integer non-linear program. To the best of the authors' knowledge, neither the maximum utilization of the asynchronous TSN networks nor the formulation of the flow allocation problem in those networks have been previously addressed in the literature. The results show that the network topology and the traffic matrix highly impact on the link utilization.

3. Irene Vilà, Jordi Pérez-Romero, Oriol Sallent, Anna Umbert, "**Evaluation of a Multi-cell and Multi-**

tenant Capacity Sharing Solution under Heterogeneous Traffic Distributions", accepted in 2021 IEEE 93rd Vehicular Technology Conference (VTC2021-Spring), 25-28 April, 2021. DOI: TBD

Abstract: One of the key features of the 5G architecture is network slicing, which allows the simultaneous support of diverse service types with heterogeneous requirements over a common network infrastructure. In order to support this feature in the Radio Access Network (RAN), it is required to have capacity sharing mechanisms that distribute the available capacity in each cell among the existing RAN slices while satisfying their requirements and efficiently using the available resources. Deep Reinforcement Learning (DRL) techniques are good candidates to deal with the complexity of capacity sharing in multi-cell scenarios where the traffic in the different cells can be heterogeneously distributed in the time and space domains. In this paper, a multi-agent reinforcement learning-based solution for capacity sharing in multi-cell scenarios is discussed and assessed under heterogeneous traffic conditions. Results show the capability of the solution to satisfy the requirements of the RAN slices while using the resources in the different cells efficiently.

4. Hamzeh Khalili, Pouria Sayyad Khodashenas, Shuaib Sidiqqui: "**On the Orchestration of Integrated Satellite Components in 5G Networks and Beyond**," in *22nd International Conference on Transparent Optical Networks (ICTON),* Bari, Italy, 2020, pp. 1-4.
DOI: 10.1109/ICTON51198.2020.9203354

Abstract: In support of inclusion of non-terrestrial network, 3GPP standardization recently developed several technical reports and specifications on the possible role of satellite systems along with the terrestrial network communications. The newest 3GPP study items under 5G created opportunity to integrate satellite systems, even beyond 5G networks. Integration between these two technologies will bring new range of features such as universal multi-access, dynamic management and ubiquitous connectivity, as well as increasing coverage, availability and reliability. This can be achieved through virtualization of satellite ground segment components, APIs and orchestration platform. In this work, we proposed an orchestration solution to manage and coordinate inter and intra satellite communication (i.e. GEO, MEO, LEO), together with terrestrial network resources. The solution is highly flexible and allows easy configuring of satellite systems including, baseband user segment, network user segment and mission segment in order to respond adequately to service requirements and end-to-end service provisioning.

Number of *IEEEXplore* Full Text Views: 149 (Date: April 6, 2021)

5. Hamzeh Khalili, Pouria Sayyad Khodashenas, Shuaib Sidiqqui: "**Study on Softwarization of Management Wavelength Allocation in EPON Networks**," in *22nd International Conference on Transparent Optical Networks (ICTON)*, Bari, Italy, 2020, pp. 1-4.
DOI: 1109/ICTON51198.2020.9203021

Abstract: Wavelength Division Multiplexing Passive Optical Network (WDM-PON) being developed to carry multiple services in PON network. WDM has a high cost of initial set up and maintenance of the components, as well as power consuming. Considering end-user requirements (i.e. multi services, high bandwidth and performance), it is extremely essential to provide a framework to manage multi-wavelengths in PON networks. Software defined Networking (SDN) and Network Function Virtualization (NFV) paradigms are potential solutions, paving the way for efficient management and operation, enabling softwarization, virtualization and centralization of distributed functions. In this work, we proposed an SDN-based AI solution for managing the wavelength based

on user requirements and daily internet usage patterns. For this, a monitoring module is used for telemetry and event collector. To make the best decision, all daily collected data will be sent to the AI layer.

Number of *IEEEXplore* Full Text Views: 27 (Date: April 6, 2021)

6. Oscar Adamuz-Hinojosa, Pablo Ameigeiras, Pablo Muñoz, Juan M. Lopez-Soler: "**Analytical Model for the UE Blocking Probability in an OFDMA Cell Providing GBR Slices**," in *IEEE Wireless Communications and Networking Conference,* 29 March - 1 April 2021, Nanjing, China.
https://wcnc2021.ieee-wcnc.org/technical-sessions

Abstract: When a network operator designs strategies for planning and operating Guaranteed Bit Rate (GBR) slices, there are inherent issues such as the under(over)-provisioning of radio resources. To avoid them, modeling the User Equipment (UE) blocking probability in each cell is key. This task is challenging due to the total required bandwidth depends on the channel quality of each UE and the spatio-temporal variations in the number of UE sessions. Under this context, we propose an analytical model to evaluate the UE blocking probability in an Orthogonal Frequency Division Multiple Access (OFDMA) cell. The main novelty of our model is the adoption of a multi-dimensional Erlang-B system which meets the reversibility property. This means our model is insensitive to the holding time distribution for the UE session. In addition, this property reduces the computational complexity of our model due to the solution for the state transition probabilities has product form. The provided results show that our model exhibits an estimation error for the UE blocking probability below 3.5%.

7. I.Vilà, J. Pérez-Romero, O.Sallent, A.Umbert: "**A Novel Approach for Dynamic Capacity Sharing in Multi-tenant Scenarios**" in *2020 IEEE 31st Annual International Symposium on Personal, Indoor and Mobile Radio Communications,* London, UK, 2020, pp. 1-6.
DOI: 10.1109/PIMRC48278.2020.9217135

Abstract: Network slicing is included as a key feature of the 5G architecture in order to simultaneously support diverse service types with heterogeneous requirements. The deployment of network slicing in the Radio Access Network (RAN) needs mechanisms that allow the distribution of the available capacity in the system in an efficient manner while satisfying the requirements of the different services. In this paper, a capacity sharing function is proposed, which is approached as a multi-agent reinforcement learning based on the Deep Reinforcement Learning (DRL) algorithm Deep Q-Network (DQN). The proposed algorithm provides the capacity to be assigned to each RAN slice. Performance assessment reveals the promising behaviour of the proposed solution.

8. Meysam Goodarzi, Nebojsa Maletic, Jesus Gutiérrez, Eckhard Grass: "**Bayesian Joint Synchronization and Localization Based on Asymmetric Time-stamp Exchange**" in *2020 International Symposium on Networks, Computers and Communications (ISNCC),* Montreal, QC, Canada, 2020, pp. 1-7.
DOI: 10.1109/ISNCC49221.2020.9297187.

Abstract: In this work, we study the joint synchronization and localization (sync&loc) of Mobile Nodes (MNs) in ultra dense networks. In particular, we deploy an asymmetric time-stamp exchange mechanism between the MNs and the Access Nodes (ANs), that, traditionally, provides us with

information about the MNs' clock offset and skew. However, information about the distance between an AN and a MN is also intrinsic to the propagation delay experienced by exchanged time-stamps. In addition, we utilize Angle of Arrival (AoA) estimation to determine the incoming direction of time-stamp exchange packets, which gives further information about the MNs' location. Finally, we employ Bayesian Recursive Filtering (BRF) to combine the aforementioned pieces of information and jointly estimate the position and clock parameters of the MNs. The simulation results indicate that the Root Mean Square Errors (RMSEs) of position and clock offset estimation are kept below 1 meter and 1 nanosecond, respectively.

The following 5G-CLARITY poster was also accepted and the presentation made virtually by the first author:

1. Daniel Camps-Mur, Mir Ghoraishi, Jesus Gutierrez, Jose Ordonez-Lucena, Tezcan Cogalan, Harald Haas, Antonio Garcia, Vladica Sark, Erik Aumayr, Sven van der Meer, Shuangyi Yan, Alain Mourad, Oscar Adamuz-Hinojosa, Jordi Pérez-Romero, Miguel Granda, and Rui Bian: "**5G-CLARITY: Integrating 5GNR, WiFi and LiFi in Private 5G Networks with Slicing Support**" in *EuCNC 2020,* Dubrovnik, Croatia, June 16-17.

   https://research-information.bris.ac.uk/ws/portalfiles/portal/239196481/PaperEuCNCposter.pdf

   https://www.eucnc.eu/pos1/

   https://www.youtube.com/watch?v=teOicfIYBeQ

3.2 Other Dissemination Actions

3.2.1 5G-CLARITY Workshops/Talks/Panels/Special Issues

Among the dissemination tasks of the project, there are other kinds of scientific dissemination activities such as workshops, talks, panels and special issues. In these mentioned activities, 5G-CLARITY is also spreading the features and advantages of the developed technologies and innovations to the research community. The following actions were carried out:

1. Andreas Muller (BOSCH) '**The Vertical View'**, Luis Miguel Contreras (Telefonica) '**The Operator View**', Alain Mourad (Interdigital) '**Private Networks in B5G Roadmap**', Daniel Camps Mur (i2CAT) '**5G-CLARITY Innovations Beyond 3GPP Rel-16**'. Mir Ghoraishi (Gigasys Solutions): Expert Discussion Panel on '**Private Network Coexistence with MNOs: Challenges, Technical Innovations and Business Opportunities**' in 5G World 2020 Event. November 2020.
   https://tmt.knect365.com/private-networks/agenda/2/
2. Jose Ordonez-Lucena (TID): "**On the Operation of Non-Public Networks (NPNs). The Operator's Perspective**" in 5G-PPP Technical Board Tele-Meeting, December 2020.
3. Daniel Camps-Mur (i2CAT): "**5G-CLARITY RAN Evolutions Beyond Rel 16, Integrating 5GNR, Wi-Fi, and LiFi**" in 5G-PPP Technical Board Tele-Meeting, December 2020.
4. Jose Ordonez-Lucena (TID) and Daniel Camps-Mur (i2CAT): "**5G-CLARITY Architecture, Innovations and Use Cases"** in 5G-PPP, Architecture WG, January 2021.
5. Jorge Navarro-Ortiz (UGR), et al.: "**Special Issue on 5G and Low Power Wide Area Networks for the IoT**" in Electronics journal, Impact Factor: 2.412, JCR Rank: 125/266, Quartile: Q2, Category: Engineering, Electrical & Electronic. September 2021.
   https://www.mdpi.com/journal/electronics/special_issues/5G_LPWAN_IoT

3.2.2 5G-CLARITY Newsletters

Another dissemination in 5G-CLARITY is the writing of newsletters for explanation and sharing with main audiences the main 5G-CLARITY contributions and visions related to the addressed challenges. The following item was achieved:

1. Mir Ghoraishi: "**5G-CLARITY Newsletter**" (Figure 3-1), March 2021. https://www.5gclarity.com/wp-content/uploads/2021/03/5G-CLARITY_NewsLetter_March2021.pdf

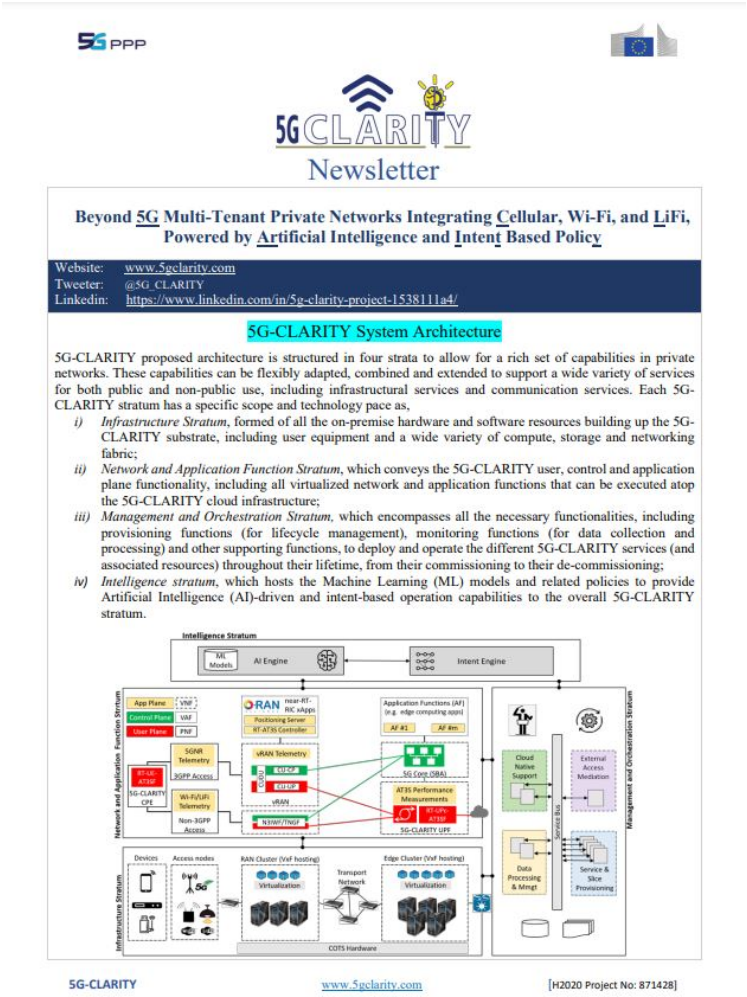

Figure 3-1: 5G-CLARITY Newsletter screenshot.

3.2.3 5G-CLARITY Press releases

Finally, the following 5G-CLARITY press releases have been published during this period:

1. Title: "**InterDigital Announces Participation in New 5G-CLARITY Project for Future Private Networks**" in http://ir.interdigital.com/file/Index?KeyFile=402423215
2. Title: "**Bosch, Ericsson, Telefonica develop AI control system for private LTE and 5G**" in https://enterpriseiotinsights.com/20200124/channels/news/bosch-ericsson-telefonica-develop-ai-control-system-for-private-lte-and-5g
3. Title: "**InterDigital to Participate in 5G-CLARITY Project for 5G Private Networks**" in https://www.lightreading.com/private-networks/interdigital-to-participate-in-5g-clarity-project-

for-5g-private-networks

4. Title: "**InterDigital announces participation in new 5G-CLARITY project for future private networks**" in https://www.telecomtv.com/content/5g/interdigital-announces-participation-in-new-5g-clarity-project-for-future-private-networks-37485/
5. Title: "**24 January 2020 Issue of The Mobile Networks**" in http://themobilenetwork.cmail19.com/t/ViewEmail/t/D60B9AA83B46DA722540EF23F30FEDED/697EECB377E7CFA144D0DD5392A9C75A
6. Title: "**InterDigital Announces Participation in New 5G-CLARITY Project for Future Private Networks**" in https://www.globenewswire.com/news-release/2020/01/24/1974758/0/en/InterDigital-Announces-Participation-in-New-5G-CLARITY-Project-for-Future-Private-Networks.html
7. Title: "**IHP announces 5G-CLARITY project for providing multi-connectivity in future private networks**" in https://www.ihp-microelectronics.com/en/infocenter/news-center/press-releases/article/ihp-announces-5g-clarity-project-for-providing-multi-connectivity-in-future-private-networks.html
8. Title: "**El Proyecto 5G-Clarity desarrollará redes privadas que integrarán múltiples tecnologías de acceso inalámbrico y sus evoluciones**" in https://smart-lighting.es/5g-clarity-redes-privadas-acceso-inalambrico/
9. Title: "**5G-CLARITY**" in http://www.bristol.ac.uk/engineering/research/smart/projects/5g-clarity/
10. Title: "**5G-CLARITY: multiconectividad de futuras redes privadas**" in https://5g.nrw/5g-clarity-multi-konnektivitaet-von-kuenftigen-privaten-netzwerken/

4 5G-CLARITY Innovation Elements for Exploitation

The project's exploitation activities have been defined in 5G-CLARITY D6.1 [1], which are aiming at using the results in further research activities other than those covered by the projects. The activities include developing, creating and marketing products or processes that creates and provides a service. Currently, the project is in the phase of implementing and producing results, while it is expected that the exploitation of these results will happen in the second half of the project and will continue beyond the project life-time. A more detailed report on the exploitation activities will be covered in 5G-CLARITY D6.5 – 'Final report on innovation management, exploitation and IPR', which is due April 30, 2022.

In the sequel, major innovation elements from 5G-CLARITY will be briefly introduced, from which the key results of the project will be generated. Most project innovations and developed solutions are planned to be demonstrated in the project use cases (UCs), which are listed below and detailed in 5G-CLARITY D5.1 [3]:

- UC1: 'Enabling enhanced human-robot interaction' (Smart Tourism);
- UC2.1: 'Alternative network for production-data exchange' (Industry 4.0);
- UC2.2: 'Enhanced automated guided-vehicle (AGV) positioning in intralogistics' (Industry 4.0).

All results collected from the corporation among partners in either individual simulations, or as part of the UC demonstrations will be the main material for future exploitation activities, as planned in 5G-CLARITY D6.1 [1]. A full list of descriptions for these items is available in deliverable D5.1 [3].

The list of 5G-CLARITY innovative elements:

- **Integration of Wi-Fi and LiFi access using a SDN enabled L2 network**

  The 5G-CLARITY Wi-Fi-LiFi integrated layer 2 (L2) SDN network that provides access to Wi-Fi and LiFi UEs and connects to a standard 802.1 Ethernet segment is described in 5G-CLARITY D2.2 and D3.1 [4], [5]. The main motivation for using a customized L2 SDN function, as compared to a standard IEEE 802.1 Ethernet segment, is to provide the 5G-CLARITY control plane with the ability to control, with fine granularity, the path followed by packets belonging to different 5G-CLARITY slices within the L2 segment.

  This item corresponds to both the Infrastructure Stratum and the Network & Application Function Stratum. The results will be collected from the evaluation of UC1 and UC2.1.

- **RAN based 5GNR SAS client**

  5G-CLARITY will enable a dynamic spectrum access paradigm based on the use of Citizen Radio Broadband Service (CBRS) spectrum access system (SAS) architecture. The current integrated LTE SAS client used in CBRS small cell context will be implemented in Accelleran Open RAN (O-RAN) dRAX™ context as an xApp for 5G-CLARITY.

  This item matches the initial exploitation route of Accelleran that via delivery of enhancements in dRAX™ Open Interface RAN Intelligence roadmap. This item corresponds to the Infrastructure Stratum and will be evaluated by simulation.

- **Multi-access based multi-connectivity**

  5G-CLARITY architecture supports the deployment of multi-WATs. The integration of a non-3GPP network such as Wi-Fi or LiFi requires inter-networking elements within the 5G core (5GC) network. The 5G-CLARITY solution for non-3GPP access integration uses multi-path steering, switching and splitting (MP3S) function, which similar to the 3GPP access traffic steering, switching and splitting (AT3S), can be operate on multi-path TCP (MPTCP) implementation and the switching, steering and splitting (SSS) operations are similar to 3GPP AT3S.

This item corresponds to both the Infrastructure Stratum and the Network & Application Function Stratum. The results will be collected from the evaluation of UC1 and UC2.1.

- **Resource management via Enhanced AT3S (eAT3S)-level traffic routing and resource scheduling**

  Resource management in 5G-CLARITY will be considered as a two-stage process namely 'traffic routing' and 'gNB/AP-level resource scheduling'. The traffic routing a real-time eAT3S problem. On the resource scheduling for gNB/AP, the 5G-CLARITY architecture assumes either gNB, Wi-Fi AP or LiFi AP will take care of scheduling its physical resources for the intended user access, once a traffic flow is routed to 5G, Wi-Fi or LiFi network respectively.

  This item corresponds to the Network and Application Function Stratum and will be evaluated by simulation.

- **Integration of multi-technology positioning information**

  Several technologies that may offer positioning estimates with different precision, based on the environment or the estimation approach, are considered in 5G-CLARITY. Each candidate technology contributing to the 5G-CLARITY positioning framework will have an interface towards the localization server. The localization server will encompass a set of methods that will allow the retrieval of requests, the control and intelligent combination of the position estimates, and will push the resulting position estimate to the network. Moreover, this innovative framework based on the localization server will be able to provide enhanced position estimates.

  This item corresponds to the Network and Application Function Stratum and will be evaluated in UC2.2.

- **Multi-domain network slicing for private networks**

  A novel slicing concept geared towards the notion of multi-tenancy was proposed in 5G-CLARITY D2.2 [4]. 5G-CLARITY slices allow a private network operator to open its physical infrastructure to connectivity (or digital service) providers, where such physical infrastructure comprises multiple domains.

  This item corresponds to the Management and Orchestration Stratum. The results will be collected from the evaluation of UC1 and UC2.1.

- **Integrated multi-WAT real-time telemetry system**

  In addition to supporting the management of the lifecycle 5G-CLARITY slices and their associated services, a critical component to enable autonomous network control is the visibility of the state of the network. For this purpose, 5G-CLARITY develops an integrated telemetry subsystem which can aggregate telemetry sources from RAN, compute and transport domains as introduced in 5G-CLARITY D4.1 [6]. Within the 5G-CLARITY telemetry subsystem, the emphasis is on the aggregation of telemetry generated by the 5GNR, Wi-Fi and LiFi networks that can enable real-time network control. This is achieved by means of a real-time RAN Radio Interface Controller (RIC) that exposes 5GNR, Wi-Fi, and LiFi telemetry to applications through a common data bus. This telemetry is critical to demonstrate the eAT3S concept that is a key innovation in 5G-CLARITY.

  This item corresponds to the Management and Orchestration Stratum and will be evaluated in UC2.1.

- **AI-engine and ML models**

  5G-CLARITY envisions an AI-engine that acts as the execution environment for the ML models operating on top of the 5G infrastructure. The 5G-CLARITY AI-engine allows to onboard ML models and manage their execution lifecycle and provides a unified application programming interface (API)

to these models to ingest network telemetry and execute network commands.

This item corresponds to the Intelligence Stratum and will be evaluated in UC2.1.

- **Intent-based networking interface**

  5G-CLARITY develops a high-level intent interface that will allow a private network operator to manage its network in a declarative manner. The functionality of the intent based interfaces, and how they are used to simplify the operation of a complex infrastructure supporting slicing and AI-driven operation, will be demonstrated in the 5G-CLARITY use cases.

  This item corresponds to the Intelligence Stratum and will be evaluated in UC2.1.

5 Conclusions

This 5G-CLARITY deliverable includes the mid-term report on communication, dissemination, and exploitation activities. All reported actions ensure that 5G-CLARITY achievements are widely spread over the 5G-CLARITY target audience to enhance the project's impact and visibility to the European Union (EU) and the entire world.

The project identifier, the communication activities carried out in the 5G-CLARITY project mid-term lifetime, the external/internal communication channels, and social media were defined in the communication plan [1]. For internal communications of the partners, the project consortium uses MS Teams tools as a repository. As a principal external communication channel, a project website has been developed and launched in December 2019. Besides, social media accounts (i.e., Twitter, LinkedIn, and YouTube), which are accessible from the project website, have been created to enhance the visibility of the project and to distribute the potential benefits derived from the solutions proposed in the project.

This document also reports the dissemination actions to communicate the project outcomes to the industry, academia, and the public in general. The key achieved activities in this regard are the production of scientific publications in leading international conferences and journals and the organization of a journal special issues. Specifically, for a target KPI of 22 scientific publications (Table 3-3), in the first mid-term 19 scientific publications (Table 3-1) have been issued. These publications are complemented by 16 actions (workshops, talks, panels, newsletters, and press releases in Table 3-2) as a result of the 5G-CLARITY dissemination plan in the mid-term project's lifetime.

In this report the major innovation elements from 5G-CLARITY were also briefly introduced which will be subject of the project's innovation plan for the efficient exploitation of the project results.

All these reported actions are complementary to 5G-CLARITY D6.2, 'Interim Report on Innovation management, [2] as well as additional 5G-CLARITY standardization achievements which will be reported in 5G-CLARITY D6.4, 'Mid-Term Report on Standards Engagements', due July 2021. In addition, this report will be also supplemented by 5G-CLARITY D6.5, 'Final Report on Innovation Management, Exploitation and Intellectual Property (IPR)', due April 2022, and 5G-CLARITY D6.6, 'Final Report on Dissemination and Communication', scheduled for July 2022 submission.

Bibliography

[1] 5G-CLARITY D6.1 , “Plan for Exploitation and Disseminaiton of Project Results,” 2020.

[2] 5G-CLARITY D6.2, “Interim Report on Innovation Management,” 2020.

[3] 5G-CLARITY D2.1, “Use Cases and Requirements,” 2020.

[4] 5G-CLARITY D2.2, “Primary System Architecture,” 2020.

[5] 5G-CALRITY D3.1, “State-of-the-Art Review and Initial Design of the Integrated 5GNR/Wi-Fi/LiFi Network Frameworks on Coexistence, Multi-Connectivity, Resource Management and Positioning,” 2020.

[6] 5G_CLARITY D4.1, “Initial Design of the SDN/NFV Platform and Identification of Target 5G-CLARITY ML Algorithms,” 2020.