WORTECS

H2020-ICT-2016-2

RIA

Project-ID: 761329

WORTECS

Networking research beyond 5G

WP5 - D5.7 Dissemination: Update - Year 3

Contractual Date of Delivery:	**2020, October 31st**
Actual Date of Delivery:	**2020, November 2nd**
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Work package:	**WP5 – D5.*7***
Security:	**PU**
Nature:	**Deliverable**
Version:	**Version 1.0**
Total number of pages:	**14**

Abstract

This report outlines the WP5 deliverable D5.7 and original tasks within this deliverable. A progress update on the tasks is detailed based on the periodical physical meetings. The contributions from the current period are detailed and a final summary of the whole project is presented.

Keyword list

Virtual Reality, High Quality / Low Latency, Wireless, OWC, radio transmission, Mac layer, HW implementation

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Document History

First name	Last name	Version	Comments
Víctor	Guerra	17th Aug 2020	First version.
Ravinder	Singh	25th September 2020	Edited UOXF contributions from Year 3
Víctor	Guerra	25th September 2020	Included dissemination activities.
Víctor	Guerra	27th October 2020	Formatting and review
Dominic	O'Brien	31st October 2020	Review

List of Acronyms

Acronym	Meaning
BB	Base Band
DFE	Digital Front End
HMD	Head Mounted Display
OWC	Optical Wireless Communication
RF	Radio Frequency
VR	Virtual Reality
WORTECS	Wireless Optical/Radio TErabit CommunicationS
LiFi	Light Fidelity
FWF	Fiber Wireless Fiber

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I. Contributions in 2017-18 period (Year 1)

Dissemination in Period 1 from the project was as shown in the table below. More details can be found in D5.1.

Title	Authors	conference/ magazine/ journal	Related WP
Terabit per Second Optical Wireless Links for Virtual Reality Technology	Olivier Bouchet, Marc Lanoiselée, Dominic O'Brien, Ravinder Singh, Mir Ghoraishi, Rafael Perez , Víctor Guerra, Suat Topsu, and Jorge Garcia-Marquez	SPIE Optics and Photonics Conference 2018	WP3/ WP4
Spatial Interpolation of Optical Wireless Impulse Responses	Victor Guerra, Julio Rufo, Jose Rabadan, and Rafael Perez-Jimenez	CSNDSP Conference 2018	WP3/ WP4
Wideband 240 GHz Transmitter and Receiver in BiCMOS Technology with 25 Gbit/s Data Rate	M. H. Eissa, A. Malignaggi, R.Wang, M. Elkhouly, K. Schmalz, A. C. Ulusoy and D. Kissinger	Journal of solid state circuits (JSSC)	WP3/ WP4
Noise Performance of Orthogonal RF Beamforming for Millimetre Wave Massive MIMO Communication Systems	Krishna Tiwari, John Thompson and Eckhard Grass	WCSP Conference 2018	WP3/ WP4

Table 1 – Contributions in 2017-2018 period (Year 1)

II. Contributions in 2018-19 period (Year 2)

A detailed description of contributions in Year 2 were reported in D5.5. Here we summarise the dissemination activities from all the partners during the 2018-2019 period.

Contributions to congresses by partner

Partner	Title	Authors	Congress	Related to
ULP	Suitability of Optical Wireless Communication receivers for Virtual Reality Applications	Victor Guerra, Jose Rabadan and Rafael Perez-Jimenes	ConTEL 2019. Graz, Austria	WP3
ORA	European H2020 Project WORTECS Wireless Mixed Reality Prototyping	Olivier Bouchet, Dominic O'Brien, Ravinder Singh, Grahame Faulkner, Mir Ghoraishi, Jorge Garcia-Marquez, Guillaume Vercasson, Marcin Brzozowski and Vladica Sark	ICISPC 2019. Singapore, Singapore.	WP5
	WORTECS Proof of Concept presentation	Olivier Bouchet	Second Towards TeraHertz Communications Workshop, Brusssels, Belgium (as part of the Beyond 5G cluster activities)	WP5
IHP	Wireless Communication Systems in the 240 GHz Band: Applications, Feasibility, and Challenges in the WORTECS Project	Nebojsa Maletic, Vladica Sark, Mohamed Eissa, Jesus Gutierrez, Eckhard Grass, Olivier Bouchet	ISWCS 2019. Oulu, Finland. Invited paper	WP3/4
	A 13.5dBm Fully Integrated 200-to-255GHz Power Amplifier with a 4-Way Power Combiner in SiGe:C BiCMOS	M.H. Eissa and D. Kissinger	ISSCC 2019, San Francisco, California, United States	
	Achieving Millimeter Precision Distance Estimation using Two-Way Ranging in the 60 GHz Band	Vladica Sark, Nebojsa Maletic, Marcus Ehrig, Jesus Gutierrez and Eckhard Grass	EuCNC 2019. Valencia, Spain (Demonstration in booth as part of the Beyond 5G cluster activities)	
	Monopulse-based THz Beam Tracking for Indoor Virtual Reality Applications	Krishan Kumar Tiwari, Vladica Sark, Eckhard Grass and Rolf Kraemer	Proc. 24. ITG Fachtagung Mobilkommunikation - Technologien und Anwendungen (2019), Osnabrueck, Germany	

	Noise Performance of Orthogonal RF Beamforming for THz Radio Communications	Krishan Tiwari, Eckhard Grass, Rolf Kraemer	CCWC 2019. Nevada, USA	
	Experimental Evaluation of Round-Trip ToF-based Localization in the 60 GHz Band	Nebojsa Maletic, Vladica Sark, Marcus Ehrig, Jesús Gutiérrez and Eckhard Grass	IPIN 2019, Pisa, Italy	
	Beam Entropy of 5G Cellular Millimetre Wave Channels	Krishan K. Tiwari, Eckhard Grass, John S. Thompson and Rolf Kraemer	VTC 2019 Fall, Honolulu, USA	
PLF	The next generation of wireless internet	Dr. Harald Burchardt	Wired Score Launch Event, Birmingham, UK	Whole Project
	A LiFi World: A New Digital World Powered By Billions Of Connections Through Light	Dr. Harald Burchardt	Internet & Mobile World, Bucharest	
	LiFi: How, What, Why	Dr. Mostafa Afgani	pureLiFi hosted Webinar	
	A Light Connected World	Prof. Harald Haas	Institute of Physis LiFi Launch Event	

Table 2 – Contributions to congresses during Year 2

Patents by partner

Partner	Title	Authors	Patent	Related to
IHP	Memory-Assisted Radio Frequency Beam Training for MIMO Channels	K.K. Tiwari	submitted EP 19 170 298.4	WP3/4
PLF	Wireless Communication System and Method	Stephan Berner, Mir Ghoraishi	Filed 03/09/2018 GB1814254.7	WP3/4
	Signal retransmission System and Method	Stephan Berner, Mostafa Afgani, Nikola Serafimovski	Filed 11/10/2018 GB1816598.5	WP3/4
	Wireless Communication System and Method	Stephan Berner	Granted 18/06/2019 US10327050	WP3/4
	Divisional based on US10327050	Stephan Berner	Filed 17/06/2019 Now Granted US	WP3/4

Table 3 – Patents submitted during Year 2

Theses by partner

Partner	Title	Authors	University	Related to
IHP	Fully Integrated 240 GHz Transmitter and Receiver for High Data Rate Communication	M. Eissa	TU Berlin, Germany	WP3/4

Table 4 – Theses supervised during Year 2

III. Contributions in 2019-2020 period (Year 3)

In this section, activities within the cluster, invited and conference presentations, open event 2 and other contributions during year 3 of the project are detailed.

Open Event-1 Organization and Report

D5.1 describes open event 1 in detail, and a brief summary is provided here. A workshop was organized as part of the European Microwave Week 2019(EuMW), on Sunday 29th of September. EuMW was chosen as it is a large event (4000 key attendees and 1,500-1,700 conference delegates according to the website). Four talks were given, as below.

1. Speaker's Name: Olivier Bouchet

Affiliation: Orange Labs, France

Presentation Title: Nanometric band, the new wireless Eldorado

2. Speaker's Name: Dr. Marcin Brzozowski

Affiliation: IHP, Frankfurt (Oder), Germany

Presentation Title: Facing the Challenges in Aggregation of Terabit Wireless Links

3. Speaker's Name: Prof Cyril Renaud

Affiliation: Professor of Photonics, University College London

Presentation Title: Photonically enabled THz wireless communication

4. Speaker's Name: Dr. Vladica Sark

Affiliation: IHP, Frankfurt (Oder), Germany

Presentation Title: Next generation terabit wireless communications in the 200 GHz band

Open Event-2 Organization

Open Event 2 is described in detail in D5.4. Nevertheless, a brief summary is presented in this deliverable since it is a dissemination and communication activity of WORTECS results. The peak audience during the event was 131 viewers with an average view time of 57 minutes. In addition, Vimeo statistics up to 26th October 2020 showed 219 views of the video and 315 downloads.

The demand for wireless communications is growing exponentially, leading to a 'spectrum crunch'. The optical and THz regions of the spectrum can provide orders of magnitude more capacity than is currently available, for applications such as virtual reality and wireless data centres.

In this event we will showcase technologies from the WORTECS project and other projects in the H2020 Beyond 5G cluster. This will include demonstrations, posters, and presentations. Attendees will see online presentations and demonstrations of showcasing the latest advances and interact with other experts in the field.

Program:

- Morning
  - 10H30: Vision on Network Evolution towards 2025, M. Eric Hardouin - Orange
  - 10H45: WORTECS presentation and Proof of Concepts, M. Olivier Bouchet _Orange
  - 11H00: 100Gbps at 240GHz, Dr.-Ing. Vladica Sark_IHP
  - 11H20: Video conversion and compression for Virtual Reality, M. Guillaume Vercasson_B<>COM
  - 11H40: Heterogeneous Network, Dr.-Ing. Marcin Brzozowski_IHP
  - 12H00: Pause
- Afternoon
  - 14H30: WORTECS Software Tool (SaaS), Dr. Victor Guerra_University of Las Palmas
  - 14H50: Hybrid Gbps 60GHz/OWC link, Rodolphe Legouable_Orange
  - 15H10: Fiber Wireless (FiWi), Prof. Dominic O'Brien or M. Ravinder Sing_University of Oxford
  - 15H30: Optical Wireless Communication (OWC), M. Bastien Bechadergue_Oledcomm
  - 15H50: OWC ecosystem in the World (standards, projects) - Prof. Dominic O'Brien ?
  - 16H10: Close

Demonstrations:

N	Title	N	
1	100Gbps at 240GHz (IHP)	**5**	Video conversion and VR (BCM/ORA)
2	WORTECS Software Tool (ULP)	**6**	Fiber Wireless Fiber (FWF) (OXF/BCOM)
3	Optical Wireless Communication (OLD/PLF/BCM)	**7**	Hybrid Gbps 60GHz/OWC link (Rodolphe-BCM/ORA)
4	Fast Heterogeneous Network management (IHP)		

Project Website: https://wortecs.eurestools.eu/ **Event Website:**

Contributions to congresses by partner

Contributions summary-contributions to conferences, journals, theses and patents by partner. Tables 8, 9, 10, and 11 illustrate the contributions to journals, congresses, patents and theses during Year 3.

Partner	Title	Authors	Congress	Related to
ORA	Nanometric band - The new wireless Eldorado	Olivier Bouchet	EuMW – Paris - France	WP5
OXF	Beyond Terabit/s WDM Optical Wireless Transmission using Wavelength-Transparent Beam Tracking and Steering	Yang Hong, Feng Feng, Kyle RH Bottrill, Natsupa Taengnoi, Ravinder Singh, Grahame Faulkner, Periklis Petropoulos and Dominic O'Brien	OSA Conference on Optical Fiber Communication (OFC), March, 2020	WP4
	Fiber-Wireless-Fiber Terminals for Optical Wireless Communication over Multiple Bands", accepted at	Ravinder Singh, Andy Schreier, Grahame Faulkner and Dominic O'Brien	IEEE Photonics Conference, Sep 2020	WP4
ULP	WORTECS: enabling untethered Virtual Reality through Optical Wireless Communication	Victor Guerra, Jose Rabadan, Rafael Perez-Jimenez, Marcin Brzozowski, Vladica Sark, Ravinder Singh, Grahame Faulkner, Dominic O'Brien, Guillaume Vercasson, Tamas Weszely, Bastien Béchadergue, Olivier Bouchet	2020 South American Colloquium on Visible Light Communications (SACVC)	WP3/4
	Analysis of Illumination-Fiber-to-Wireless Links	Victor Guerra, Carlos Guerra, Jose Rabadan, Rafael Perez-Jimenes, Beatriz Ortega	CSNDSP 2020 (Porto)	WP3/4
IHP	Experimental Evaluation of Round-Trip ToF-Based Localization in the 60 GHz Band	N. Maletic, V. Sark, M. Ehrig, J. Gutierrez Teran, E. Grass	10th International Conference on Indoor Positioning and Indoor Navigation (IPIN 2019)	WP3/4
	Performance Evaluation of LOS Round-Trip ToF Localization: A 60GHz Band Case Study	N. Maletic, V. Sark, M. Ehrig, J. Gutierrez Teran, E. Grass	24th International ITG Workshop on Smart Antennas (WSA 2020)	WP3/4
	100 Gbps 0.8-M Wireless Link based on Fully Integrated 240 GHz IQ Transmitter and	M.H. Eissa, N. Maletic, E. Grass, R. Kraemer, D.	IEEE MTT-S International Microwave Symposium (IMS 2020)	WP3/4

	Receiver	Kissinger, A. Malignaggi		
	Performance Evaluation of a Time-of-Arrival Based Indoor Localization	V. Sark, N. Maletic, J. Gutiérrez, E. Grass	8th Small Systems Simulation Symposium (SSSS 2020)	WP3/4
	Performance Investigation of 2-GBaud QAMs using Fully-Integrated SiGe Chipset at 240-GHz	N. Maletic, M.H. Eissa, V. Sark, A. Malignagg, E. Grass	Workshop on Microwave Theory and Techniques in Wireless Communications (MTTW 2020) (BEST PAPER AWARD)	WP3/4
	Memory-Assisted Statistically-Ranked RF Beam Training Algorithms for Sparse MIMO	K.K. Tiwari, E. Grass, J.S. Thompson	91st IEEE Vehicular Technology Conference (VTC-Spring 2020)	WP3/4
BCM	High-Throughput on the fly LDPC decoder (*postponed*)	Jean Dion, Guillaume Vercasson	International Symposium on Topics in Coding 2020	WP3/4

Table 5 – Contributions to congresses by partners during Year 3

Contributions to journals by partner

Partner	Title	Authors	Journal	Related to
OLD	Freeform geometrical optics I: principles	Juan Camilo Valencia-Estrada and Jorge Garcia-Marquez	Applied Optics	WP3/4
	Freeform geometrical optics II: from parametric representation to CAD/CAM	Thibault Grillon, Camilo Valencia-Estrada, Jorge Garcia-Márquez, Alejandro Espinoza-Garcia, and Bastien Béchadergue	Applied Optics	WP3/4
OXF	Design and Characterisation of Terabit/s Capable Compact Localisation and Beam-steering Terminals for Fiber-Wireless-Fiber Links	Ravinder Singh, Feng Feng, Yang Hong, Grahame Faulkner, Rushikesh Deshmukh, Guillaume Vercasson, Olivier Bouchet, Periklis Petropoulos and Dominic O'Brien	IEEE/OSA Journal of Lightwave Technology	WP4

Table 6 – Contributions to journals by partners during Year 3

Patents by partner

Partner	Title	Authors	Patent	Related to
OLD	Dispositif de communication optique sans fil	Carlos Dominguez-Gonzales, Clément Lartigue, Bastien Béchadergue, and	FR 19 12700	WP3/4

		Benjamin Azoulay		
	Dispositif d'isolation intégré dans un équipement de communication optique sans fil	Alejandro Espinoza-Garcia, Clément Lartigue, and Carlos Dominguez-Gonzales,	FR 20 08138	WP3/4
	Procédé de conception d'un Concentrateur Parabolique Composé Expansé (CPCE) pouvant être corrigé pour collecter la lumière dans le champ proche	Juan Camilo Valencia-Estrada, and Alejandro Espinoza-Garcia	FR 20 10004	WP3/4

Table 7 – Submitted patents by partners during Year 3

Presentations by partner

Partner	Title	Authors	Patent	Related to
IHP	WORTECS: Wireless Optical/Radio TErabit CommunicationS	M. Brzozowski, E. Grass, O. Bouchet	5G World Forum Workshop: From Evolution to Revolution, a roadmap for beyond 5G - 49th European Microwave Week (EuMW 2019)	WP3/4
	Next Generation Terabit Wireless Communications in the 200 GHz Band	V. Sark, M. H. Eissa, N. Maletic	5G World Forum Workshop: From Evolution to Revolution, a roadmap for beyond 5G - 49th European Microwave Week (EuMW 2019)	WP 3/4

Table 8 – Submitted patents by partners during Year 3

IV. WORTECS project dissemination in numbers

WORTECS' dissemination objectives have been widely fulfilled. During the three years of the project, results were disseminated at 30 congresses, in 6 journals, 8 patents, 2 presentations and 1 thesis (Figure 1). Furthermore, the project has gathered attention not only in scientific and specialized journals, but also more general audiences, as shown in previous deliverables. Several press releases from the countries of each partners were issued, communicating the objectives and advances of WORTECS to the public in general.

WORTECS has reached a significant impact in both academic and industrial terms, presenting the numbers of Figure 1.

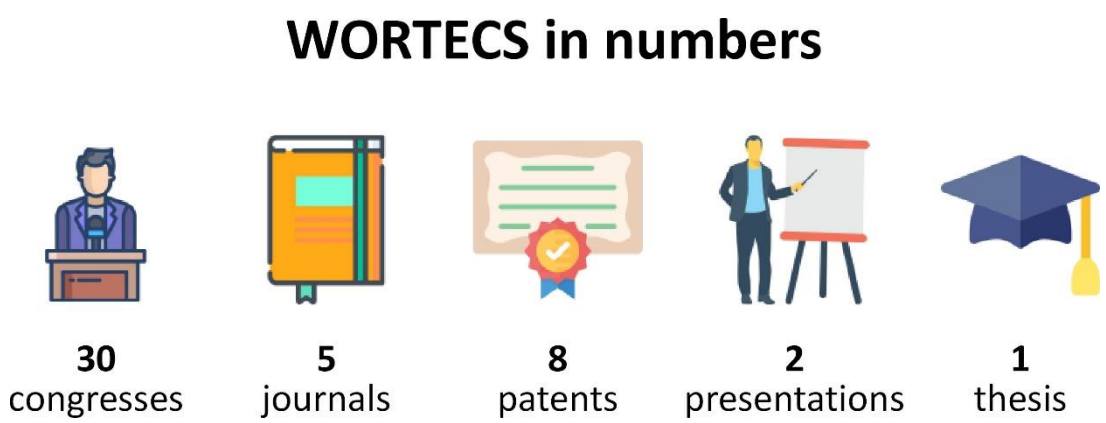

Figure 1 – Overall WORTECS project numbers

In addition, WORTECS have had worldwide reach thanks to contributions in the major 3 continents (Europe, Asia, America). Figure 2 illustrates the reach of the project. Only those countries that held events are marked. However, researchers and industrial key players from other countries attended all the events in which WORTECS have participated.

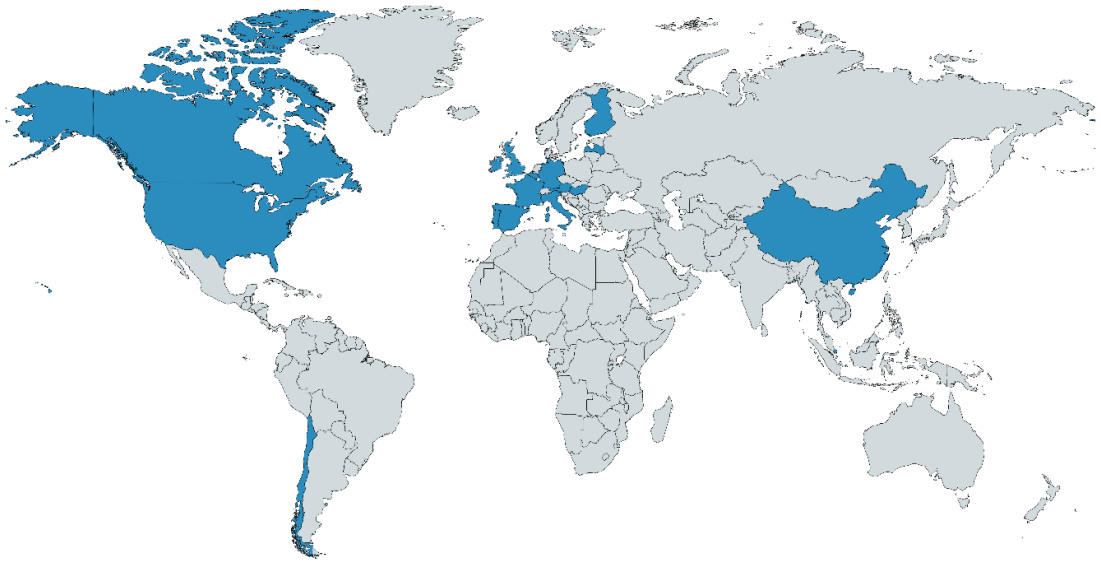

Figure 2 – Worldwide reach of WORTECS