5G Communication with a Heterogeneous, Agile Mobile network in the Pyeongchang Winter Olympic competitioN

Grant agreement n. 723247

Deliverable D7.2
Status of standardization and dissemination and update of plan

Date of Delivery:	28 February 2017 (Contractual)	28 February 2017 (Actual)
Editor:	INTEL Deutschland GmbH – Germany	
Associate Editors:	CEA	
Authors:	Markus Mueck, Emilio Calvanese-Strinati, HyeonWoo Lee, Taesang Choi, Giuseppe Destino, Petri Uosukainen, Nicolas Chuberre, Antonio Clemente, Wouter Tavernier, Roc Maymo-Camps, Jafar Mohammadi, Gosan Noh, Junhyeong Kim, Seok Ho Won, Heesang Chung, Ilgyu Kim	
Dissemination Level:	PU	
Security:	Public	
Status:	Final	
Version:	V1.3	
File Name:	5GCHAMPION_D7.2_Final.pdf	
Work Package:	WP7	

	Title:	Deliverable D7.2: Status of standardization and dissemination and update of plan
	Date: 28-02-2017	**Status:** Final
	Security: PU	**Version:** V1.3

Abstract

Following a first report on the 5G CHAMPION strategy and agreed actions in order to drive standardization, regulation and dissemination activities, this deliverable provides a status of respective actions after the first 9 months of the project. In particular, actions in standards bodies, organization of Special Sessions at Key Conferences, submissions to scientific conferences, the set-up of a project web-site, etc. are summarized.

In this context, the current activities are analyzed in order to understand whether the project is on track for meeting its obligations to meet its objectives in the space of Standards Contributions, Regulation Contributions, Scientific Publications, Workshops/Tutorials and Interaction with Media. If required, corrective actions are identified and implemented.

Index terms

5G, 5G CHAMPION, Dissemination, Regulation, Standardization.

Contents

1 Introduction

In the first 9 months of the 5G CHAMPION project, the consortium has invested substantial effort to create visibility and impact of the work through actions in Standards Bodies, the organization of Workshops and Special Sessions and the submission of scientific papers to key conferences and journals as well as co-authorship of a book chapter.

To give a few examples, 5G CHAMPION has successfully co-organized the ETSI supported Workshop on "*Multi-RAT and Network/Terminal Function Virtualization*" on 23rd February 2017 at Orange Gardens, Châtillon, France which is co-located with the ETSI RR standardization meeting and with active participation by 5G CHAMPION leaders. Furthermore, a Special Session proposal was accepted on "*Software Reconfiguration enabling 5G*" at the 2015 European Signal Processing Conference (EUSIPCO 2017). Another exception example is the organization of the Industry Track on "5G and Wireless" at the **2017** IEEE 85th **Vehicular Technology Conference**: **VTC2017-Spring** 4–7 June **2017 in Sydney, Australia**. Additional submissions have been submitted with the proposal to organize a Globecom'17 Workshop in Singapore, the European Conference on Networks and Communications 2017 in Oulu, Finland, etc.

Furthermore, 5G CHAMPION partners substantially impacted standards and regulation activities. To give a few examples, ETSI RRS work progressed substantially in the field of Software Reconfiguration and active participation to TCAM SDR Subgroup activities in the same field supported the overall European Efforts in this space. The 5G CHAMPION consortium is now building on the generated momentum to further impact on a world-wide scale in standards, regulation, scientific activities, etc. In this context, the specific European / Korean collaboration framework has turned out to be highly instrumental in order to ensure global coverage of the corresponding activities and initiatives.

Overall, 5G CHAMPION has been highly active in the first 9 months of its activities and achieved substantial success in terms of acceptance of a Special Session, scientific publications, workshop organization, etc. A large number of proposals are still pending and 5G CHAMPION is prepared to drive its influence further.

2 Technology Directions and related Dissemination Strategy

Table 1 summarizes the 5G CHAMPION strategy for contribution to standards bodies and regulation bodies, to influence and educe the scientific community and to interact with media representatives in order to maximize the impact and visibility of the project. The overall plan is consistent with the initial project intentions and no changes have been implemented after 9 months. The key technological directions of the 5G CHAMPION project are identified and mapped with respect to specific actions that are candidates over the lifetime of the project.

Table 1: Dissemination Strategy.

	Standards Contributions	**Regulation Contributions**	**Scientific Publications**	**Workshops/ Tutorials/ Tracks**	**Interaction with Media**
complex 5G set-up			Conference/ Journal contributions		TV interview, press releases
mmWave high capacity backhaul in 24-28 GHz using novel antenna arrays	IEEE & 3GPP	CEPT	Conference/ Journal contributions	Educational events	
virtualization through NFV/SDN in a secure backhaul architecture as well as a novel SDN-based IPsec tunnel architecture	ETSI		Conference/ Journal contributions	Educational events	
novel accurate positioning solutions (<1m accuracy) using mmWave combined with GNSS PPP	ETSI		Conference/ Journal contributions	Educational events	
direct UL/DL communication between satellites and 5G User Equipment			Conference/ Journal contributions	Educational events	
Software Reconfiguration	ETSI	TCAM SDR Working Group	Conference/ Journal contributions	Educational events	

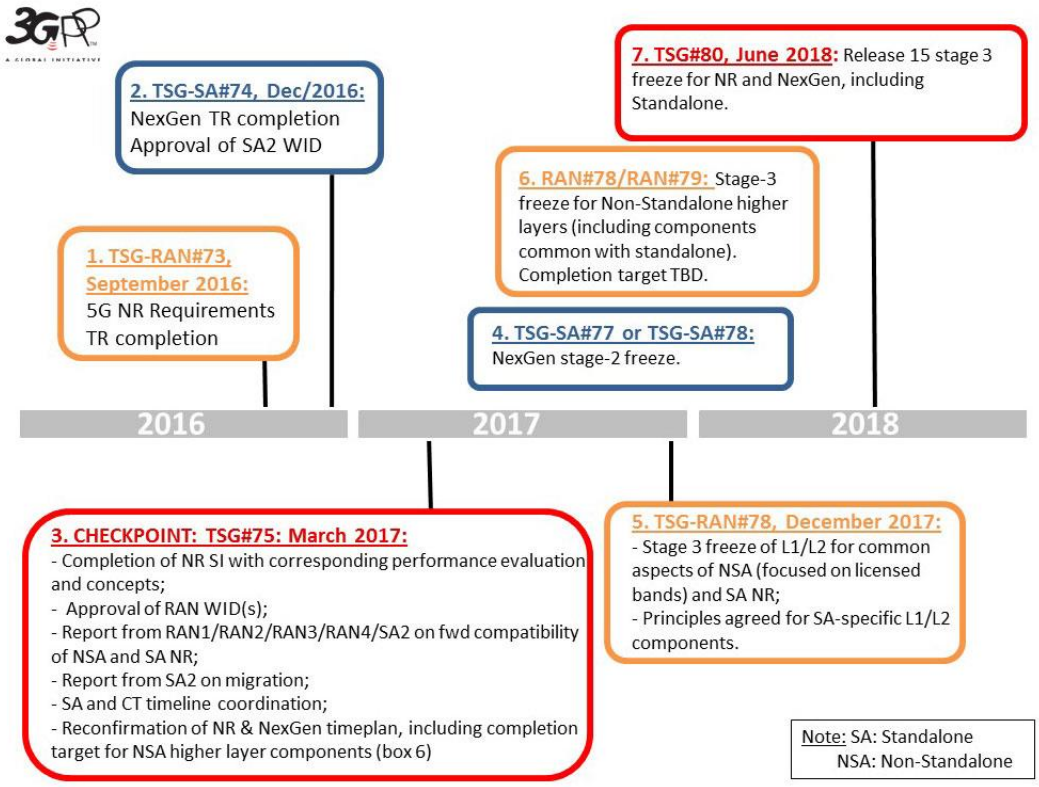
3 Standards & Fora Strategy

It is a key objective of the 5G CHAMPION consortium to influence most relevant standards and fora with the object to drive thought leadership and the 5G technology evolution across the entire eco-system. Similar to the upper planning, the overall schedule is considered to be well thought and relevant. This section outlines the consortium strategy for the most relevant bodies that are identified.

3.1 3rd Generation Partnership Project (3GPP)

The 3rd Generation Partnership Project (3GPP) is identified to be one of the key bodies for the definition of future 5G technology. The checkpoints to be met by the 5G CHAMPION consortium with respect to the 3GPP planning are indicated in Table 2.

Table 2: 3GPP 5G activities during 5G CHAMPION project (http://www.3gpp.org/images/articleimages/5g_timeline.jpg).



In order to cope with the 5G requirements, 3GPP initiated studies on use cases and new radio (NR) technologies for the 5G network in a 3GPP RAN Workshop held in Phoenix, AZ in Sep. 2015 [1]. At the workshop, there was a consensus that the new radio will cover three high level use cases:

- Enhanced Mobile Broadband;
- Massive Machine Type Communications;
- Ultra-reliable and Low Latency Communications.

3GPP has started the 5G standardization effort for developing the “New Radio” access technology in TSG RAN and the “Next Generation” core network in TSG SA. The New Radio will be non-backward compatible to the legacy LTE-Advanced technology, and will meet all the 5G requirements and use cases defined by the IMT-2020 [2]. The Next Generation core network will define new architecture to support diverse use cases and scenarios, and enable tight multi-RAT interworking. There are also under planning Standalone and Non-Standalone NR operations, where the latter one would have LTE as control plane anchor.

The study item (SI) on New Radio access technology approved in Mar. 2016 will cover initial evaluation of various new physical-layer techniques such as modulation, waveform, multiple access, channel coding, and MIMO for difference deployment scenarios [3]. Among those various 5G deployment scenarios, the high speed scenario focuses on providing continuous coverage along high speed train tracks using either 4 or 30 GHz frequency band [2]. The access link to the UE in the train is directly established for the 4 GHz band. For the 30 GHz band, the access link for the UE is established through a relay which is deployed outside of the train. During the project time frame, new Study and Work Items could be expected, especially one could target for items regarding physical layer measurements and procedures related to beamsteering and beamforming.

Indeed, 5G CHAMPION partners have already been contributing to the scenario and evaluation assumption descriptions for the 5G NR high speed scenario in 3GPP RAN1#84bis, RAN1#85, and RAN1#86 meetings. In addition, there have been partner contributions on the study of new radio technology standardization especially on the numerology, frame structure, channel structure, and MIMO-related topics. 5G CHAMPION partners are thus recognized by the community as key contributors and thought leaders and are perfectly positioned to further drive the technology evolution. 5G CHAMPION will keep seeking worldwide for solid partnership and support for better dissemination and great promotion of 5G CHAMPION standardization activities in 3GPP standard body by actively participating technical discussions and jointly generating contributions.

Hence, the technical solutions developed during the 5G CHAMPION project will significantly impact on the development of the NR access technology SI, especially on high speed scenario and beamforming related items.

The relevant 3GPP working groups for possible contribution from 5GCHAMPION are:

- SA1: Service aspects;
- SA2 : Architecture aspects;
- SA3: Security aspects;
- SA5 : Network management aspects;
- RAN1: Radio Layer 1;
- RAN2: Radio Layer 2 and Radio Layer 3.

In the framework of 5G CHAMPION, we have furthermore set the objective to determine the feasibility of **seamlessly integrating satellite communication in the 5G network infrastructure** to meet selected 5G Key Performance Indicators. In particular to define the technical enablers and configurations allowing operation of a 5G User Equipment via satellite for global service continuity beyond terrestrial network coverage.

In terms of standardisation activity, this translates into the following ambitions:

- Ensure that the 3GPP Next Gen architecture will support satellite Radio Access Network as any other 3GPP defined RAN technologies;
- Define a future Uu interface which is satellite "friendly" for example in terms of latency and Doppler characteristics associated to the proposed space segment (whether NGSO or GSO);
- Define the high level architecture of the Satellite Radio Access Network.

Similar to the upper statements, 5G CHAMPION consortium partners have been actively contributing to 3GPP standardization in the field of satellite communication and have thus created a fruitful basis for future work to be performed in the framework of the consortium. Examples of specific past and planned future contributions contributions are indicated in Table 3. The 5G CHAMPION consortium will be able to build on this basis and benefit from an established channel into the community.

Table 3: Examples of contributions to 3GPP by 5G CHAMPION consortium members.

Reference	Document Title	Impact	Status
3GPP TR 22.891	Feasibility Study on New Services and Markets Technology Enablers; Stage 1 (Release 14)	Adding a use case "5G Connectivity Using Satellites" (clause 5.72)	Done in SA1
3GPP TS 22.261	Service requirements for next generation new services and markets [TBD]; Stage 1 (Release 15)	Add a new basic capability "Satellite Access" (Clause 6.3.2.3): *The 3GPP system shall be able to provide services using satellite access.* *The 3GPP system shall support service continuity between land based and satellite based access networks owned by the same operator or by an agreement between operators*	SA1#75 decision (August 2016)
3GPP TR 38.913	Study on Scenarios and Requirements for Next Generation Access Technologies; (Release 14)	Adding of a new deployment scenario "Satellite extension to Terrestrial" (Clause 6.1.12)	RAN#72 decision (June 2016)
3GPP TR 23.799	Study on Architecture for Next Generation System (Release 14)	Add an architectural requirement (Clause 4.1): *Satellite radio access network (3GPP and non 3GPP defined) shall be supported (for phase 2)*	SA2#116bis decision (September 2016

		Add a new key issue 22: Support of "5G connectivity via satellite" use case	
3GPP TR 38.912	Study on New Radio Access Technology (Release 14)	Add relevant information and parameters that would be needed to model a NextGen (5G) system with satellite access in order to evaluate the performance of 5G technologies over such a system	To be submitted in future RAN1 meetings

As a specific next step, 5GCHAMPION is expected to be an input for several 3GPP SA and RAN WG preparation meetings for the possible contributions for actual SA and RAN WG Study or Work items, especially related to mmWave beamforming and/or steering and Satellite Technology. Gained hands-on experiences from 5GCHAMPION demonstration will be exploited internally for the future product releases in the 5G CHAMPION partner organizations.

3.2 European Telecommunications Standards Institute (ETSI)

ETSI is an independent, not-for-profit organization which provides a platform for all those who need to be involved in the standardization of telecommunications: ETSI creates standards via consensus and through the direct input of our members.

ETSI is working on key technologies which enable the future 5G Eco-System, including for example Mobile Edge Computing, Network Function Virtualization, Security solutions, Reconfigurable Radio Systems, Satellite Systems, etc.

In the context of the 5G CHAMPION project, the focus of the ETSI work will be on the ETSI Satellite Earth Stations and Systems (ETSI TC SES) and ETSI Reconfigurable Radio Committee (ETSI TC RRS). The latter is currently chaired by Dr. Markus Mueck of INTEL. As a key enabler of future 5G systems, TC RRS develops solutions for software reconfigurability in alignment to article 3(3)(i) and 4 of the novel Radio Equipment Directive (RED) and thus supports related European Commission activities in the TCAM SDR (Software Defined Radio) WG (Working Group) which is currently in an early phase – the timing is thus perfect for 5G CHAMPION to influence the corresponding work of TC RRS and TCAM.

Furthermore, ETSI RRS recently started to develop a Radio Interface Engine. The committee is currently working on a corresponding Feasibility Study. With context information management being a key enabler in the future 5G eco-system, 5G CHAMPION will contribute to this activity and influence corresponding discussions.

In the field of virtualization, contributions will be prepared to standards bodies in the field of MANO (Management and Orchestration) as it is for example ongoing in ETSI. To give a specific example, 5G CHAMPION partner KT plans to test a variety of 5G VNF solutions from global vendors. From the view point of service provider, KT will produce the requirements for 5G MANO.

In the context of Satellite systems handled in ETSI TC SES, a new work item referenced DTR/SES-00405 has been initiated. Entitled "Satellite Earth Stations and Systems (SES); Seamless integration of satellite and/or HAPS (High Altitude Platform Station) systems into 5G system;", it aims at identifying 5G systems architecture integrating satellite and/or HAPS systems (communication and/or navigation) for relevant use cases. The intent is to identify the

necessary standardisation activity in relation to relevant satellite (communication and/or navigation) technologies.

3.3 Institute of Electrical and Electronics Engineers (IEEE)

Within IEEE standards activities, the center of interest for 5G CHAMPION lies in the IEEE 802 family. It relates to IEEE standards, which deals with local area networks (LANs) and metropolitan area networks (MANs) and is maintained by the IEEE 802 LAN/MAN Standards Committee (LMSC). In the IEEE 802, there are several individual Working Groups (WGs) providing the focus for each area. Among them, ETRI has been participating in the IEEE 802.11, IEEE 802.15 and IEEE 802.16 WGs, and brief descriptions of which are given as follows:

- IEEE 802.11 WG: Wireless LAN WG developing a set of media access control (MAC) and physical layer (PHY) specifications for implementing wireless local area network (WLAN) communication in the 900 MHz and 2.4, 3.6, 5, and 60 GHz frequency bands
- IEEE 802.15 WG: Wireless Personal Area Network (WPAN) WG focusing on the development of consensus standards for Personal Area Networks (PANs) or short distance wireless networks
- IEEE 802.16 WG: Broadband Wireless Access WG currently focusing on developing standards and recommended practices to support the development and deployment of broadband Wireless Metropolitan Area Networks

Recently, in order to offer a better mobile Internet service in high-speed environments, IEEE 802.15, a working group (WG) of the IEEE 802 standards committee, created an Interest Group High Rate Rail Communications (IG HRRC) in November 2014 [4], based on the proposal made by 5G CHAMPION partners [5]. The main objective of this group is to focus on standardization of a mobile wireless backhaul for user groups located in the fast moving vehicles, especially for high-speed railway. Before the proposal was approved by IEEE 802.15 WG, the proposal was initially presented in the IEEE 802.16 WGs. However due to lack of participants in the 16 WG, 5G CHAMPION partners realized that it is difficult to keep standardization activities in the group. That was the main reason why 5G CHAMPION partners and delegates from the 16 WG finally decided to propose it to the IEEE 802.15 WG.The IEEE 802.15 IG HRRC currently chaired by ETRI holds a joint meeting with the 802.16 WG. The group usually organizes the meeting during IEEE 802 plenary session, so there will be 3 meetings of IG HRRC in March, July and November each year. The main participants of the group include ETRI, IEEE 802.16 WG delegates as well as Beijing Jiaotong University (BJTU), China. They have already had 9 meetings so far and during the meetings, a wide range of frequency bands including millimeter-wave have been studied as a candidate for the broadband wireless backhaul links for the fast moving vehicles through ray-tracing channel modeling and system demonstration, showing its infinite feasibility and potentiality [6][7][8]. Besides, various technical challenges and key technologies have been discussed as well [9].

Recently, our main concern is considering the transition from the IG to Study Group (SG) when enough interest has been identified. Since the group is completely led by ETRI, as long as both Korean and European consortiums could be able to collaborate on driving on the IEEE 802.15 IG HRRC standardization activities, there would be a high possibility of the transition to the SG, even to Task Group (TG) that is responsible for developing the specification. At the stage of either SG or TG, it is would be a great chance for both Korean and European partners to closely work on specification development and include their key technologies to the specification, which will not only highly be beneficial to the project, but also create a long lasting synergy for

5G research, innovation and commercialization. Therefore, the main strategies for the IEEE 802.15 IG HRRC standardization activities are to invigorate the group with collaboration from European and other Korean partners, which will finally paved the way for transition to SG and TG. As a first step, 5G CHAMPION PARTNERS will distribute the call for participation document in order to give a comprehensive understanding of the IG status and to encourage European partners and other companies to participate in upcoming meetings scheduled as follows:

- IEEE 802 plenary session on November 6-11, 2016 (Grand Hyatt San Antonio, San Antonio, TX, USA);
- IEEE 802 plenary session on March 12-17, 2017 (Hyatt Regency Vancouver, 802 Plenary Session);
- IEEE 802 plenary session on July 9-14, 2017 (Estrel Hotel and Convention Center, Berlin, Germany);
- IEEE 802 plenary session on November 5-10, 2017 (Caribe Hotel and Convention Center, Orlando, FL, USA).

3.4 Internet Engineering Task Force (IETF)

The Internet Engineering Task Force (IETF) is a large open international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet.

5GCHAMPION will monitor the IETF SFC working group, IRTF SDNRG and IRTF NFVRG as well as Operation & Maintenance activities (Transport Network Control and Management related solutions) which are expected to play a key role in future 5G systems.

The IETF Distributed Mobility Management (DMM) working group specifies solutions for IP networks so that traffic between mobile and correspondent nodes can take an optimal route. 5GCAHMPION is actively participating in this group to distribute and place IP anchoring functions over the network to address issues stemming from conventional centralized single anchoring architecture.

The Soongsil University in Team-GIST has plans to propose drafts about deployment models and anchoring in IETF DMM WG.

- Deployment models for distributed mobility management will provide available deployment models for distributed mobility management networks, consisted of mobility management functions: anchoring function, location management, and forwarding management functions.
- Enhanced mobility anchoring in distributed mobility management aims to identify what should be enhanced for mobility anchoring and to provide possible approaches for enhanced mobility anchoring over deployment models.

3.5 Next Generation Mobile Networks (NGMN)

The Next Generation Mobile Networks NGMN Alliance is an open forum to evaluate candidate technologies to develop a common view of solutions for the next generation of wireless networks. It was founded by major telecommunication corporates in 2006, and it is regarded as an association of mobile operators, vendors, manufacturers, and research institutes.

The main objective of NGMN is to provide a platform that facilitates the successful commercial launch of future mobile broadband technologies, thereafter, providing affordable broadband mobile services to the end-user. In more details the objectives are:

- expansion and evolution of mobile broad band with an especial focus on 5G
- setting clear goals and functionalities as well as basic requirements for deployment scenarios
- recommendations to equipment providers and standardization bodies, leading to cost-effective network evolution
- to facilitate the information flow among the industry partners on critical and immediate concerns and to share experiences, and
- stating and dealing with the spectrum necessities and supporting the foundation of a transparent and clear IPR regime.

The NGMN envisions 5G is an end-to-end platform that enables a fully mobile and connected world, which empowers value creation towards customers and partners.

5G CHAMPION partners are vigorously involved in NGMN activities on various levels. The consortium will be able to showcase the outputs of 5G CHAMPION within the NGMN exhibitions and forums to broaden to projects impact. In addition to showcasing, 5G CHAMPION will provide and contribute to talks held at NGMN workshops which advance the 5G CHAMPION's influence.

3.6 Small-cell Forum

The Small-Cell Forum works to ensure the adoption of industry wide standards, a positive regulatory environment, common architectures and interoperability.

Small-cell network management will be a key component of future 5G systems. The activities in the forum will be as in the following.

1. Standardization, regulation & interoperability: ensuring the adoption of industry wide standards, an effective regulatory structure, common architectures and interoperability.

2. Marketing, promotion & business case: promoting the value & potential of small cells across the industry and to press, analysts, regulators, and targeted interest groups and standards bodies.

5G CHAMPION partners will reach out to the small-cell forum for dissemination and standardization purposes.

3.7 ITU-T IMT-2020 Focus Group

In early 2012, ITU embarked on a programme on "International Mobile Telecommunications (IMT) for 2020 and beyond", setting the stage for IMT-2020 research, development, and marketing activities around the world. ITU-T Study Group 13 is mandated to study the requirements, architectures, capabilities and mechanisms of future networks including mobile. There is a desire to establish an open platform for experts representing ITU members and non-members in order to gain deep understanding of the IMT-2020 agenda, from non-radio transmission related network perspective. Recognizing activities being undertaken around the world, it is necessary to identify the specific areas for ITU-T Study Group 13, in order for ITU-T Study Group 13 to make constructive contributions to IMT-2020, together with other standardization bodies. The outcomes of this Focus Group will consist of continuing to define

the visions and objectives related to IMT-2020, in order to help progress and promote standardization by ITU-T Study Group 13 and other SDOs on IMT-2020. With regard to specific tasks, the following areas have been identified as areas of study/activity:

- Explore demonstrations or prototyping with other groups, notably the open source community - this task investigates demonstration or prototyping various aspects of IMT-2020 networks;
- Enhance aspects related to Networks softwarization and ICN.

This work refines aspects related to network softwarization, building on, or refining the output from the first Focus Group. Softwarization of the network has been studied in academia, this work will help identify issues that may exist in translating this from theory to application. It also investigates the use of ICN approaches within the IMT-2020 goals. There is much academic and industrial work around ICN in the 5G context at this time. We will suggest experiments aimed at guiding the broader community in next steps that can help bridge the gap between the research and practical use of ICN in IMT-2020. The output of this work will be a document that describes those experiments and provides recommendations on how ICN can be adopted in IMT-2020.

- Continue to refine and develop the IMT-2020 network architecture;

The work produces base material for the development of draft Recommendations to be approved by SG13, based on the architecture work produced during the identification of standardization gaps as reported in the report of FG IMT-2020. The output of this work will be a document that describes in depth the network architecture needed to address identified architectural gaps.

- Continue the study of fixed mobile convergence aspects;

Recognizing that a connected society in the years beyond 2020 will need to accommodate a similar user experience for end-users regardless of whether they are on the move or stationary, the new 5G standards aim at maintaining high quality service at high mobility, enabling the successful deployment of applications on a moving platform, such as in cars or high-speed trains.

- Continue to study network slicing for the front haul/back haul network;

This work studies and defines the use of network slicing in the context of control of the front haul/back haul network. Note, that it is expected that the transport and equipment aspects of front haul and back haul networks will be performed by Study Group 15. The work of the Focus Group is limited to dealing only with control aspects.

- Continue to define new traffic models and associated QoS and OAM aspects applicable to IMT-2020 network

IMT-2020 is seen as enabling new applications not limited to requiring high bandwidth, low latency and diverse service requirements. This item will define new network management aspects for the IMT-2020 network, including any QoS or OAM aspects. The work will produce base material for the development of draft Recommendations to be approved by SG13.

Based on the objectives of this group, 5G CHAMPION will evaluate the possibility for contributing to items 1, 2, 3, and 6. Among these items, we need a phased approach starting from architecture to demonstration & prototyping contributions. Especially, due to the objective of our project, demonstration & prototyping related contribution has higher priority than other working items.

4 Regulation Strategy

Government administrations and regulation bodies are currently in the process of defining the regulation framework of future 5G systems. 5G CHAMPION will identify key opportunities in this field and evaluate the possibility for contribution such that the project impact is maximized.

4.1 International Telecommunication Union (ITU)

ITU is a specialized agency of the United Nations (UN) that is responsible for issues that concern information and communication technologies.

5G CHAMPION is in particular interested in influencing parathion discussions for WRC (World Radio Conference) 2019 on Agenda Item 13, which relates to future usage of mmWave bands:

> "*This agenda item relates to consideration of identification of frequency bands for the future development of International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis, in accordance with Resolution 238 [COM6/20] (WRC-15). It calls for studies on frequency-related matters for IMT identification including possible additional allocations to the mobile services on a primary basis in portion(s) of the frequency range between 24.25 and 86 GHz.*"

5G CHAMPION will in particular liaise with CEPT in order to influence the European position on the corresponding WRC'2019 discussions.

In WP5D of ITU-R, 13 technical performance requirements, deployment scenarios, evaluation methodologies and circular letter for IMT-2020 have been intensively discussed and will be finalized by June 2017. From Dec. 2017, WP5D will be ready for receiving IMT-2020 proposals until June 2019.

In addition, spectrum requirements for IMT-2020, network model for sharing study with other services e.g. satellite, are under discussion in WP5D.

4.2 European Conference of Postal and Telecommunications Administrations (CEPT)

As indicated in section 4.1, 5G CHAMPION has specific interests in influence preparatory discussions of WRC'2019 on agenda item 13 related to future usage of mmWave frequency bands. 5G CHAMPION will interact and liaise with CEPT in order to influence the European position for the upcoming WRC'2019 negotiations.

4.3 Telecommunications Conformity Assessment and Market Surveillance Committee (TCAM)

The Telecommunications Conformity Assessment and Market Surveillance Committee (TCAM) is an advisory and regulatory committee that assist the European Commission in matters regarding conformity assessment and market surveillance. TCAM recently created a Software Defined Radio (SDR) Working Group (WG) in order to discuss the implementation of software reconfiguration related articles 3(3)(i) and 4 of the Radio Equipment Directive (RED).

5G CHAMPION will influence the corresponding discussions through its activities in ETSI TC RRS (Reconfigurable Radio Systems) on technology solutions in the field of software reconfigurations.

In particular, 5G CHAMPION partners have contributed to the below mentioned TCAM SDR Subgroup report (see overview page of the current draft below) and have submitted their candidature to the EC Expert Group on Reconfigurable Radio Systems. In this context, 5G CHAMPION partners are expected to substantially influence Europe's discussions on Software Reconfiguration.

Ref TCAM WG(10)20, SDRsubgroup interim report

TABLE OF CONTENTS

5 Scientific Publication and Education Strategy

5.1 Scientific Conferences

The 5GCHAMPION partners have the ambition to generate a highly visible and impacting footprint of their research outcomes in the scientific community. The main KPI that the project is using to measure this impact are in the form of publications in journals and at best-in-class conferences, as well as through speeches, tutorials, etc. Concerning scientific publications, the consortium has the target to publish at least 20 conference papers, in the most suitable venues.

While there are no conferences explicitly excluded from the consortiums publication targets list, there are a number of venues that are particularly targeted to disseminate the scientific findings of the project, which are listed below.

Table 4: Identified key conference candidates for contribution by 5G CHAMPION.

Event name	Main topics
SPAWC – Signal Processing Advances in Wireless Communications	Signal Processing in Wireless Communication Systems.
IEEE WCNC – Wireless Communications and Networking Conference	New approaches in wireless communications and networking technology.
IEEE GLOBECOM	IEEE flagship conference covering all aspects of networking and communications.
ICC - International Conference on Communications	IEEE flagship conference covering all aspects of networking and communications.
EuCNC – European Communications and Networking Conference	Communication and networking.
IEEE VTC – Vehicular Technologies Conference	Networking and vehicular aspects.
IEEE APS - Antennas and Propagation International Symposium	Electromagnetics, antennas and propagation
EuCAP - Europe Conference on Antennas and Propagation	Electromagnetics, antennas and propagation
European Microwave Week	Radiofrequency, electromagnetics, and antennas
Train Communications Systems conference in 2017 – 2018	Railroad related communication conference
EUSIPCO - European Signal Processing Conference	Signal Processing related conference

5G CHAMPION has identified specific contributions in order to ensure that key project results will have maximum visibility and impact. Priority paper submissions are planned on

- Adaptive hybrid beamforming, algorithm and implementation aspects. At this stage of the project, the target conferences are EuCNC 2017 (submission deadline 24 February 2017) and PIMRC 2017.
- An overview of MHN system to the session on “Propagation Channels for Wide-Sense Vehicle-to-X Communications” in EuCAP 2017.
- Train Communications Systems conference in 2017 – 2018, since the event is the only conference to focus directly on the problems and opportunities of putting Wi-Fi services onto trains. Customer services will be presented on mobile internet in Seoul subway and promote the outcomes as relentless efforts to improve the service qualities.
- Massive machine-type communication and special purpose modems for large capacity wireless backhauls in addition to the existing designs. These high-tech modems will be promoted at flagship conferences or events in wireless communications.
- A signal transmission schemes for high speed railway (HSR). The target conference is IEEE VTS APWCS 2017 or IEEE VTC 2017-Fall (deadline: 2017).
- Implementation of MU-MIMO system supporting a dynamic precoding. Results will be submitted to the IEEE VTC 2017 (submission deadline: 30 September 2016).
- Distributed mobile core system architecture and its mobility management technology supporting ultra-high speed mobility.
- ITS (Intelligent Transport Systems), Smart Cities, and IoT results will be disseminated towards the relevant User communities. To this end, papers will be submitted to the future ITS Europe, and ITS world congresses, and various Smart Cities Conferences.
- EUSIPCO 2017: A special session **“Software Reconfiguration enabling 5G”** is accepted and organized by 5G CHAMPION.

5.2 Scientific Journals

Contributions to Scientific Journal are a suitable means to disseminate mature and substantial results of the 5G CHAMPION consortium with great visibility in the scientific community. A list of target Journal Paper candidates is indicated in the sequel.

Table 5: Identified key Journal Paper candidates for contribution by 5G CHAMPION.

Publication name	Main topics
EURASIP Journal on Wireless Communications and Networking	General wireless and access network topics, covering PHY to System level.
EURASIP Journal on Advances in Signal Processing	Algorithms and Signal Processing approaches in general.
IEEE Communications letters	Communication technologies.
IEEE Communication and signal processing magazines	Communication technologies and systems in more tutorial style.
IEEE Transactions on Signal Processing	Algorithms and Signal Processing approaches in general.
IEEE Wireless Transactions	Communication technologies – scientific evaluation of approaches and techniques.
IEEE Vehicular Technology Magazine	Networking and vehicular aspects.
IEEE Access	Communication and networking aspects.
IEEE Communications Magazine	Communications and networking aspects.
IEEE Transaction on Antennas and Propagation	Electromagnetics, antennas and propagation
IEEE Antenna and Wireless Propagation Letters	Electromagnetics, antennas and propagation

5G CHAMPION has identified specific contributions in order to ensure that key project results will have maximum visibility and impact. Priority paper submissions are planned on

- Signal transmission schemes for high speed railway (HSR) to a major journal. The target journal is IEEE Transactions on Vehicular Technology or IEEE Communications Letters (deadline: 2018).
- Concept of RVM (Radio Virtual Machine) which is being standardized in ETSI TC RRS to the Journal of Korean Institute of Electromagnetic Engineering and Science (submission deadline: 31 December 2016).

5.3 Education – Teaching, Tutorials, etc.

Education and teaching is an important target for the exploitation of 5G CHAMPION results. It is indeed of key importance to feed latest findings and progress beyond the state of the art into University programs in order to ensure teaching at the edge of the technology:

5G CHAMPION strategic directions will be implemented by consortium partner Universities into selected University programs. Key targets are master and high-quality PhD programs.

To give a specific example, 5G CHAMPION will establish new teaching directions in the field of Software-Defined Networks, Service Orchestration and Programmable networks & service. The 5G CHAMPION related research in these fields is fully embedded, for example, in the different Flemish universities allowing a very efficient exploitation of knowledge by embedding this in the more advanced University courses. In this specific project, the research group IBCN (Internet Based Communication Networks and Services), part of Ghent University, is involved which will assimilate 5G CHAMPION results into advanced master courses on Future Internet and related high-quality PhD.

As part of the 5G CHAMPION platform development, selected contributions will be open-sourced and as such available for the European research community. This involves 5G CHAMPION developments in orchestration components, monitoring components, and/or network functions.

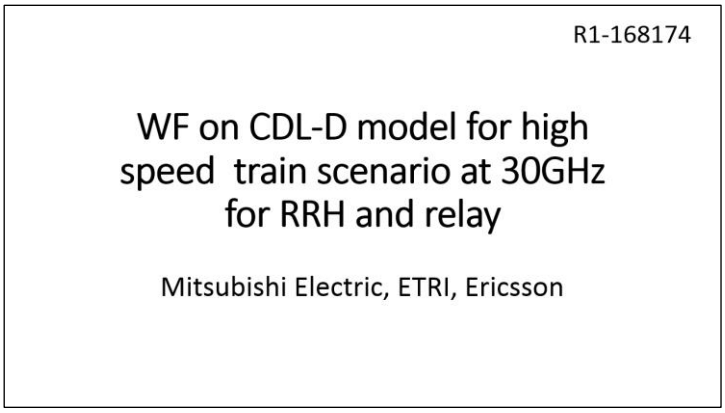
Tutorials are useful tools to disseminate and share project results among a professional community. Typically, tutorials are organized in conjunction with major scientific conferences. Participants typically include academic, governmental and industrial representatives who wish to acquire knowledge in new field.

5G CHAMPION will thus not only promote the project and its results through press releases and joint workshops, but also tutorials are a key target to address many of the major industrial stakeholders.

6 Achieved Contributions

6.1 Standards Contributions Conference Publications

- **R1-168174, "WF on CDL-D model for high speed train scenario at 30GHz for RRH and relay"**: Agreed at 3GPP RAN1#86 meeting in Aug. 2016.
  - Source: Mitsubishi Electric, ETRI, Ericsson
  - Agreements were made on the angular spread-related parameters specific to high speed train scenario
  - The first page of the contribution is illustrated below:

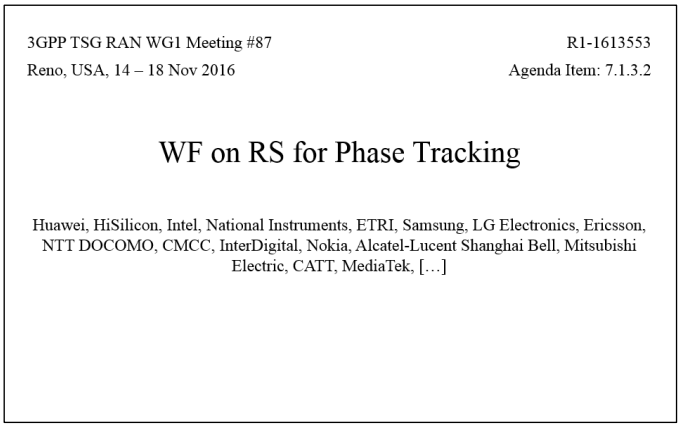

R1-168174

WF on CDL-D model for high speed train scenario at 30GHz for RRH and relay

Mitsubishi Electric, ETRI, Ericsson

Figure 1: Contribution to 3GPP RAN1#86/

- **R1-1613553, "WF on RS for Phase Tracking"**: Agreed at 3GPP RAN1#87 meeting in Nov. 2016.
  - Source: Huawei, HiSilicon, Intel, National Instruments, ETRI, Samsung, LG Electronics, Ericsson, NTT DOCOMO, CMCC, InterDigital, Nokia, Alcatel-Lucent Shanghai Bell, Mitsubishi Electric, CATT, MediaTek
  - Agreements were made on the design of phase tracking reference signal especially for mmWave-based transmission
  - The first page of the contribution is illustrated below:


3GPP TSG RAN WG1 Meeting #87 R1-1613553

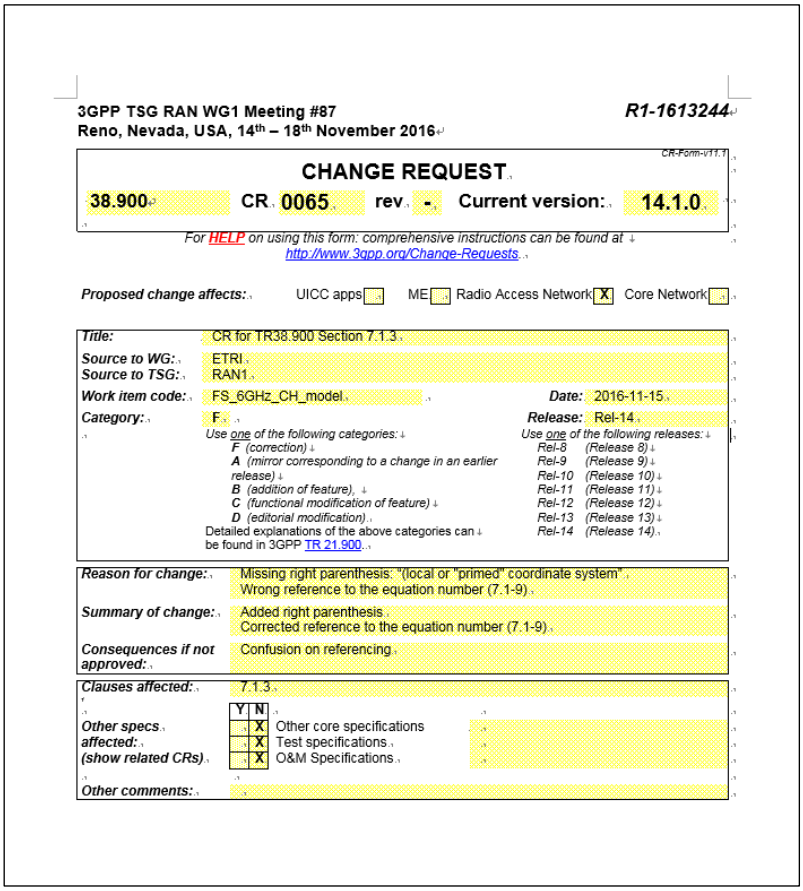
Reno, USA, 14 – 18 Nov 2016 Agenda Item: 7.1.3.2

WF on RS for Phase Tracking

Huawei, HiSilicon, Intel, National Instruments, ETRI, Samsung, LG Electronics, Ericsson, NTT DOCOMO, CMCC, InterDigital, Nokia, Alcatel-Lucent Shanghai Bell, Mitsubishi Electric, CATT, MediaTek, […]

Figure 2: Contribution to 3GPP RAN1#87.

- **R1-1613244, "CR for TR38.900 Section 7.1.3"**: Agreed at 3GPP RAN1#87 meeting in Nov. 2016.
  - Source: ETRI
  - Agreements were made on the correction of Section 7.1.3
  - The first page of the contribution is illustrated below:



3GPP TSG RAN WG1 Meeting #87 R1-1613244
Reno, Nevada, USA, 14th – 18th November 2016

CR-Form-v11.1

CHANGE REQUEST

38.900 CR 0065 rev - Current version: 14.1.0

For HELP on using this form: comprehensive instructions can be found at http://www.3gpp.org/Change-Requests

Proposed change affects: UICC apps [ ] ME [ ] Radio Access Network [X] Core Network [ ]

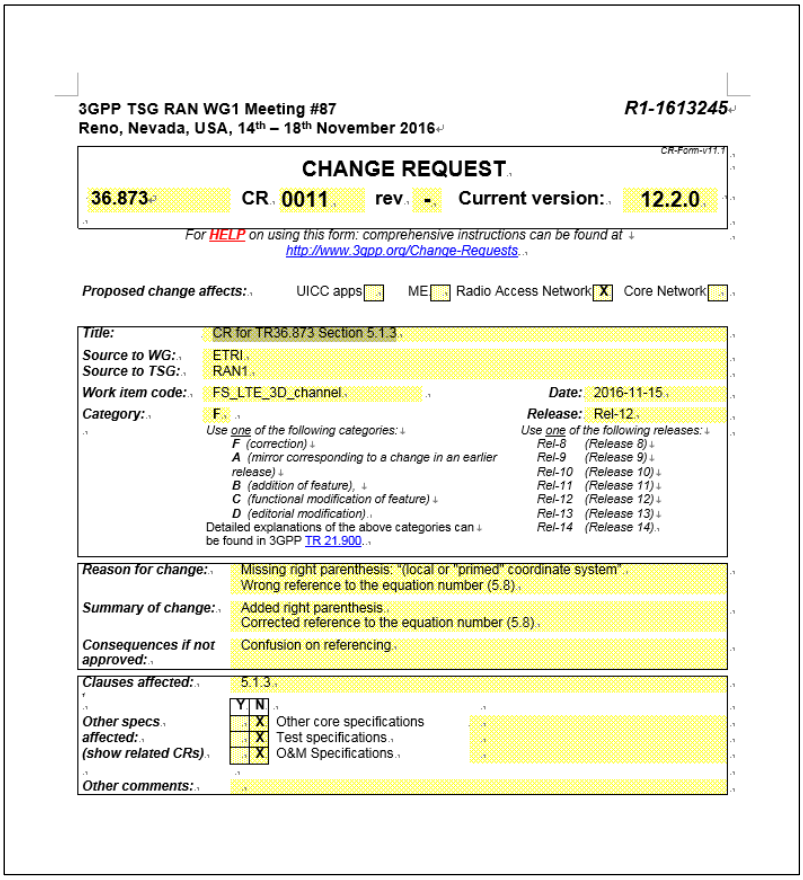
Title:	CR for TR38.900 Section 7.1.3		
Source to WG:	ETRI		
Source to TSG:	RAN1		
Work item code:	FS_6GHz_CH_model	*Date:*	2016-11-15
Category:	F	*Release:*	Rel-14
	Use one of the following categories: *F (correction)* *A (mirror corresponding to a change in an earlier release)* *B (addition of feature),* *C (functional modification of feature)* *D (editorial modification)* Detailed explanations of the above categories can be found in 3GPP TR 21.900		*Use one of the following releases:* Rel-8 (Release 8) Rel-9 (Release 9) Rel-10 (Release 10) Rel-11 (Release 11) Rel-12 (Release 12) Rel-13 (Release 13) Rel-14 (Release 14)

Reason for change:	Missing right parenthesis: "(local or "primed" coordinate system" Wrong reference to the equation number (7.1-9)
Summary of change:	Added right parenthesis Corrected reference to the equation number (7.1-9)
Consequences if not approved:	Confusion on referencing

Clauses affected:	7.1.3		
	Y	N	
Other specs affected: (show related CRs)		X	Other core specifications
		X	Test specifications
		X	O&M Specifications
Other comments:			

Figure 3: Contribution to 3GPP RAN1#87.

- **R1-1613245, "CR for TR36.873 Section 5.1.3"**: Agreed at 3GPP RAN1#87 meeting in Nov. 2016.
  - Source: ETRI
  - Agreements were made on the correction of Section 5.1.3
  - The first page of the contribution is illustrated below:



3GPP TSG RAN WG1 Meeting #87 R1-1613245
Reno, Nevada, USA, 14th – 18th November 2016

CR-Form-v11.1

CHANGE REQUEST

36.873 CR 0011 rev - Current version: 12.2.0

For HELP on using this form: comprehensive instructions can be found at http://www.3gpp.org/Change-Requests

Proposed change affects: UICC apps [ ] ME [ ] Radio Access Network [X] Core Network [ ]

Title:	CR for TR36.873 Section 5.1.3
Source to WG:	ETRI
Source to TSG:	RAN1
Work item code:	FS_LTE_3D_channel — *Date:* 2016-11-15
Category:	F — *Release:* Rel-12
	Use one of the following categories: F (correction), A (mirror corresponding to a change in an earlier release), B (addition of feature), C (functional modification of feature), D (editorial modification). Detailed explanations of the above categories can be found in 3GPP TR 21.900 — *Use one of the following releases:* Rel-8 (Release 8), Rel-9 (Release 9), Rel-10 (Release 10), Rel-11 (Release 11), Rel-12 (Release 12), Rel-13 (Release 13), Rel-14 (Release 14)
Reason for change:	Missing right parenthesis: "(local or "primed" coordinate system". Wrong reference to the equation number (5.8)
Summary of change:	Added right parenthesis. Corrected reference to the equation number (5.8)
Consequences if not approved:	Confusion on referencing
Clauses affected:	5.1.3

Other specs affected: (show related CRs)	Y	N	
		X	Other core specifications
		X	Test specifications
		X	O&M Specifications

Other comments:

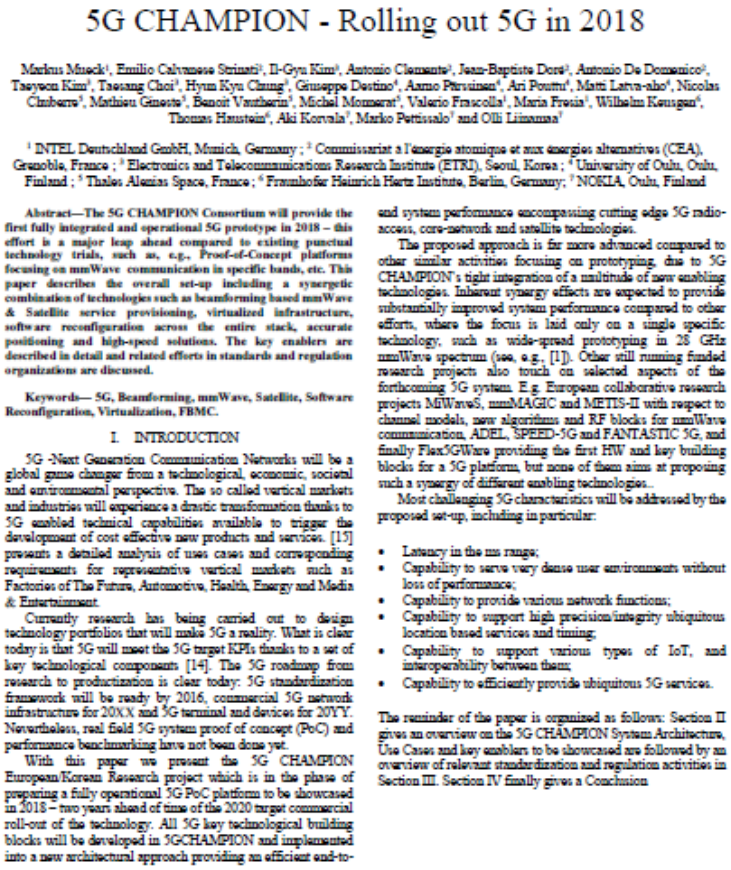
Figure 4: Contribution to 3GPP RAN1#87.

6.2 Scientific Conference Publications

- **"5G CHAMPION - Rolling out 5G in 2018"**: Accepted Scientific Paper at Globecom'2016 (International Workshop on Emerging Technologies for 5G Wireless Cellular Networks; In conjunction with IEEE GLOBECOM 2016, Sunday, December 4, 2016, Washington, DC, USA)
  - Authors: 5G CHAMPION - Rolling out 5G in 2018
  - Markus Dominik Mueck (Intel Mobile Communications, Germany); Emilio Calvanese Strinati (CEA-LETI, France); Ilgyu Kim (ETRI of KOREA, Korea); Antonio Clemente (CEA-LETI Minatec, France); Jean-Baptiste Doré (CEA, France); Antonio De Domenico (CEA-LETI Minatec, France); Taeyeon Kim (Chungnam National University, Korea); Taesang Choi (Electronic and Telecommunications Research Institute, Korea); Hyun Kyu Chung (ETRI, Korea); Giuseppe Destino (CWC, University of Oulu, Finland); Aarno Pärssinen (University of Oulu, Finland); Ari T. Pouttu (Centre for Wireless Communications University of Oulu, Finland); Matti Latva-aho (UoOulu, Finland); Nicolas Chuberre and Mathieu Gineste (Thales Alenia Space, France); Benoit Vautherin (Thales Alenias Space, France); Michel Monnerat (Thales Alenia Space, France); Valerio Frascolla (Intel

Deutschland Gmbh, Germany); Maria Fresia (Intel Deutschland, Germany); Wilhelm Keusgen (Fraunhofer Heinrich Hertz Institute, Germany); Thomas Haustein (Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, Germany); Aki Korvala and Marko Pettissalo (Nokia, Finland); Olli Liinamaa (Centre for Wireless Communications University of Oulu, Finland)

- The first page of the paper is illustrated below:



5G CHAMPION - Rolling out 5G in 2018

Markus Mueck[1], Emilio Calvanese Strinati[2], Il-Gyu Kim[3], Antonio Clemente[2], Jean-Baptiste Doré[2], Antonio De Domenico[2], Taeyoon Kim[3], Taesang Choi[3], Hyun Kyu Chung[3], Giuseppe Destino[4], Aarno Pärssinen[4], Ari Pouttu[4], Matti Latva-aho[4], Nicolas Chuberre[5], Mathieu Gineste[5], Benoit Vautherin[5], Michel Monnerat[5], Valerio Frascolla[1], Maria Fresia[1], Wilhelm Keusgen[6], Thomas Haustein[6], Aki Korvala[7], Marko Pettissalo[7] and Olli Liinamaa[7]

[1] INTEL Deutschland GmbH, Munich, Germany ; [2] Commissariat à l'énergie atomique et aux énergies alternatives (CEA), Grenoble, France ; [3] Electronics and Telecommunications Research Institute (ETRI), Seoul, Korea ; [4] University of Oulu, Oulu, Finland ; [5] Thales Alenia Space, France ; [6] Fraunhofer Heinrich Hertz Institute, Berlin, Germany; [7] NOKIA, Oulu, Finland

Abstract—The 5G CHAMPION Consortium will provide the first fully integrated and operational 5G prototype in 2018 – this effort is a major leap ahead compared to existing punctual technology trials, such as, e.g., Proof-of-Concept platforms focusing on mmWave communication in specific bands, etc. This paper describes the overall set-up including a synergetic combination of technologies such as beamforming based mmWave & Satellite service provisioning, virtualized infrastructure, software reconfiguration across the entire stack, accurate positioning and high-speed solutions. The key enablers are described in detail and related efforts in standards and regulation organizations are discussed.

Keywords— 5G, Beamforming, mmWave, Satellite, Software Reconfiguration, Virtualization, FBMC.

I. INTRODUCTION

5G -Next Generation Communication Networks will be a global game changer from a technological, economic, societal and environmental perspective. The so called vertical markets and industries will experience a drastic transformation thanks to 5G enabled technical capabilities available to trigger the development of cost effective new products and services. [15] presents a detailed analysis of uses cases and corresponding requirements for representative vertical markets such as Factories of The Future, Automotive, Health, Energy and Media & Entertainment.

Currently research has being carried out to design technology portfolios that will make 5G a reality. What is clear today is that 5G will meet the 5G target KPIs thanks to a set of key technological components [14]. The 5G roadmap from research to productization is clear today: 5G standardization framework will be ready by 2016, commercial 5G network infrastructure for 20XX and 5G terminal and devices for 20YY. Nevertheless, real field 5G system proof of concept (PoC) and performance benchmarking have not been done yet.

With this paper we present the 5G CHAMPION European/Korean Research project which is in the phase of preparing a fully operational 5G PoC platform to be showcased in 2018 – two years ahead of time of the 2020 target commercial roll-out of the technology. All 5G key technological building blocks will be developed in 5GCHAMPION and implemented into a new architectural approach providing an efficient end-to-end system performance encompassing cutting edge 5G radio-access, core-network and satellite technologies.

The proposed approach is far more advanced compared to other similar activities focusing on prototyping, due to 5G CHAMPION's tight integration of a multitude of new enabling technologies. Inherent synergy effects are expected to provide substantially improved system performance compared to other efforts, where the focus is laid only on a single specific technology, such as wide-spread prototyping in 28 GHz mmWave spectrum (see, e.g., [1]). Other still running funded research projects also touch on selected aspects of the forthcoming 5G system. E.g. European collaborative research projects MiWaveS, mmMAGIC and METIS-II with respect to channel models, new algorithms and RF blocks for mmWave communication, ADEL, 5PEED-5G and FANTASTIC 5G, and finally Flex5GWave providing the first HW and key building blocks for a 5G platform, but none of them aims at proposing such a synergy of different enabling technologies..

Most challenging 5G characteristics will be addressed by the proposed set-up, including in particular:

- Latency in the ms range;
- Capability to serve very dense user environments without loss of performance;
- Capability to provide various network functions;
- Capability to support high precision/integrity ubiquitous location based services and timing;
- Capability to support various types of IoT, and interoperability between them;
- Capability to efficiently provide ubiquitous 5G services.

The remainder of the paper is organized as follows: Section II gives an overview on the 5G CHAMPION System Architecture, Use Cases and key enablers to be showcased are followed by an overview of relevant standardization and regulation activities in Section III. Section IV finally gives a Conclusion

Figure 5: Paper to Globecom 2016 Workshop.

- A poster was presented at the event:

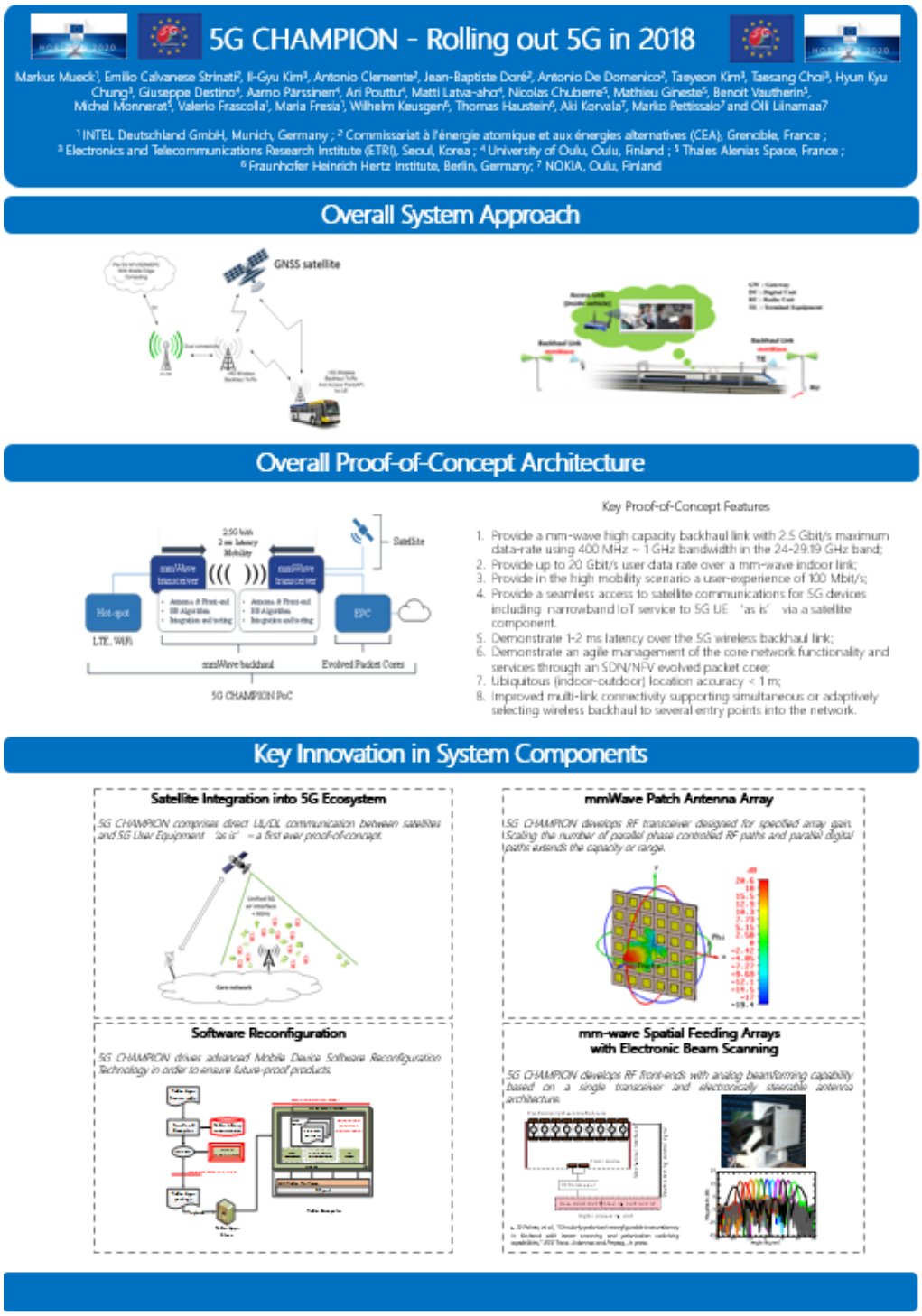
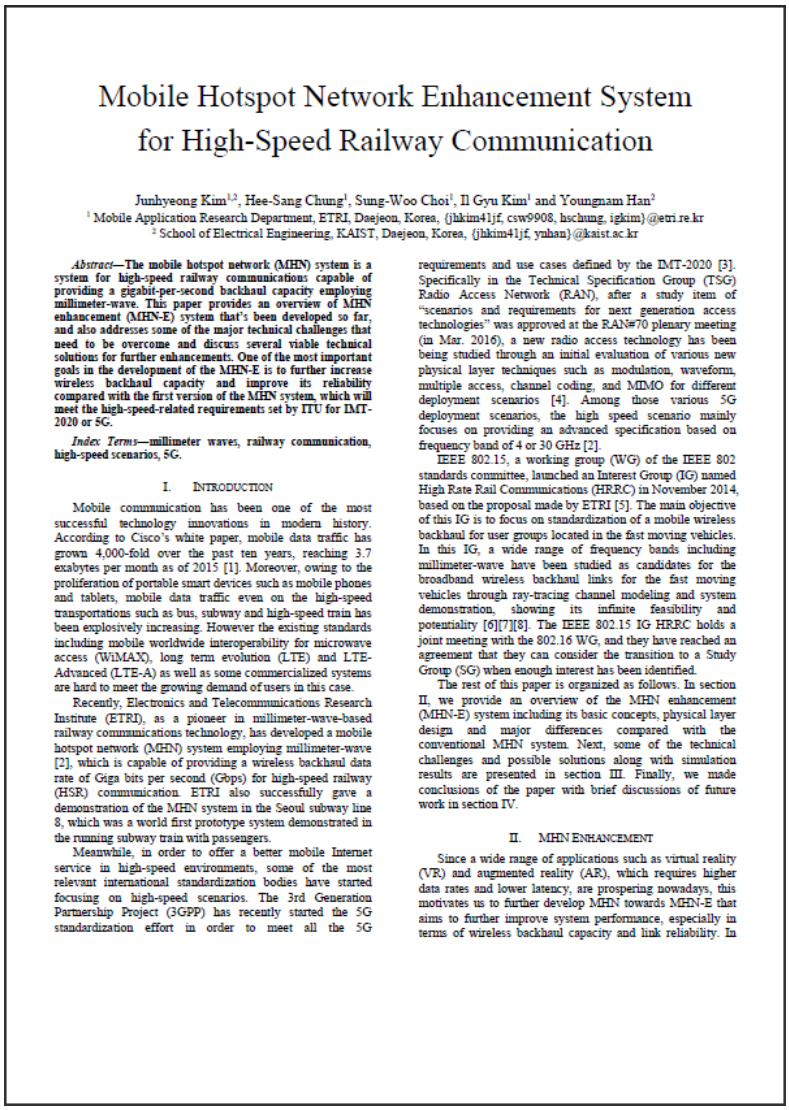


Figure 6: Poster Presented at Globecom 2016 Workshop.

- **"Mobile Hotspot Network Enhancement System for High-Speed Railway Communication"**: Accepted Scientific Paper at EuCAP2017 (the 11th European Conference on Antennas and Propagation, to be held in Paris, France, on 19-24 March 2017)
  - Authors: Junhyeong Kim (ETRI), Hee-Sang Chung (ETRI), Sung-Woo Choi (ETRI), Il Gyu Kim (ETRI), and Youngnam Han (KAIST)
  - The first page of the paper is illustrated below:



Mobile Hotspot Network Enhancement System for High-Speed Railway Communication

Junhyeong Kim[1,2], Hee-Sang Chung[1], Sung-Woo Choi[1], Il Gyu Kim[1] and Youngnam Han[2]
[1] Mobile Application Research Department, ETRI, Daejeon, Korea, {jhkim41jf, csw9908, hschung, igkim}@etri.re.kr
[2] School of Electrical Engineering, KAIST, Daejeon, Korea, {jhkim41jf, ynhan}@kaist.ac.kr

***Abstract*—The mobile hotspot network (MHN) system is a system for high-speed railway communications capable of providing a gigabit-per-second backhaul capacity employing millimeter-wave. This paper provides an overview of MHN enhancement (MHN-E) system that's been developed so far, and also addresses some of the major technical challenges that need to be overcome and discuss several viable technical solutions for further enhancements. One of the most important goals in the development of the MHN-E is to further increase wireless backhaul capacity and improve its reliability compared with the first version of the MHN system, which will meet the high-speed-related requirements set by ITU for IMT-2020 or 5G.**

***Index Terms*—millimeter waves, railway communication, high-speed scenarios, 5G.**

I. Introduction

Mobile communication has been one of the most successful technology innovations in modern history. According to Cisco's white paper, mobile data traffic has grown 4,000-fold over the past ten years, reaching 3.7 exabytes per month as of 2015 [1]. Moreover, owing to the proliferation of portable smart devices such as mobile phones and tablets, mobile data traffic even on the high-speed transportations such as bus, subway and high-speed train has been explosively increasing. However the existing standards including mobile worldwide interoperability for microwave access (WiMAX), long term evolution (LTE) and LTE-Advanced (LTE-A) as well as some commercialized systems are hard to meet the growing demand of users in this case.

Recently, Electronics and Telecommunications Research Institute (ETRI), as a pioneer in millimeter-wave-based railway communications technology, has developed a mobile hotspot network (MHN) system employing millimeter-wave [2], which is capable of providing a wireless backhaul data rate of Giga bits per second (Gbps) for high-speed railway (HSR) communication. ETRI also successfully gave a demonstration of the MHN system in the Seoul subway line 8, which was a world first prototype system demonstrated in the running subway train with passengers.

Meanwhile, in order to offer a better mobile Internet service in high-speed environments, some of the most relevant international standardization bodies have started focusing on high-speed scenarios. The 3rd Generation Partnership Project (3GPP) has recently started the 5G standardization effort in order to meet all the 5G requirements and use cases defined by the IMT-2020 [3]. Specifically in the Technical Specification Group (TSG) Radio Access Network (RAN), after a study item of "scenarios and requirements for next generation access technologies" was approved at the RAN#70 plenary meeting (in Mar. 2016), a new radio access technology has been being studied through an initial evaluation of various new physical layer techniques such as modulation, waveform, multiple access, channel coding, and MIMO for different deployment scenarios [4]. Among those various 5G deployment scenarios, the high speed scenario mainly focuses on providing an advanced specification based on frequency band of 4 or 30 GHz [2].

IEEE 802.15, a working group (WG) of the IEEE 802 standards committee, launched an Interest Group (IG) named High Rate Rail Communications (HRRC) in November 2014, based on the proposal made by ETRI [5]. The main objective of this IG is to focus on standardization of a mobile wireless backhaul for user groups located in the fast moving vehicles. In this IG, a wide range of frequency bands including millimeter-wave have been studied as candidates for the broadband wireless backhaul links for the fast moving vehicles through ray-tracing channel modeling and system demonstration, showing its infinite feasibility and potentiality [6][7][8]. The IEEE 802.15 IG HRRC holds a joint meeting with the 802.16 WG, and they have reached an agreement that they can consider the transition to a Study Group (SG) when enough interest has been identified.

The rest of this paper is organized as follows. In section II, we provide an overview of the MHN enhancement (MHN-E) system including its basic concepts, physical layer design and major differences compared with the conventional MHN system. Next, some of the technical challenges and possible solutions along with simulation results are presented in section III. Finally, we made conclusions of the paper with brief discussions of future work in section IV.

II. MHN Enhancement

Since a wide range of applications such as virtual reality (VR) and augmented reality (AR), which requires higher data rates and lower latency, are prospering nowadays, this motivates us to further develop MHN towards MHN-E that aims to further improve system performance, especially in terms of wireless backhaul capacity and link reliability. In

Figure 7: Paper to EuCAP 2017.

  - The paper will be presented in the oral session (CS39 Propagation Channels for Wide Sense Vehicle to X Communications), which is scheduled on March 23.

- **"Development of 5G CHAMPION Testbeds for 5G Services at the 2018 Winter Olympic Games"**: Paper submitted to 18th IEEE International Workshop on Signal Processing Advances in Wireless Communications, SPAWC 2017.

Development of 5G CHAMPION Testbeds for 5G Services at the 2018 Winter Olympic Games

(Contributer's name will be updated) Seok Ho Won[1], Jun-Hyoung Kim[1], Il-Gyu Kim[1], … Markus Mueck1, Emilio Calvanese Strinati2, Antonio Clemente2, Jean-Baptiste Doré2, Antonio De Domenico2, Taeyeon Kim1, Taesang Choi1, Hyun Kyu Chung1, Giuseppe Destino4, Aarno Pärssinen4, Ari Pouttu4, Matti Latva-aho4, Nicolas Chuberre5, Mathieu Gineste5, Benoit Vautherin5, Michel Monnerat5, Valerio Frascolla1, Maria Fresia1, Wilhelm Keusgen6, Thomas Haustein6, Aki Korvala7, Marko Pettissalo7 and Olli Liinamaa7

1 Electronics and Telecommunications Research Institute (ETRI), Seoul, Korea, 2 INTEL Deutschland GmbH, Munich, Germany ; 3 Commissariat à l'énergie atomique et aux énergies alternatives (CEA), Grenoble, France ; 4 University of Oulu, Oulu, Finland ; 5 NOKIA, Oulu, Finland

***Abstract*— This paper describes the 5G testbed developed in the process of the 5G CHAMPION project that began with over twenty consortium member companies and that is targeting the provision of 5G services at the 2018 Winter Olympics. In order to provide 5G services such as augmented reality (AR), virtual reality (VR), and real time, high quality, interactive multi-player video games, the testbeds must fulfill specific challenging requirements such as ultra-high data rates, ultra-reliable low latency, and mass connectivity. Furthermore, the testbeds have revolutionary architectures that are designed with cost- and energy-efficiency, flexibility. The testbeds will also provide interoperable and seamless connection between two different access networks located in the European continent and the Korean Winter Olympic site.**

Inedex terms—5G Services; 5G Mobile Communication; 5G Testbed; 5G CHAMPION; Heterogeneous Network

I. Introduction

While 2G, 3G, and 4G mobile communication systems primarily evolved in order to obtain higher data rates and/or broader bands, the 5G systems need more diversified key performance indicators (KPIs) for enhanced mobile broadband (eMBB), ultra-reliable low latency communication (URLLC), and mass connectivity for emerging services [1]. With the plan to begin commercial 5G services in 2020, these include services for ultra-high definition TV (UHD-TV), augmented reality (AR), virtual reality (VR), digital holograms (for eMBB), air and road self-driving vehicles (URLLC), and various Internet of Things (IoT) applications. In order to demonstrate these services in conjunction with worldwide events such as the 2018 Winter Olympic Games in Korea, the 5G CHAMPION consortium companies have been developing 5G testbeds.

The developed testbeds are the first 5G testbeds with heterogeneous, agile mobile networks for the services described above, and that have been particularly developed to provide service at the Winter Olympic Games; the testbeds have been built by the 5G CHAMPION project that began on June 1, 2016, with more than twenty consortium member companies located in the European Union and in Korea. The testbeds have been developed following the overall setup described in [2] with the component technologies such as beamforming-based mmWave and satellite service provisioning, virtualized infrastructure, software reconfiguration across the entire stack, accurate positioning, and high speed solutions. This paper presents the testbed foundations being developed and implemented with a new architectural approach that provides efficient end-to-end system performance with interoperable and seamless connections between two different access networks (i.e. the access network in the European continent and the access network at the Korean Olympic site) consisting of leading mmWave and sub-6 GHz 5G radio access, core network, and satellite technologies [2].

The 5G testbeds are important because they provide researchers with a clear understanding of the new 5G technologies and they have flexible architectures that can change frequently. Moreover, their requirements are tens of gigabits per second (Gbps) of data rate, sub-millisecond levels of service latency, and high reliability in the packet loss rates of at least 10^{-9} [1]. Some 5G testbeds with revolutionary architectures that fulfill these features and requirements have been introduced previously in the literature [3-5]. In [3], the authors introduced 5G testbeds for mmWave systems with high bandwidth analog front ends, parallel and interleaved analog-to-digital converters (ADCs) and digital-to-analog converters (DACs) for giga-samples per second (GS/s), specific placements of the field programmable gate arrays (FPGAs) for parallel processing because the leading FPGA clock rates cannot support Gbps processing, and so on. However, their testbeds are proof-of-concept (PoC) systems for mmWave radio technology, while the 5G CHAMPION testbeds embrace these mmWave technologies and sub-6 GHz 5G radio access, core network, and satellite technologies.

The 5G open testbeds have also been introduced in [4] with the virtual Wi-Fi testbed and virtualization tools in order to support hundreds of virtual Wi-Fi nodes. Other notable testbeds have been developed by another 5G project "Integration of Broadcast and Broadband in LTE/5G" (IMB5) introduced in [5] using evolved multimedia broadcast multicast service (eMBMS) testbeds. Embracing these features and technologies, our 5G CHAMPION testbeds aim to provide 5G services with interoperable and seamless connection between two different

Figure 8: Paper to SPAWC 2017.

- **A Hierarchical Anchor Selection Scheme for Distributed Moble Network Architecture"**: Accepted Scientific Paper at ICTC2016 (The 7th International Conference on Information and Communication Technology Convergence (ICTC 2016), Jeju Island, Korea, October 19-21, 2016)
  - Authors: Kyoungjae Sun and Younghan Kim (Soongsil University)
  - The first page of the paper is illustrated below:

A Hierarchical Anchor Selection Scheme for Distributed Mobile Network Architecture

Kyoungjae Sun
Dept. of Electronic Engineering
Soongsil University
Seoul, Korea
gomjae@ssu.ac.kr

Younghan Kim
Dept. of Electronic Engineering
Soongsil University
Seoul, Korea
younghak@ssu.ac.kr

***Abstract*— In this paper, we propose distributed mobile core network architecture and anchor allocation scheme to provide fine-grained mobility management depending on the requirements of user's application. For each case for different types of IP address, we analyze IP allocation and handover procedure.**

***Keywords*— Distributed Mobility Management(DMM), Anchoring, Distributed Mobile Architecture.**

I. Introduction

The main object of the 5G mobile network is to process a large amount of data traffic in a more flexible and efficient way at a lower cost. To process huge traffic with different characteristics generated by the existing typical mobile device (e.g. smartphone) and different types of mobile access devices (e.g. IoT devices, vehicles, etc.), the current 4G network architecture is facing with challenges from highly centralized and static architecture to more flexible and scalable manner. In order to overcome the above limitations of the current mobile network, 5G mobile network is proposed with distributed core network, while increasing density of radio access network.

In centralized networks, session continuity for mobile user is provided by forwarding all data packets through a central anchor point. Between the anchor and access router, GPRS Tunneling Protocol (GTP) [1] or Proxy Mobile IPv6 (PMIPv6) [2] is used for establishing tunnel interface to support routing packet to current location of mobile nodes. In future 5G, mobile network is expected that mobility management entities are split and located closer to the edge of network where mobile users are connected. Distributing mobility management entities can solve problems suffered from centralized mobility network such as single point failure, scalability issue and sub-optimal routing. Such a solution is currently being discussed in the Distributes Mobility Management (DMM) working group [3] of Internet Engineering Task Force (IETF). According to the charter of DMM working group, they define protocol semantic and deployment models considering new network trends, such as separation of control/data plane Software Defined Networking (SDN) and Network Function Virtualization (NFV) technology.

Additionally, in the future 5G mobile network architecture, mobile network operator will be able to provide different sets of network entities and user traffic through variable connection points to the Internet. For example, data traffic can be allowed to be broken out to the edge network. Another example is on-demand mobility support in which the session continuity is provided selectively based on characteristics of data flow. To provide different services based on the fine-grained policy, IETF DMM working group defines three types of IP address and a solution for the applications running on mobile devices to indicate whether they need IP session continuity or IP address reachability [4].

In this paper, based on the definition of IP address types, we propose a novel scheme for session-based anchor assignment in distributed mobile architecture. We first design a distributed mobile architecture including two types of core network in a partially hierarchical manner: central core network and edge core network. Based on the level of mobility demand, different types of IP address are assigned by different anchors.

II. Related Works

A. Network Architecture Considerations

4G mobile network architecture [5], standardized in 3GPP, is composed of Evolved Packet Core (EPC) and Radio Access Network (RAN). The EPC includes network components for control plane such as the Mobility Management Entity (MME), Home Subscriber System (HSS) and Policy Charging and Rules Function (PCRF), and for data plane such as Serving Gateway (SGW) and Packet Gateway (PGW). The EPC architecture is designed in centralized and hierarchical manner, in which the PGW is an anchor point of network to forward all data packets through the external Internet. To support mobility, tunnel establishment protocol such as GTP or PMIPv6 is using between the SGW and PGW. Since all of network entities in the EPC are generally deployed in dedicated hardware tightly coupled with their functionality, current mobile network architecture causes significant cost for scaling infrastructure to meet demands of increasing data traffic.

The most important objective of 5G mobile network design is to increase scalability with flexible resource management for taking into account explosion of mobile device and data traffic. Recently, many researches are going on for studying and designing 5G network architecture [6]. To achieve the objective, SDN and NFV technologies are emerging as a promising solution. SDN [7] is a networking paradigm that separates the control plane form packet forwarding device (i.e. switch and

978-1-5090-1325-8/16/$31.00 ©2016 IEEE

Figure 9: Paper to ICTC 2016.

- **"Dynamic Flow Steering for IoT Monitoring Data in SDN-coordinated IoT-Cloud Services"**: Accepted Scientific Paper at ICOIN 2017 (The 31st International Conference on Information Networking, Da Nang, Vietnam, January 11-13, 2017)
  - Authors: Heebum Yoon, SeungRyong Kim, TaekHo Nam and JongWon Kim (GIST)
  - The first page of the paper is illustrated below:

Dynamic Flow Steering for IoT Monitoring Data in SDN-coordinated IoT-Cloud Services

Heebum Yoon, Seungryong Kim, Taekho Nam, and JongWon Kim
School of Electrical Engineering & Computer Science
Gwangju Institute of Science & Technology
Republic of Korea
{hbyoon, srkim, thnam, jongwon}@nm.gist.ac.kr

***Abstract*—By effectively coupling IoT and Cloud together, we need to enable diversified IoT-Cloud services. To effectively support IoT-Cloud services, it is essential to maintain persistent data transport between IoT and Cloud. Also the emerging Software-Defined Networking (SDN) paradigm can assist flexible flow-centric networking of persistent data between IoT and Cloud. Thus, in this paper, we take an example of IoT-Cloud service realized over miniaturized IoT-SDN-Cloud environment (named as SmartX-mini Playground) and propose the application of SDN-based flow steering to dynamically adjust the overlay data paths for IoT-Cloud services. More specifically, we attempt to combine the overlay data transport of Apache Kafka messages and the underlay flow-based networking coordinated by an ONOS (Open Networking Operating System) SDN controller.**

Keywords*— *Software-Defined Networking (SDN), flow steering, Internet of Things (IoT), and Apache Kafka messaging.

I. INTRODUCTION

To process and store huge data gathered from distributed IoT (Internet of Things) devices, emerging IoT services are being tightly coupled with the cloud-based shared infrastructure [1]. To exploit the value of dispersed IoT data, we need to securely collect and quickly analyze a large amount of data [2] without any serious interrupt. That is, a persistent monitoring (including the collection and analysis) of IoT data is required between IoT devices and the supporting cloud infrastructure. Based on this IoT and cloud linkage, so-called IoT-Cloud services can be efficiently created. Then, in order to maintain the linkage reliably for IoT-Cloud service, we can utilize the flexible flow-centric tagging, steering, and mapping capability of SDN (Software-Defined Networking). From logically-centralized SDN controllers, the operators can flexibly prepare multiple paths to support the inter-connection needs of targeted IoT-Cloud services.

Thus, in this paper, we demonstrate the support capability of SDN-based flow coordination for IoT-(SDN)-Cloud services. As an example case, the proposed SDN-based flow coordination (mostly for flow steering) assists the resource monitoring functionality for a miniaturized IoT-Cloud testbed environment, named as SmartX-mini Playground. In this example, persistent monitoring of SmartX-mini Playground is assisted to enable fast and timely delivery of IoT device status data. As depicted in the upper side of Fig. 1, IoT monitoring data is delivered by Apache Kafka [1] messaging functions located in both IoT and cloud sides [3]. In the bottom side of Fig. 1, ONOS SDN controller is adopted to assist flexible flow-based steering for IoT monitoring data [4].

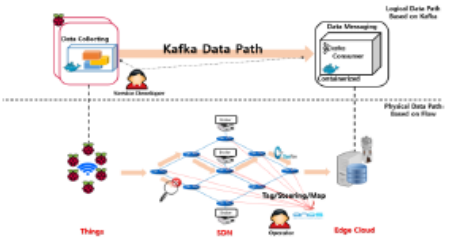


Fig. 1: SDN-coordinated delivery of IoT data for IoT-Cloud services.

In summary, to support IoT-Cloud services by persistently collecting IoT monitoring data, we combine Kafka-based overlay data delivery with SDN-coordinated underlay flow-steering. More specifically, we prepare flow-based multiple paths coordinated by the SDN controller. Note that a prior knowledge about the underlay networking topology is assumed. Next, we maintain the continuity of streaming-style delivery of Kafka-based IoT monitoring data messages. Here mix-and-matching both Kafka data transport with SDN-coordinated flow-steering is the key factor in maintaining the persistent delivery of IoT monitoring data.

The remainder of the paper is organized as follows. In Section II, we discuss the design and implementation details about ONOS-coordinated IoT data monitoring over SmartX-mini Playground. Next, in Section III, we discuss the verification result and then conclude the paper in Section IV.

[1] Apache Kafka is an open-source distributed messaging package originated from LinkedIn, which aims to provide a unified, high-throughput, low-latency solution for handling real-time data feeds. It is, in its essence, a "massively scalable pub/sub message queue architected as a distributed transaction log," making it highly valuable in processing streaming data.

978-1-5090-5124-3/17/$31.00 ©2017 IEEE 625 ICOIN 2017

- **"Study of Distributed Wireless Access Point Controller"**: Accepted Scientific Paper at ICOIN 2017 (The 31st International Conference on Information Networking, Da Nang, Vietnam, January 11-13, 2017)
  - Authors: Gyewan An, Sangyun Han and Sungwon Lee (KyungHee University)
  - The first page of the paper is illustrated below:

Study of Distributed Wireless Access Point Controller

Gyewan An, Sangyun Han, Sungwon Lee*
Department of Computer Science and Engineering
Kyung Hee University
Yong-in, South Korea
{danielahn, sangyun0628, drsungwon}@khu.ac.kr

***Abstract*— In these days, as proliferating the use of mobile devices like tablet PC and smartphone, wireless AP should be distributed arrangement and cover a wide area by radio signal. There is the necessity of wireless AP controller because administrators of a wireless network can manage remotely and efficiently many APs on distributed area. The most of wireless AP has to use only one controller, so it may cause failure of the whole system in case of having some problem on controller managing APs. Therefore, in this paper, we propose distributed wireless AP controller using replicated key-value store called etcd. The distributed controllers connected by etcd protect the data about the managed AP, even if some controller fails. And each controller manages nearly located AP by using the way of the draft like what is uses in sports. This way using draft can reduce time to communicate between controller and APs and increase an efficiency of managing mechanism. We expect that this proposed method enhances reliability and provides high availability of wireless network managed by the controller.**

***Keywords*—wireless network; distributed; WiFi orchestration; availability;**

I. Introduction

Recently, the amount of worldwide wireless network demand has grown rapidly. Since the grown of mobile devices, such as a smartphone, tablet PC and laptop. To deal well with the demand of wireless network, a lot of the access point(AP)s are widely installed. However, there is not the way to control to the APs.

Someone try to control by the only one controller. However, the only one controller is unstable. When the controller is down, APs can't find the controller and have control. It occurs that the network manager should repair each APs to be re-connected to the controller. Moreover, it's too inconvenience to use since has to use with a specific application and vendor.

In this paper, we propose a scheme that the union of distributed AP controller for controlling wireless access points. It can provide a high availability service to ensure stability. Furthermore, it offers the better wireless access point control service than ordinary.

II. Relative Research

A. Wireless AP controller.

There are a lot of projects about wireless AP controller. One of the projects is the Odin projects. [1] It is designed for programmatic orchestration of WiFi Networks. Because the Odin agent is implemented in the Click Modular Router [2], it is difficult to use and to develop. In addition, the Odin controller is less stable because it only works on a single machine.

B. etcd.

etcd [3] is written in Go programming language developed by Google and uses the Raft consensus algorithm [4] to manage a highly available replicated log. etcd is a distributed key-value storage that supports a reliable way to save data across a cluster of instances and provides a tolerance of machine failure. It stores data in directories similar to a file system.

III. Proposed Scheme

When the wireless AP are up, they request the initial session to all controllers. After replying requests, each controller measures the roundtrip between the AP and controller. One of the controllers requests to other controllers the draft. Using the roundtrip time, the controller selects the fastest AP in a rotation. And then each wireless AP has only one primary controller while other controllers become backups. If AP lost the main controller, one of the other controllers selects it. It can provide high availability for a stable management and more efficient management without physically direct repairing.

APs and controllers should use AP agent that runs on the device that installed hostapd [5] and dhcpd without a complicated program. If the command comes in from controller, AP agent process it and re-send to the controller. For example, if AP agent receives the command to change the WiFi SSID, AP agent re-write the hostapd config file with new SSID, and then AP agent restart hostapd. After all, AP agent sends the new information to the main controller.

The agent sends the heartbeat packets to the main controller to check the controller's life and AP's life. In

978-1-5090-5124-3/17/$31.00 ©2017 IEEE 679 ICOIN 2017

- **"A Proposal of OpenFlow Controller to improve Transfer Rate in Mesh Network"**: Accepted Scientific Paper at ICOIN 2017 (The 31st International Conference on Information Networking, Da Nang, Vietnam, January 11-13, 2017)
  - Authors: Seawon Koh and Sungwon Lee (KyungHee University)
  - The first page of the paper is illustrated below:

A Proposal of OpenFlow Controller to Improve Transfer Rate in Mesh Network

Seawon Koh, Junho Kim, Sungwon Lee*
Department of Computer Science and Engineering
Kyunghee University
Yongin, Republic of Korea
{dream365, junhoya924, drsungwon}@khu.ac.kr

***Abstract*—In these days, the Internet is growing and the amount of user to use network increases rapidly. The mesh(ad-hoc) network has studied for many areas where people can't use the Internet. Also, mesh(ad-hoc) network is used for special purposes, and it expands its domain recently. However, low transfer rate and small coverage are a critical issue in mesh(ad-hoc) network. In this paper, it suggests improving transfer rate using BATMAN, Open vSwitch, and Dijkstra algorithm. This paper has three section. In the first section, it suggests network architecture for improving transfer rate. This structure consists of network, controller, and storage. In the second section, it explains the algorithm for finding the optimal path using modified Dijkstra algorithm. Finally, it shows the testbed to realize this proposal. We describe some advantage of controlling traffic flow.**

***Keywords*—wireless mesh(ad-hoc) network; BATMAN; Open vSwitch; Open Source; Dijkstra algorithm; SDN; SDN controller**

I. INTRODUCTION

Due to growing the Internet and penetration rate recently, networks are used by several areas. However, many areas can't supply network service. The wireless mesh(ad-hoc) network, one of the network technology, is getting attention. To solve this problem, the wireless mesh(ad-hoc) network is studied for a difficult environment to use networks, such as war situation or disaster. Recently, the mobile mesh(ad-hoc) network has appeared, which is embedded in a vehicle and called VANET(Vehicular Ad Hoc Network) [1]. Thus, mesh(ad-hoc) network is used for the special purposes like a VANET, so that its usage rate is higher than past usage rate. To transmit packets from one node to another node, mesh(ad-hoc) network doesn't need to have the base network. And, its nodes perform a role as a router to transmit packets from one node to another node. Also, all mesh(ad-hoc) network's nodes have mobility. So, network's status changes steadily, the transfer rate decreases and the packet drop rate increase. In mesh(ad-hoc) network, low transfer rate and small coverage are claimed as a critical issue [2]. This situation gets worse by strong wind and occurring heavy traffic.

In this paper, OpenFlow technology is applied on mesh(ad-hoc) network to improve low transfer rate. It suggests that mesh(ad-hoc) network is managed by the controller on the control plane. Packets move from the path which has low transfer rate to the path having high transfer rate to increase transfer rate.

SDN(Software Defined Networking) is rising in the way of new networking approach [3]. On SDN, control and data plane are separated. So, OpenFlow which is controlled by software is SDN's representative technology. OpenFlow technology provides several network service through the development of new network software module. Also, the user defines the path to move packet by setting flow table of SDN switch with OpenFlow and network controller. And user configures flow by setting several actions.

In this paper, it proposed controller to improve transfer rate using batman-adv. And it makes SDN switch which can receive OpenFlow command by loading Open vSwitch [5, 6]. Then, a path having low transfer rate caused by heavy traffic is controlled by a controller which is combined Dijkstra algorithm. Dijkstra algorithm is the algorithm for finding the shortest path, which is used for OSPF(Open Shortest Path First) protocol.

II. RELATED WORK

A. BATMAN

BATMAN(Better Approach To Mobile Ad-hoc Network) is routing protocol for the wireless mesh(ad-hoc) network. BATMAN knows optimal path's information, and BATMAN sends packets to optimal path. Also, it broadcasts small sized packet called OGM to each node. So, each node knows neighboring node's link information. In OGM packet, it contains the address of the originator, the address of the transmitting the packet, a TTL, and a sequence number.

BATMAN consists of batman-adv, Alfred, batctl, batmand. From among these, batman-adv is an implement of layer 2 protocol in the form of a Linux kernel module operating on layer 2. Other many routing protocols transfer packets by kernel's routing information. In Contrast, batman-adv is formed on layer 2, and it treats data traffic using raw Ethernet frame. Also, batman-adv is configured and debugged through batctl tool. And it contains layer 2 ping, traceroute, and TCP dump.

*Corresponding author

6.3 Scientific Conference Presentation

- IEEE PIMRC 2016, 5G CHAMPION: 5G, we will prove it works', Emilio Calvanese Strianti, CEA-LETI, France. At the panel on 'The Path to 5G Enhanced Mobile Broadband'.
- IEEE 5G Berlin Summit, "5G CHAMPION: 28 GHz 5G Proof-of-Concepts at 2018 Winter Olympic games", Dr. Emilio CalvaneseStrinati, CEA-LETI, France
- IEEE Globecom Conference, "5G CHAMPION: 28 GHz 5G Proof-of-Concepts at 2018 Winter Olympic games", Dr. Emilio CalvaneseStrinati, CEA-LETI, France at the industrial panel on '5G Networks Prototyping: Entering the Next phase of experimentation for future Radio Access Technologies.

6.4 Scientific Journal Publications

- **"Enabling Technologies Towards Fully LTE-Compatible Full-Duplex Radio"**: Accepted Scientific Paper in IEEE Communications Magazine
  - Authors: Gosan Noh, Hanho Wang, Changyong Shin, Seunghyeon Kim, Youngil Jeon, Hyunchol Shin, Jinup Kim, and Ilgyu Kim
  - The first page of the paper is illustrated below:

RADIO COMMUNICATIONS

Enabling Technologies toward Fully LTE-Compatible Full-Duplex Radio

Gosan Noh, Hanho Wang, Changyong Shin, Seunghyeon Kim, Youngil Jeon, Hyunchol Shin, Jinup Kim, and Ilgyu Kim

The authors provide technical challenges and solutions for an LTE-compatible full-duplex cellular network, featuring wideband and wide dynamic range support for RF self-interference cancellation and robust and efficient self-interference channel estimation for digital self-interference cancellation. Based on a realistic LTE-based cellular model, their full-duplex radio design is evaluated through system-level simulations and real-world testbed experiments.

This work was supported by the Institute for Information & Communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (No.B0115-16-0001, 5G Communication with a Heterogeneous, Agile Mobile Network in the PyeongChang Winter Olympic Competion.

Digital Object Identifier: 10.1109/MCOM.2017.1600791CM

ABSTRACT

Full-duplex radio has potential to double spectral efficiency by simultaneously transmitting and receiving signals in the same frequency band, but at the expense of additional hardware and power consumption for self-interference cancellation. Hence, the deployment of a full-duplex cellular network can be realized by employing full-duplex functionality only at an eNodeB, which is supposed to have sufficient computation and power resources, and by scheduling pairs of half-duplex UEs that are in either downlink or uplink. By doing so, fast and smooth full-duplex deployment is possible while minimally affecting the legacy UEs and the rest of the network entities. In this article, we provide technical challenges and solutions for an LTE-compatible full-duplex cellular network, featuring wideband and wide dynamic range support for RF self-interference cancellation, and robust and efficient self-interference channel estimation for digital self-interference cancellation. Based on a realistic LTE-based cellular model, our full-duplex radio design is evaluated through system-level simulations and real-world testbed experiments. Simulation results show that a significant throughput gain can be achieved by the full-duplex technique despite the existence of physical limiting factors such as path loss, fading, and other-cell interference. Testbed measurements reveal that at a bandwidth of 20 MHz, self-interference cancellation up to 37 dB is achieved in the RF domain, and most of the residual self-interference is further cancelled down to the noise floor in the subsequent digital domain.

INTRODUCTION

The explosion of wireless data traffic leads to an exponential increase in the target data rate requirements of the fifth generation (5G) wireless cellular networks. A 5G network is expected to provide 1000-fold capacity gains compared to the existing 4G networks such as 3GPP Long Term Evolution (LTE) and LTE-Advanced (LTE-A) systems [1].

The highly demanding capacity requirements of a 5G network can be met by a combination of increasing cell density, utilizing formerly unused spectrum, and improving spectral efficiency. Among them, full-duplex transmission has recently drawn much attention as a means of potentially doubling spectral efficiency by simultaneously transmitting both the downlink and uplink signals in the same frequency band, which is a prominent advantage compared to the conventional half-duplex schemes such as frequency-division duplex (FDD) and time-division duplex (TDD).

One of the key challenging issues for full-duplex radio is the existence of strong self-interference from the transmit to receiver chains. The self-interference comes from imperfect isolation between the transmit and receive paths and reflections from nearby scatterers. It is usually much stronger than the desired received signal, sometimes even 100 dB or so stronger [2]. Thus, such self-interference should be mitigated before processing the received signals. Otherwise, any information contained in the received signal cannot be properly decoded. In this regard, there have been various attempts to suppress or cancel the self-interference in the RF and digital domains [3–5]. Kim *et al.* presented a point-to-point full-duplex scheme based on polarization-division duplexing [3]. Bharadia *et al.* implemented a full-duplex WiFi radio using analog and digital self-interference cancellation techniques [4]. Huusari *et al.* developed a wideband RF self-interference cancellation circuit having self-adaptive and self-healing features [5].

Different from the above prior works dealing with point-to-point and WiFi links, an attempt to apply full-duplex transmission into a cellular network was recently reported in [6], where the self-interference cancellation for full-duplex transmission is performed only at the eNodeB (i.e., base station) while the user equipments (UEs) are limited to half-duplex transmissions. Combined with an appropriate UE scheduling strategy, this scheme achieves a significant full-duplex gain. Based on this, we further improve the eNodeB-side only full-duplex scheme with the aim of ensuring compatibility with the existing LTE and LTE-A systems. Therefore, we expect a fast and smooth deployment of the full-duplex radio with minimal impact on the legacy UEs and the rest of the network entities.

Hence, in this article, we suggest system architecture and enabling technologies for the full-duplex support in an LTE-compatible cellular network, including:

- Identifying a system description with deployment scenarios and requirements
- Providing some important implementation challenges and solutions focusing on the

Gosan Noh, Jinup Kim, and Ilgyu Kim are with the Electronics and Telecommunications Research Institute (ETRI); Hanho Wang is with Sangmyung University; Changyong Shin is with Sun Moon University; Seunghyeon Kim was with Kwangwoon University and now is with GCT Semiconductor Inc.; Youngil Jeon, and Hyunchol Shin are with Kwangwoon University.

Figure 10: Paper to IEEE Communications Magazine.

6.6 Book Chapters

- **"Spectrum Policy and Cognitive Radio Standards"** Section of the "Handbook of Cognitive Radio", to be published by Springer (49 pages)
- Authors: Dr. Markus Mueck
- 1st page of the chapter:

ETSI-RRS Reconfigurable Radio Systems Standards

Dr. Markus Mueck, INTEL Deutschland GmbH, Am Campeon 10-12, 85579 Neubiberg, Germany,
email: Markus.Dominik.Mueck@intel.com

Abstract: The evolution of classical, static Radio Systems towards Reconfigurable Radio Systems is a clear trend in the industry for several reasons – first, the lack of spectral resources forces manufacturer to exploit novel technological trends in order to meet 5G related promises in terms of Quality of Service, Latency, Reliability, etc. Second, the fast evolution and heterogeneous nature of the radio environment combined with an ever increasing computation power in mobile devices calls for new ways of ensuring that the diverse environment is exploited in the best possible way; software reconfigurability is the key to dynamically adapt any target device to the specific needs of its owner through installation of tailored and targeted software components. All this flexibility, however, is useless without access to real-time, reliable context information which feeds decision making entities in the network, in the mobile device or implemented in a distributed way such that the network as well as mobile devices participate in the decision making process. The European Commission has recognized this trend in an early stage and acted correspondingly. ETSI received EC Mandate M/512: "STANDARDISATION MANDATE TO CEN, CENELEC AND ETSI FOR RECONFIGURABLE RADIO SYSTEMS" which lead to the development of the Licensed Shared Access Spectrum Sharing solution in ETSI's Technical Committee Reconfigurable Radio Systems (TC RRS). Furthermore, the new Radio Equipment Directive creates a clear framework for Software Reconfigurable Radio Equipment in Europe. This section details the respective technical solutions and trends as they are currently being developed in ETSI standards.

Keywords: Cognitive Radio Systems, ETSI, Reconfigurable Radio Systems, Software Reconfiguration, Spectrum Sharing

Figure 11: First page of the Book Chapter "Spectrum Policy and Cognitive Radio Standards".

6.7 Special Sessions

- **"Software Reconfiguration enabling 5G"**: Accepted Special Session at The 2017 European Signal Processing Conference (EUSIPCO 2017)
  - Organizers: Dr. Markus Mueck (5G CHAMPION, INTEL), Prof. Seungwon Choi (5G CHAMPION, Hanyang University), Dr. Dr. Emilio Calvanese Strinati (5G CHAMPION, CEA)
  - **Scope**: The "Radio Equipment Directive (RED)" was recently published and replaces the previous "Radio and Telecommunication Terminal Equipment (R&TTE) Directive" which was in force since 1999. The RED creates a new regulation framework in Europe and includes in particular clear provisions in order to enable the introduction of software reconfiguration technology in the Single European Market. This Special Session will gather cross-regional experts, including Korean and European thought leaders, in order to address state of the art technological solutions enabling software reconfiguration in wireless radio equipment. Furthermore, challenges in the field of security and certification will be discussed in order to provide the audience with a holistic picture on the multi-disciplinary challenge. This proposal is supported by the 5G CHAMPION consortium which is working towards a real-field PoC of 5G Networks capabilities at Peyong Olymic games in 2018.
  - Structure of the Special Session – 5 invited Scientific Papers:
  - ***Adaptive automotive communications solutions of 10 years lifetime enabled by ETSI RRS Software Reconfiguration technology;*** KIM Kyunghoon (Hanyang University, Korea), AHN Heungseop (Hanyang University, Korea), HAUSTEIN Thomas (HHI, Germany), FRASCOLLA Valerio (INTEL, Germany)
    - **Short Abstract:** ETSI RRS has recently published a set of standards for Client side Software Reconfiguration covering the technical, security and regulation vectors. It will be shown how the basic features for downloading and installation of software can be applied to a vehicular context. Furthermore, a novel highly efficient way of introducing generic reconfigurable code through a Radio Virtual Machine based representation will be considered for its applicability to the automotive context.
  - ***Highly efficient representation of reconfigurable code based on a Radio Virtual Machine: Optimization to any target platform;*** IVANOV Vladimir (LG, Korea), JIN Yong (Hanyang University), DESTINO Guiseppe (University of Oulu, Finland)
    - **Short Abstract:** This paper introduces a novel way of adapting a Radio Virtual Machine (RVM) based code representation to any target platform. The approach indeed consists in reconstructing a generic RVM based code representation to the available resources of a target platform in order to enable efficient back-end compilation. Finally, highly efficient code is generated which is substantially superior to a middle-ware based code execution approach.
  - ***An SDN/NFV evolved packet core approach enabling agile management of core network functionality and services***; CHOI TaeSang (ETRI, Korea), KIM TaeYeon (ETRI, Korea), CLEMENTE Antonio (CEA, France)
    - **Short Abstract:** Virtualization of major parts of the network in combination with Software Defined Networking are a clear trend in 5G Communications. This paper will discuss novel solutions combining SDN and NFV approach in order to enable an agile management of the infrastructure core network functionalities and related services.

- ***Reconfiguration of 5G radio interface for positioning:*** SALORANTA Jani and DESTINO Giuseppe (University of Oulu, Finland)
  - **Short Abstract:** In addition to high data-rate, mmWave technology has great potential to provide extremely high localization accuracy. In this paper, we outline the benefits of this technology for positioning and their main applications, which are no longer confined to services but also to improve communication. We shall focus on the reconfiguration mechanisms of the radio interface in order to achieve optimum trade-off with data communication.
- ***Radio Equipment Directive – A novel software reconfiguration framework:*** Markus Mueck (INTEL), Christoph Legutko (INTEL), Emilio Calvanese Strinati (CEA)
  - **Short Abstract:** The European Commission has recently replaced the R&TTE Directive – which was in force since 1999 – by the novel Radio Equipment Directive (RED). The RED represents the basic regulation framework for wireless equipment and includes novel provisions for software reconfigurability. This paper summarizes the novel rules and provides solutions which will enable manufacturers to meet technical, security and certification requirements for 3rd party software reconfigurable equipment.
- First page of the submission:

Special Session Title: Software Reconfiguration enabling 5G

Short description of proposed field (one paragraph):

The "Radio Equipment Directive (RED)" was recently revised for the first time since 1999 and replaces the previous "Radio and Telecommunication Terminal Equipment (R&TTE) Directive". The RED creates a new regulation framework in Europe and includes in particular clear provisions in order to enable the introduction of software reconfiguration technology in the Single European Market. This Special Session will gather cross-regional experts, including Korean and European thought leaders, in order to address state of the art technological solutions enabling software reconfiguration in wireless radio equipment. Furthermore, challenges in the field of security and certification will be discussed in order to provide the audience with a holistic picture on the multi-disciplinary challenge.

This proposal is supported by the 5G CHAMPION consortium which is working towards a real-field PoC of 5G Networks capabilities at Peyong Olymic games in 2018.

Novelty and motivation (one to two paragraphs), including why this topic is of interest to the EUSIPCO community

Software Reconfigurability is going to be a substantial driver for future signal processing solutions, since it will make underlying radio platforms open and available for 3rd party components introducing new and competitive features across all layers – from the physical layer up to the application layer. The technology clearly is one of the focus topics of the EUSIPCO conference and of utmost interest to the community. In the context of future 5G systems, this technology will be a key enabler to allow for an adaptation of generic hardware platforms to the needs of specific vertical markets.

Talks on the opportunities and first generation solutions will be highly instructive and insightful to the audience. The corresponding exchange of views may indeed accelerate the overall European 5G effort and increase Europe's leading edge.

Short biography of the organizers

Dr. Markus Mueck oversees Intel's technology development, standardization and partnerships in the field of spectrum sharing. In this capacity, he has contributed to standardization and regulatory efforts on various topics including spectrum sharing within numerous industry standards/regulation bodies, including ETSI, 3GPP, IEEE, the Wireless Innovation Forum and CEPT. Dr. Mueck is an adjunct professor of engineering at University of Technology, Sydney, Australia and Macquarie University, Sydney, Australia, he acts as ETSI Board Member supported by INTEL and as general Chairman of ETSI RRS Technical Body (Software Radio and Cognitive Radio Standardization). He has earned engineering degrees from the University of Stuttgart, Germany and the Ecole Nationale Supérieure des Télécommunications (ENST) in Paris, France, as well as a doctorate degree of ENST in Communications.

Figure 12: Special Session at EuSIPCO 2017.

6.8 Workshops

- "**Multi-RAT and Network/Terminal Function Virtualization**" **on 23rd February 2017 at Orange Gardens, Châtillon, France**" by Orange, b<>com and INTEL and co-located with ETSI RRS strandardization meeting and with active participation by 5G CHAMPION leaders:
    - See http://www.multi-rat--network-terminal-function-virtualization-02.webself.net/
    - **Scope**: "This full day workshop, within the framework of H2020 challenges, addresses multi-RAT architectures in conjunction with Network and Terminal Function Virtualization (NTFV). Network and terminal scalability in the 5G multi-RAT context, involves innovative RAT management and new virtualization functions for Software Designed Networking (SDN) and mobile device reconfiguration. The goal of this workshop is to provide recent trends in these research topics topics from a technical, security and regulation perspective with a focus on the future joint Multi-RAT and NTFV approach for 5G seamless access networks. The workshop includes oral presentations and exhibitions."

T

- **5G CHAMPION** Talk by Dr. Emilio Calvanese-Strinati: 5G CHAMPION – 28 GHz 5G Proof-of-Concept at 2018 Winter Olympic Games

- **5G CHAMPION** Talk by Dr. Markus Mueck (jointly with Francois Ambrosini of IBIT): Terminal Reconfigurability, Technical Solutions, Security and Regulation Aspects

General Program

9.00	Welcome to participants
9.30	Workshop opening, O. Simon, P. Cordier, I. Siaud, M. Mueck
10.00	Virtual RAN towards 5G, A. de Lannoy
10.30	Mobile Core Network Virtualization: Performances Analysis, I. Alawe
11.00	Coffee Break
11.15	Evolution of OAI Software for Data-Center Deployments, R. Knopp
11.45	Challenges in SON for 5G, S. Ben Jemaa
12.15	On convergent mm-MAGIC and ETSI-RRS multi-RAT architectures for 5G, I. Siaud
12.45	Lunch
14.00	Terminal reconfigurability, technical solutions , security and regulation aspects, M. Mueck, F. Ambrosini
14.30	5G Champion: 28 GHz 5G Proof-of-Concepts at 2018 Winter Olympic games, E. Calvanese Strinati
15.00	ETSI RRS –Radio Interface Engine Work Item, R. Raulefs, M. Mueck, I. Siaud
15.30	Flexible radio (hardware + software) under new RE-Directive: a compliance issue?, B. Smith
16.00	Workshop Conclusions
16.15	Coffee Break
16.30	Demos and Exibitions
19.30	Social Event, Bouillon Racine Restaurant

Démos and Exhibitions

16.30	5G — Connectivity as a service, Grégory AKPOLI-JOHNSON [Orange]
	5G — Visualizing the customer experience, Mohamad MAAZ [Orange]
	Green Multi-Technology Engineering platform and extensions, mm-MAGIC project, Anne-Marie Ulmer-Moll, Isabelle Siaud
to	[Orange], Angelos Goulianos, Evangelos Mellios [Univ. of Bristol]
	LTE TDD coexistence management (CXM) on FCC 3.5 GHz CBRS band, C. Le Thierry d'Ennequin, P.J. Muller [RED Technologies]
	EU FLEX-LSA project: multi-countries LSA experimentation on FLEX LTE testbeds, [RED Technologies, ALLBESMART]
18.00	Anticipatory video streaming for mobile networks, S. Valentin, S. Mekki [Huawei, Paris]

- Proposal on a Workshop to EuCNC 2017, Oulu, Finland on "**Prototyping 5th Generation Cellular Wireless Technology**"
  - A full day workshop is proposed in collaboration of
    - 5G CHAMPION (**5G C**ommunication with a **H**eterogeneous**, A**gile **M**obile network in the **PyeongChang** w**I**nter **O**lympic competio**N**)
    - Flex5Gware: (**Flex**ible and efficient hardware/software platforms for **5G** network elements and devices)
    - 5G-MiEdge (**Mi**llimeter-wave **Edge** cloud as an enabler for **5G** ecosystem)
    - MiWaveS (Beyond 2020 Heterogeneous Wireless Networks with **Mi**llimeter-**Wave S**mall Cell Access and Backhauling)

EUCNC 2017 June 12-15

European Conference on Networks and Communications | Oulu, Finland

5G: European Roadmap, Global Impact

Tekes 12 - 15 June 2017 www.eucnc.eu

IEEE ComSoc EURASIP

Workshop Proposal

This document contains a template for all the information relevant to each Workshop to be organised within EuCNC 2017. The rules for organising and attending Workshops, as well as the items for the evaluation of proposals, are available at the conference website, under "Authors / Call for Workshops" (http://www.eucnc.eu/?q=node/60). If the proposal is accepted, this text (the public information in it) will be used to advertise the Workshop in the conference website.

The proposal should be submitted by the deadline, 2017 Feb. 06, to eucnc-workshop@ee.oulu.fi. The name of the file should be the Workshop title (abbreviated, if necessary).

Proposer's Name	Dr. Markus Mueck (5G CHAMPION), Michael Faerber (Flex5Gware), Dr. Valerio Frascolla (5G-MiEdge), Sylvie Mayrargue (MiWaveS) *Note: Since this proposal is a collaboration among four Horizon-2020 projects, we choose to provide a proposer's name for each of the projects.*
Proposer's Institution	INTEL Germany, CEA-Leti France
Proposer's Email	Markus.Dominik.Mueck@intel.com, Michael.Faerber@intel.com, Valerio.Frascolla@intel.com, Sylvie.Mayrargue@cea.fr.
Proposer's Phone Number	Dr. Markus Mueck: +49 (0)89 99 8853-63149, Michael Faerber: +49 (0)89 99 8853- 26912, Dr. Valerio Frascolla: +49 (0)151 12278516, Sylvie Mayrargue: +33 4 38 78 62 42

Figure 13: Special Session Proposal to EuCNC 2017.

- Workshop submission to IEEE Globecom 2017 on "**5G Test-Beds & Trials – Learnings from implementing 5G (5G-Testbed)**", 4-December-2017, Singapore. This is a joint submission by 5G CHAMPION anf 5G Mi-Edge projects.

Call for Papers
International Workshop on
5G Test-Beds & Trials – Learnings from implementing 5G (5G-Testbed)
In conjunction with Globecom 2017, 4-8 December 2017, Singapore

Scope and Objectives:

Early stage 5G prototyping and proof-of-concept has been successfully completed. First generation 5G technology is now moving towards productization. Test-bed experiments and trials are further pursued for three reasons: first, final fine-tuning of first stage products is performed with a focus on specific technical challenges; second, equipment in a pre-production stage is tested in massive deployment scenarios through suitable trials; and third, innovation continues towards second generation 5G features and corresponding new ideas are implemented and tested. The objective of this Workshop is to address the above mentioned challenges. 5G Experts will be to meet and exchange findings, views and opinions on current test-beds, trials, early phase products and next generation 5G features and functionalities. The key objective is to exchange learnings encountered during practical tests in order to understand where the real challenges, weaknesses but also strengths of 5G lie and how they can be addressed in the future evolution of the technology.

We solicit original submissions in the following areas:

- 5G applications, use cases and business models
- 5G test-beds and trials
- Prototyping of 5G evolution features
- Implementation and operation of mmWave technology
- Implementation and operation of heterogeneous technologies and networks
- Implementation and operation of vertical services including vehicular, medical, Internet-of-Things and Machine-to-Machine applications
- Implementation and operation of spectrum sharing, including Licensed Shared Access (LSA) and Spectrum Access System (SAS)
- Low latency strategies and related implementations
- Energy efficiency vs. QoS vs cost-efficiency trade-offs
- Architectural evolution of mobile networks
- Virtualization across the entire 5G ecosystem including backhaul and access network as well as user devices
- Network Function Virtualization (NFV) and related test-beds
- Mobile Edge Computing (MEC) and related test-beds
- Software Reconfiguration of radio features
- Lessons learned from 5G test-beds and trials, including required standards changes, gaps to be filled, etc.
- Regulation framework and required evolution

Important Dates:

Paper Submission: July 1, 2017
Acceptance Notification: September 1, 2017
Camera-Ready: October 1, 2017
Workshop: December 4, 2017

Submission Guidelines:

Papers need to be submitted using EDAS. The paper should be in English, not exceeding 5 two-column A4 pages, and should follow standard IEEE conference templates available here (*). Accepted papers will be published in IEEE Xplore. They will be presented either orally or by means of a poster.

Organising Committee:

General Chairs
Markus Mueck (INTEL Germany)
Taesang Choi (ETRI, Korea)
Emilio Calvanese Strinati (CEA LETI, France)

TPC co-chairs
Antonio Clemente (CEA, France)
Kei Sakaguchi (Fraunhofer HHI, Germany)

Publicity chair
Zdenek Becvar (Czech Technical University, Czech Republic)
Eryk Dutkiewicz (University of Technology, Australia)
Thomas Haustein (Fraunhofer HHI, Germany)

Technical Programme Committee:

DUTKIEWICZ, Eryk (UTS, Australia)
JAYAWICKRAMA, Beethanga Abeywardana (UTS, Australia)
HEIMLICH, Michael (Macquarie University, Australia)
SIAUD, Isabelle (b<>com, France)
FILIPPOU, Miltiadis (INTEL, Germany)
ROTH, Kilian (INTEL, Germany)
SCHULZ, Egon (Huawei, Germany)
SRIKANTESWARA, Srikathyayani (INTEL, US)
DEBBAH, Merouane (Huawei, France)
DEMESTICHAS, Panagiotis (University of Piraeus, Greece)
KIM, TaeYeon (ETRI, Korea)
LEE, HyeonWoo (Dankook University, Korea)
MAJEED, Erfan (Institut fuer Kommunikationstechnik, Germany)
YOUSSEF, Ziad (Institut fuer Kommunikationstechnik, Germany)
CHOE, Seungwon (Hanyang University, Korea)
FREDA, Martino (Interdigital, Canada)
BARBAROSSA, Sergio (Sapienza University of Rome, Italy)
TRAN, Khanh (Tokyo Tech, Japan)
DE DOMENICO, Antonio (CEA-LETI, France)
RAULEFS, Ronald (DLR, Germany)
DE MARI, Matthieu (University of Technology, Singapore)
PESCOSOLIDO, Loreto (National Research Council, Italy)
DENIS, Benoit (CEA LETI, France)

(*) http://www.ieee.org/conferences_events/conferences/publishing/templates.html

Figure 14: Workshop Proposal to IEEE Globecom 2017, 4-8 December, Singapore.

6.9 Workshops

5G CHAMPION partners have organized the **2017** IEEE 85th **Vehicular Technology Conference**: **VTC2017-Spring** (4–7 June **2017)** Industry Track on "*5G and Wireless*" with the following list of speakers:

- Adrian Scrase (ETSI, France)

- David Soldani (NOKIA, Germany)
- Takehiro Nakamura (NTT DoCoMo)
- Emilio Calvanese Strinati (CEA, France)
- Kyungwhoon Cheun (SAMSUNG)
- Huyn Kyu Chung (ETRI, Korea)
- David Cooper (ERICSSON, Australia)
- Ray Owen (NOKIA, Australia)
- Brian Hutson (Juniper Networks, Australia)
- Jeff Owen (Vodafone, Australia)
- Karl Nieman, National Instruments

- 5G CHAMPION talk by Dr. Emilio Calvanese Strinato (CEA, France):
  - Title: "**5G CHAMPION: 28 GHz 5G Proof-of-Concepts at 2018 Winter Olympic games**"

- Abstract: 5G -Next Generation Communication Networks - will be a global game changer from a technological, economic, societal and environmental perspective. The 5G CHAMPION develops, prototype and trials key enabling technologies for a proof-of-concept environment to be showcased at the 2018 Winter Olympics in PyeongChang, Korea. This will allow maximum visibility for the available technology two years ahead of 2020, i.e. the official launch of 5G. Key enabling technologies included in the 5G PoC include i) a complex 5G set-up operating inside and close to the PyeongChang Olympic venue, addressing indoor and outdoor propagation channels in mmWave & below 6GHz spectrum; ii) high-speed broadband connection via mmWave high capacity backhaul in 24-28 GHz, using novel antenna arrays for wireless back/front-hauling, enabling the provision of >2Gbps; iii) advanced evolved packet core solutions for efficient system management with virtualization through NFV/SDN in a secure backhaul architecture as well as a novel SDN-based IPsec tunnel architecture; iv) novel accurate positioning solutions (<1m accuracy) using mmWave combined with GNSS PPP; v) direct UL/DL communication between satellites and 5G User Equipment 'as is' – a corresponding first ever proof-of-concept will set-up; vi) better mobility support through a novel small cell architecture & hybrid adaptive beamforming. The overarching objective is to achieve a highly energy efficient system approach – which is a key requirement and challenge for 5G. Key novel 5G building blocks are under development and implementation into a new architectural approach providing an efficient end-to-end system performance encompassing cutting edge 5G radio-access, core-network and satellite technologies. 5G CHAMPION targets to validate in the PoC the following KPIs: 1) 20 Gbit/s maximum data-rate over a mmWave link, 2) 2.5 Gbit/s over a wireless mmWave backhaul link, 3) 100 Mbit/s of user-experience in moving hot-spots, 4) seamless access to satellite communications for 5G devices, 5) 1-2 ms latency over the 5G wireless backhaul link, 6) agile management of the core network functionality and services, 7) ubiquitous (indoor-outdoor) location accuracy < 1 m.

- 5G CHAMPION talk by Dr. Huyn Kyu Chung, ETRI, Korea
  - Title: "**Mobile Xhaul Network for 5G RAN evolution**"
  - Abstract: For 5G mobile communication services, it is expected that small cells will be more densely deployed and moving network could be a key feature to accommodate various 5G service requirements. Based on these technical trends, it is necessary to study technical solutions to support network mobility and to provide wireless connectivity to functional entities within radio access network (RAN) with scalable and flexible manner. In this talk, the Mobile Xhaul Network (MXN) will be introduced which is the ongoing research project as a way to provide wireless transport connectivity to 5G RAN including moving cell via Xhaul link consisting with front-haul, mid-haul and backhaul. Currently, the MXN project is focusing on network architecture and essential radio transmission technologies such as MIMO and beamforming with millimeter wave on 28GHz frequency band. In this talk, as a preliminary study of MXN, a wireless backhaul solution for moving network, called Mobile Hotspot Network (MHN) will be introduced, which is one of candidate technologies for mobile backhaul commercial solutions in the metro environment in Seoul, Korea.

- 5G CHAMPION talk by Dr. Markus Mueck:
  - Title: "**Enabling IoT for a multitude of vertical applications**"
  - Abstract: The market of IoT devices is expected to be vast – including diverse target applications related to metering, medical, sports, gaming, etc. It is obvious that a large number of different modem chipset features will be required addressing various application domains, form factors and user interfaces. This environment is a serious challenge for Chipset manufacturers since it will be impossible to serve each target use case with a tailored solution. Rather, a small number of generic components need to be designed which are finally reconfigured to optimally fit their market needs. This reconfiguration will rely in particular of software component provision – affecting radio parameters as will as higher layer functionalities. This talk will explain how a recent change in European Regulation (the introduction of the Radio Equipment Directive) and related ETSI standards will address precisely this problem and provide an agreed technical approach to the problem.

7 5G CHAMPION Website

A 5G CHAMPION project website has been implemented at the following registered address: www.5g-champion.eu/. The objective of this website is to provide an international visibility on the project scope, consortium, scientific activities and contributions, and public results.

7.1 Website structure

The web site contains the following facilities:

- The website home page (Figure 15) with the project loge, name, objectives, consortium, and an overview technical key contributions,
- A menu bar with folding list giving direct access to all the others pages,
- Several static pages regularly updated by the Administrators (CEA): news, project, consortium, advisory board, results, links, and contact.

To help understand the usage of the website, the website was registered with the free Google Analytics facility. This will allow rich reports to be run on the website, giving a very clear picture of information such as:

- How many users are visiting the site,
- Where are visitors coming from geographically?

The 5G CHAMPION project website is hosted by the project coordinator, CEA, and is under its responsibility. The website will remain functional and updated at last one year after the end of the project. The project coordination team edits the site content and collects the necessary materials.

Figure 15: 5G CHAMPION website home page.

7.2 Project

The menu Project contains two different pages: project overview (Figure 16) and project structure. The first page presents briefly the project and the 5G CHAMPION system concept implementation. Instead, the page project structure presents in details the seven project work packages.

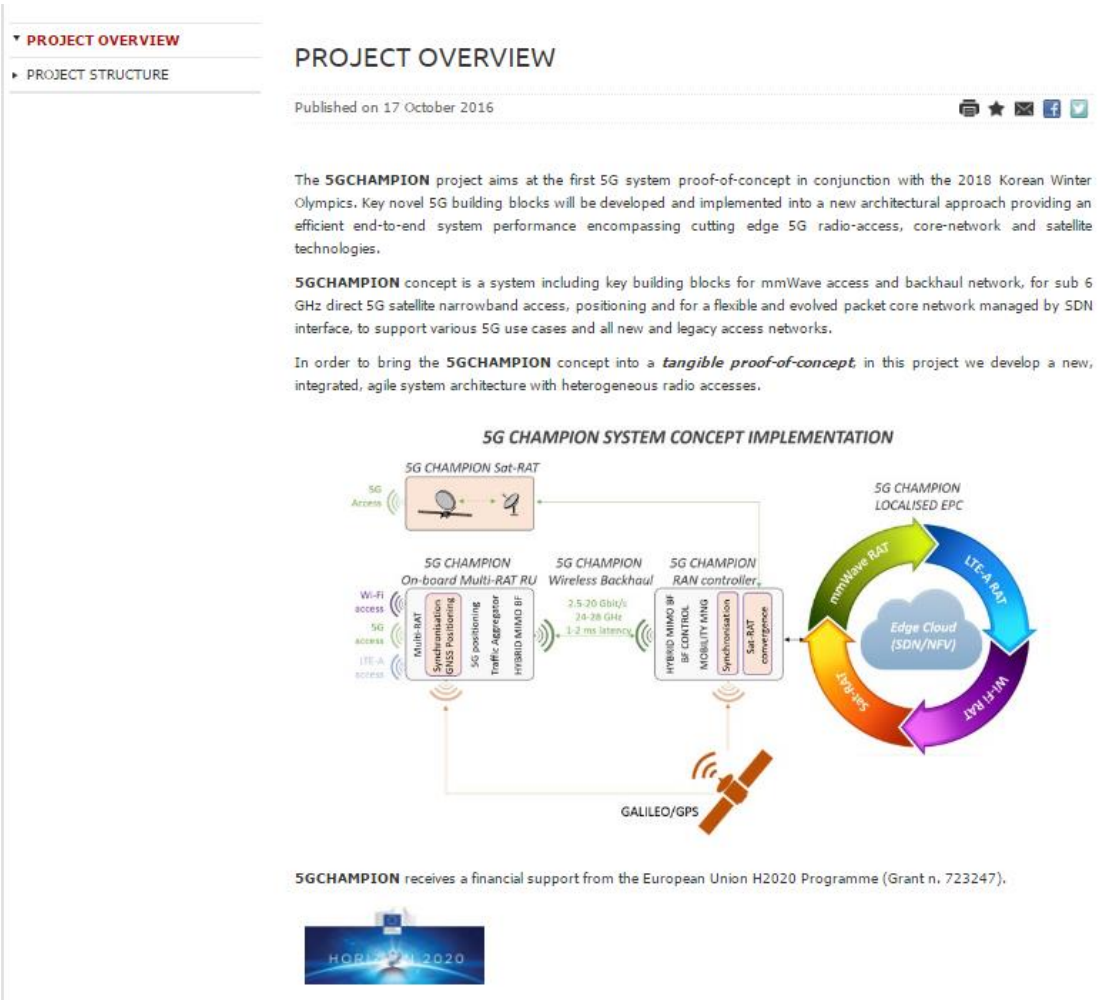


Figure 16: 5G CHAMPION website project structure page.

7.3 Results

The menu results (Figure 17) contains several web page resuming all the results of the 5G CHAMPION project: presentations, deliverables, publications, workshops, keynotes and invited talks, and demos.

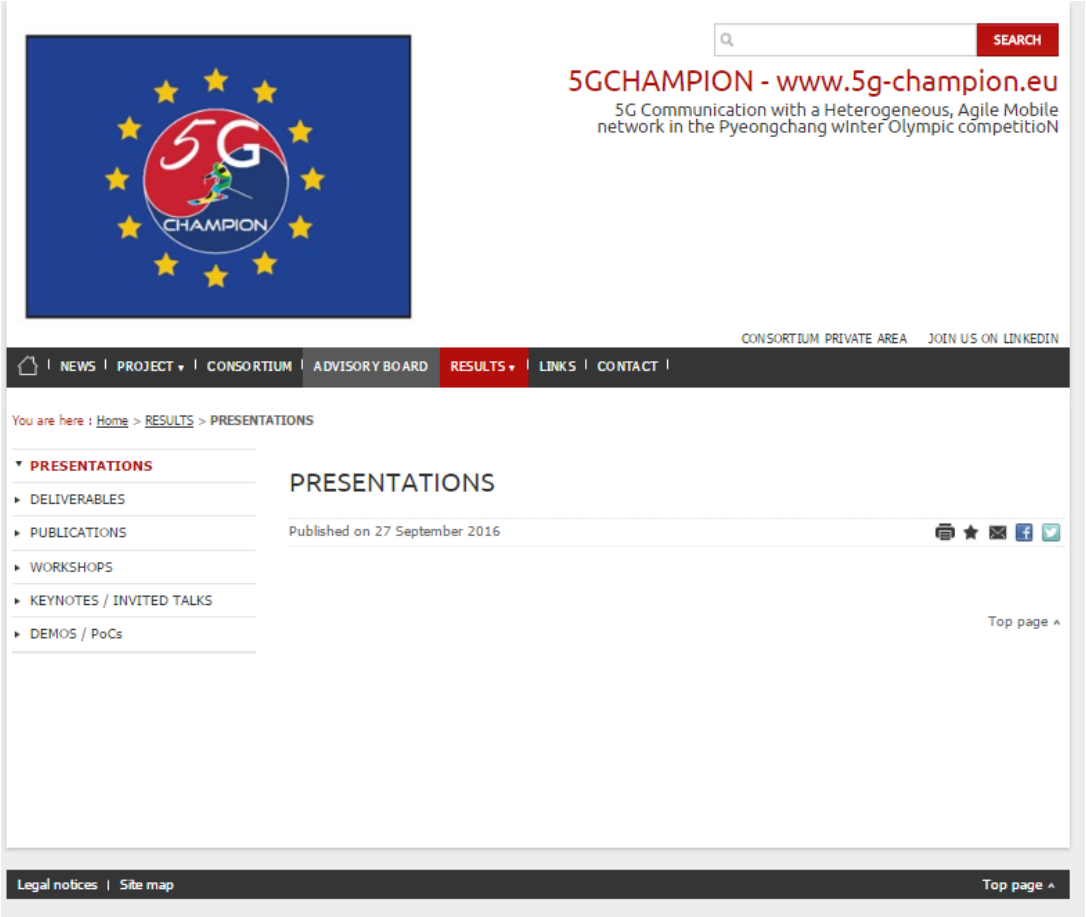


Figure 17: 5G CHAMPION website results page.

7.4 Links

This page lists links to other web sites of the related collaborative projects. These links will be checked periodically by the webmaster and updated if necessary.

7.5 Contacts

The page contacts (***Figure*** 18) provides the contact information to the project coordinator and management team with workpackage leaders.

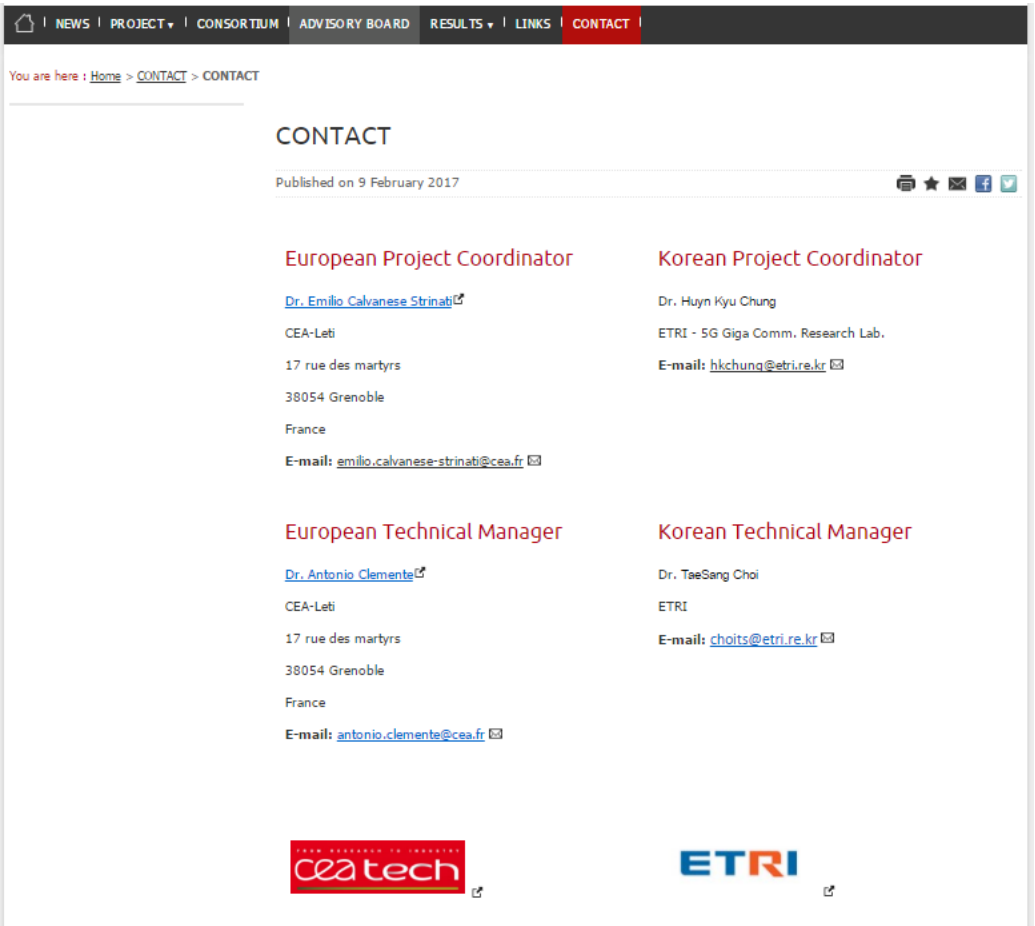


Figure 18: 5G CHAMPION website contacts page.

8 Collaboration with other research projects

5G CHAMPION has already started to prepare the background for collaboration with other projects in order to extend 5G CHAMPION consortium collaboration to other European Commission projects in H2020. More precisely 5G CHAMPION has organized jointly with MiEdge project two major events in 2016 and 2017:

- '10th International Workshop on Evolutional Technologies & Ecosystems for 5G and Beyond (WDN-5G ICC2017)' that will be held in Mai 2017 at IEEE ICC conference, Paris (http://icc2017.ieee-icc.org/); (ii) The special session at 5G Berlin Summit 2016 on 'Joint 5G Projects and Trials' (http://www.5gsummit.org/berlin/).
- 5G CHAMPION has planned on 10-11/10/2016 a joint workshop (http://zzzdana.wixsite.com/ict-techday) in Seoul with WiseIoT and Basamati EU-KR projects.

5G CHAMPION has already started discussing with mmMagic 5G PPP phase 1 project on network prototyping. A joint participation to the IP9 industrial panel held at IEEE Globecom 2016 with title "5G Networks Prototyping: Entering the Next Phase of Experimentation for Future Radio Access Technologies" on 7th of December 2016.

Furthermore in order to maximize the European momentum towards, and benefits from, the future 5G integrated, ubiquitous and ultra-high capacity networks, 5G CHAMPION is paving the way for collaborating with ongoing 5G PPP phase 1 projects and with the 5G-Infrastructure Association and the NetWorld2020 European Technology Platform.

5G CHAMPION foreseen active collaboration and exchanges with 5G PPP phase 2 project in the wireless strand.

Furthermore, 5G CHAMPION has already started discussing with GK-5G project (Project Name: 5G mobile communication system development based on mmWave) and QK-5G project (Project Name: Development of 5G Mobile Communication Technologies for Hyper-connected smart services) in Korea. Technical discussions for the related issues and joint contributions for the IEEE and 3GPP standardizations have been done.

9 Cross Korean / European Collaboration Benefits

5G is a ***global*** revolution and it requires cross-national validation and **cross-continental** interoperability and economical sustainability validation. Regulation on 5G spectrum is already globally discussed and indication on potential '*5G new bands'* has been indicated by the WRC'15 [10]. Final decision is expected by 2019 during the WRC'19. WRC'19 decision will be based on several parameters: political, economic and technical. Therefore 5G ecosystem cannot wait 2020 for a full scale validation of 5G technology and related services.

Industry, SMEs, Operators and academia from two of most active areas of the world on 5G revolutions - Korea and Europe - decided to federate in order to anticipate the validation of **potentials of on 5G** key enabling technologies **in 2018**, delivering a joint an unprecedented proof-of-concept show cased at the **2018 Winter Olympics** in PyeongChang, Korea.

5G CHAMPION started in July 2016, few months ago, but already bilateral benefits of Korean-European collaboration are clear for 5G CHAMPION partners, Korean and European ecosystems. In a global scale, the worldwide 5G community already benefits from active 5G CHAMPION dissemination activities.

At this stage of the project, we experience the benefit of **jointly validating potentials of on 5G** key enabling technologies 5G CHAMPION. Benefits are for:

- **Korean and European Consortium members** which can drive the development of a holistic and global fully integrated 5G system definition and solutions. This creates momentum for strengthening the cooperation between Europe and Korea for ***future research projects*** not only at the consortium scale but also between Korean and European future collaborations frameworks under discussion. Today, 5G partners experience that joining forces in such unique collaborative ecosystem give them an edge in the attempt to get ahead of the game in developing ultra-fast 5G wireless communications networks and preparing global standardization for it.
  Industry, service providers and operators which will enable practical feedback to improve reliability and performance of the newly developed products and related services from both Europe and Korean market players. Moreover, working together towards global standards for 5G, in support of ongoing standardization in relevant fora, such as 3GPP and ITU and indeed developing common interest in research activities and products ensuring global 5G interoperability. Specifically from satellite perspective and related service provisioning, Cooperation between Korea and Europe will spread the usage of Galileo in Asia with win-win benefits.
- **5G Global Community** which benefits from a very vivid and active dissemination activity from 5G CHAMPION. Moreover, 5G CHAMPION has already started producing common interest and forge a consensus on key 5G functionalities that can be proved in 2018. Europe, Korea and in a global scale many other countries in the world have demonstrated strong interest on 5G CHAMPION activities. For instance 5G CHAMPION has already today, few months after its start, a large community that follows actively 5G CHAMPION news and achievement. Today the 5G CHAMPION LinkedIn group accounts for about 350 members.

10 Exhibitions

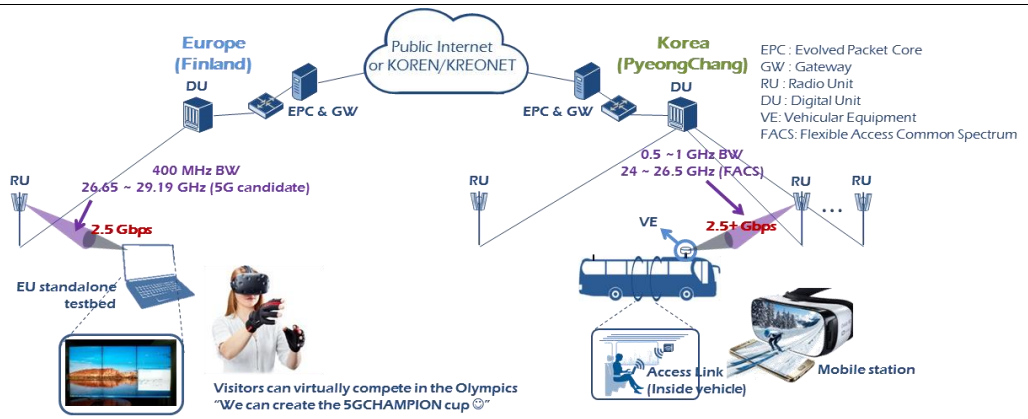
The key target exhibition event for the 5G CHAMPION project is the 2018 Winter Olympics in PyeongChang, Korea. This event in combination with the European/Korean partnership is expected to maximize the visibility of 5G CHAMPION results and hardware/software solutions. The highest level of attention is ensured by the scientific community and the public audience which will be introduced to benefits and advantages of 5G technology.

For this purpose, a communication flyer was developed as indicated below.

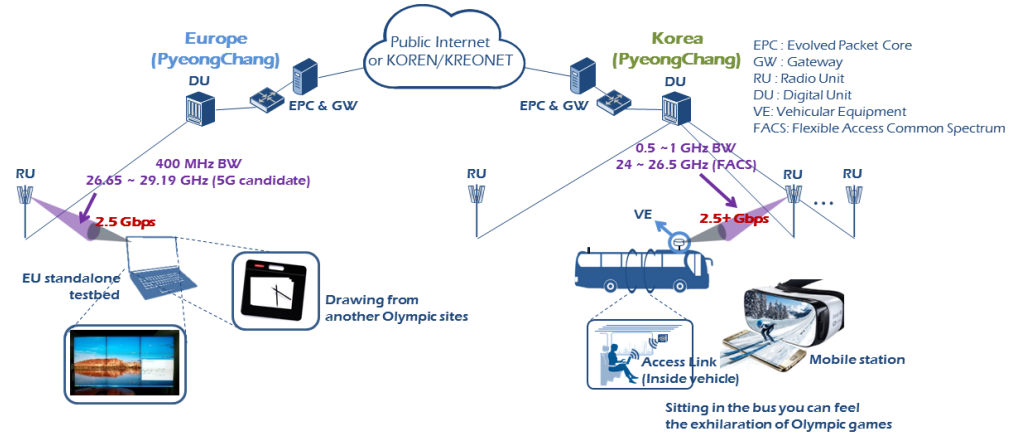
5G CHAMPION PyeongChang Olympic Venue Demonstration Proposal

Objective
Providing various high-speed/high-quality Internet multi-media 5G services for visitors to PyeongChang through the achievements of the Korea-Europe joint research project (5G CHAMPION) deployed in the Olympic venue will contribute to, - Success in the ICT Olympic that is the Korean government's goal - Promotion of joint research and development results through a interworking service based on the 5G access and high-speed core networks - Escalation of National brand value through promotion of 5G-based ICT technologies

PoC Scenario	※Need to check with the Olympic organizing committee to see if both scenarios are possible (including mmWave backhaul frequency)
(Scenario 1) Provide demonstrations of various service scenarios through interworking between Europe and Korea PoC testbeds deployed in the PyeongChang Olympic Venue and EU counterpart (Finland)	



(Scenario 2) Provide demonstrations of various service scenarios as well as an interworking service between Europe and Korea using the Korean and European PoC testbeds both deployed in the PyeongChang Olympic Venue



Contents of Service Demonstration

(Technology demonstration) A millimeter-wave mobile wireless backhaul technology supporting data rate of 2.5 Gbps and A SDN/NFV-based mobile core technology

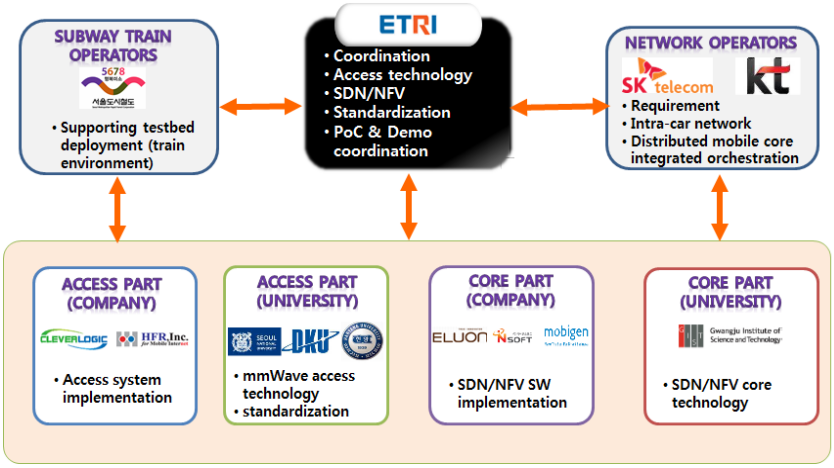
(Service demonstration for scenario 1) Demonstrations of virtual reality, holograms and high-definition video from Korea to Europe through the stationary EU testbed and Korean moving testbed (in bus)

(Service demonstration for scenario 2) Demontrations of drawing board and virtual gaming services using the stationary EU testbed and a virtual reality service using the Korean moving testbed (in bus)

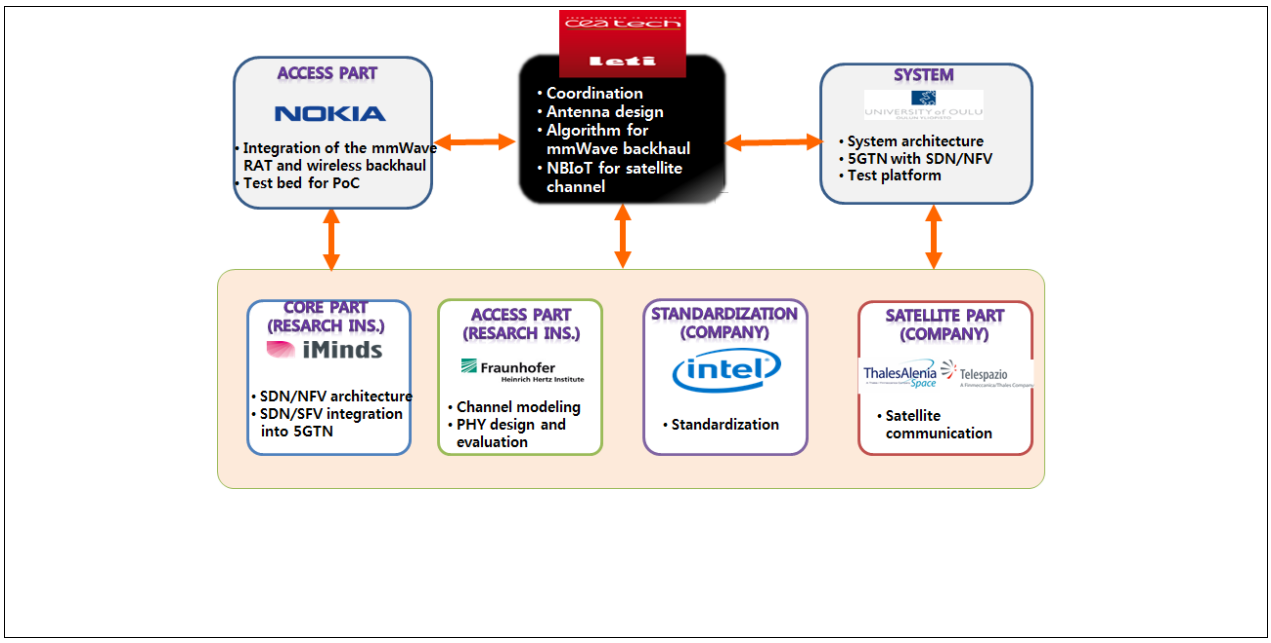
(Service demonstration target) Tourists and officials of the PyeongChang Winter Olympics Games

Participants and Roles

(Korean participants) ETRI, KT, SKT, SMRT, Cleverlogic, HFR, Eluon, InSoft, Mobigen, Seoul National University, Dankook University, Hanyang University, GIST



(European participants) CEA-LETI(France), Nokia(Finland), iMinds(Belgium), Fraunhofer(Germany), Intel(Germany), ThalesAlenia(France), Telespazio(France), UOULU(Finland)



Beyond the 2018 Winter Olympics in PyeongChang, Korea, the project evaluates contributions to further key events, such as

- Mobile World Congress, Barcelona, Spain, 2017/18;
- Mobile World Congress, Shanghai, China, 2017/18;
- Consumer Electronics Show (CES), 2017/18;
- ITS World Congress, rotating between Europe, the Asia Pacific region and the Americas, returning to Europe every three years:

Year	World congress	European congress
2017	ITS World Congress, Montréal, Canada, 29 October – 2 November	ITS European Congress, Strasbourg, France, 19-22 June
2018	ITS World Congress, Copenhagen, Denmark, 17-21 September	No congress

- Smart cities related exhibitions
    - Regarding the smart cities, there are many European cities working on the technologies that will enable smarter cities. However, most of them are concentrated on their own problems and only a few of them organize more global events where stakeholders from several countries are invited. Among these can be found: Smart city expo which takes place every year in Barcelona; Smart countries & cities congress in Paris; Future of cities forum in Ljubljana;
    - Other local events have as well visibility because the cities in which they take place have decided to support the smart city development: Copenhagen; Amsterdam; Vienna; Ljubljana; Barcelona;
- IoT related congresses, including topics on the smart cities and intelligent transport systems.

11 Interaction with press and media

On the 28.08.2016, the UOULU team was invited by the MBC Korean TV to present the 5GCHAMPION project and cooperation with Korean partners. In this context, the consortium was able to provide thought leadership to a large public community, to educate and prepare a public audience for future 5G technology and to illustrate the benefits of a cross-regional collaboration between Europe and Korea.

The broadcasting event will be scheduled in the near future.

12 Corrective Actions

The 5G CHAMPION consortium has been highly productive and successful in terms of standardization, regulation and dissemination activities in the first 9 months. It is planned to further build on this momentum and to drive activities further. No corrective actions are planned.

13 Conclusion

The present document is a sound basis for the 5G CHAMPION consortium. It documents the progress achieved so far and introduces a clear strategy on how to address the exploitation and dissemination of project results. The consortium will continue in this direction and in particular focus on

- Drive the 5G technology development forward and show thought leadership in the scientific, industrial and media community,
- Influence key standards and regulation bodies in order to contribute the suitability of future product standards and the related regulation framework,
- Exploit key events to showcase the 5G CHAMPION consortium results, in particular proof-of-concept equipment and to thus maximize the project visibility and overall impact.

The strategy and plan outlined throughout this document in combination with the efficient cross-region collaboration between Europe and Korea is expected to manifest in the highest level of visibility and impact of the project results and outcomes – first results obtained after the first 9 months are encouraging and validate the strategy taken by the 5G CHAMPION consortium.

14 References

[1] D. Flore, "RAN workshop on 5G: Chairman summary," RWS-150073, Sep. 2015. [Online]. Available: ftp://ftp.3gpp.org/workshop/2015-09-17_18_RAN_5G/Docs/RWS-150073.zip.

[2] 3GPP TR 38.913, "Study on Scenarios and Requirements for Next Generation Access Technologies," 2016.

[3] 3GPP TR 38.802, "Study on New Radio (NR) Access Technology Physical Layer Aspects," 2016.

[4] http://www.ieee802.org/15/

[5] Junhyeong Kim et al., "Mobile Wireless Backhaul for Fast Moving Cells", IEEE 802.15-14-0671-00-wng0, Nov. 2014

[6] Ke Guan et al., "Mobile Channel Characterization in Typical Subway Tunnels at 30 GHz", IEEE 802.15-15-0666-02-hrrc, Sep. 2015

[7] Ke Guan et al., "Ray-tracing based Study on Mobile Channel in Typical Urban Environment with Various Beamforming Strategies at 32 GHz", IEEE 802.15-15-0837-01-hrrc, Nov. 2015

[8] Sung-Woo Choi et al., "Performance Evaluation of Millimeter-wave-based Communication System in Subway Tunnels", IEEE 802.15-16-0185-01-hrrc, Mar. 2016

[9] https://mentor.ieee.org/802.15/documents

[10] World Radio Conference 2015, see http://www.itu.int/en/ITU-R/conferences/wrc/2015/Pages/default.aspx

[11] World Radio Conference 2019, see http://www.itu.int/en/ITU-R/conferences/wrc/2019/Pages/default.aspx