CELTIC-NEXT
Next Generation Telecommunications

Project Report

CELTIC-NEXT AIMM Project

WP1: Project Management and Dissemination

Deliverable D1.6 – Final Dissemination Report

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Project Acronym:	**AIMM**
Project Full Title:	**AI-enabled Massive MIMO**
Project Coordinator:	**Arman Shojaeifard (InterDigital)**
Project Duration:	**24 months (Oct. 2020 – Sep. 2022)**
Submission Date:	**30 September 2022**
Dissemination Level:	**External**

Abstract

This report provides a summary of the dissemination activities undertaken in CELTIC-NEXT AIMM project as part of the Work-Package 1 (WP1) on “Project Management & Dissemination”. The dissemination activities involved coordination of dissemination and exploitation plans, giving broad visibility of the project outcomes in the relevant European and international fora. The work-packages WP2, WP3, WP4, WP5, and WP6 yielded different types of output which were disseminated in different forums and in a diverse manner, as captured in this report.

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Executive Summary

This report describes the dissemination activities undertaken within the CELTIC-NEXT AIMM project Work-Package 1 (WP1) on “Project Management & Dissemination”.

The focus of this work-package is on the overall steering, co-ordination, and dissemination activities of the CELTIC-NEXT AIMM project. Dissemination activity types include patent applications, paper publications, publication of over-the-air channel datasets, simulation codes, standards participation and contributions, newsletters, press releases, workshops, and industry talks/panels.

This deliverable is supported by D1.5, which is the final report on the coordination activities undertaken throughout the duration of the project.

For details on other work packages, please refer to the AIMM final public deliverables that are published online.

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Abbreviations

Abbreviation	Definition
3GPP	3rd Generation Partnership Project
AI	Artificial Intelligence
AI/ML	Artificial Intelligence/Machine Learning
AIMM	AI-enabled Massive MIMO
BT	British Telecommunications plc
CSI	Channel State Information
ETSI	European Telecommunications Standards Institute
IDE	InterDigital Europe Limited
ISG	Industry Specification Group
Lboro	Loughborough University
MDT	Minimization of Drive Tests
MIMO	Multiple-Input Multiple-Output
NCR	Network Controlled Repeaters
NG	Next-Generation
O-RAN	O-RAN Alliance
PCA	Project Cooperation Agreement
PCR	Project Change Request
RAN	Radio Access Network
RIC	RAN Intelligent Controller
RIS	Reconfigurable Intelligent Surface
SDO	Standards Development Organization
SI	Study Item
SON	Self-Organizing Networks
UoB	University of Bristol
UST	University of Stuttgart
WI	Work Item
WP	Work Package

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1. Work-Package 1 Overview

WP1 (Project Management & Dissemination) has taken care of the administrative tasks and the technical management of the project including the coordination of dissemination activities across the project. The timely kick-off of project activities and their overall coordination, ensuring participation from all project partners, contractual matters and the provision of collaborative tools are examples of the activity undertaken.

The timely preparation of deliverables has been monitored throughout the duration of the project and quality checks have been conducted by the Project Coordinator. All project milestones and deliverables due in the project have been achieved as planned.

The dissemination activities involved coordination of dissemination and exploitation plans, giving broad visibility of the project outcomes in the relevant European and international fora. The work-packages WP2, WP3, WP4, WP5, and WP6 yielded different types of output which were disseminated in different forums and in a diverse manner.

The objectives of project dissemination in WP1 included the following:

- Promoting the results of the consortium to the European and global research community by setting up a project website and participate in related events.
- Arranging the project's participation in CELTIC events and other similar events.
- Keeping track of the relevant standardisation activities in particular with respect to 3GPP, O-RAN, and ETSI.
- Coordination of dissemination activities including submission of patents and publications in scientific journals and conferences.
- Exchange with other projects active in neighbouring fields with similar focus.

1.1. Project Overview and Work Package Structure

The AIMM project targeted radical performance improvements and efficiency dividends for 5G and beyond Radio Access Network (RAN) through advanced antenna array (Massive MIMO) and Reconfigurable Intelligent Surface (RIS) technologies powered through and managed by the latest advancements in AI.

The AIMM project was divided into six tightly coupled work-packages (WPs) as illustrated in Fig. 1:

- WP1 provided the overall project management and dissemination activities.
    - Led by Arman Shojaeifard (IDE) and supported by Hannah Taylor (BT).
- WP2 provided use case definitions including key-performance-indicators which drove comparisons between new and existing architectural approaches.
    - Led by Adrian Sharples (BT).
- WP3 focused on the benefits and practical realisation of extremely large antenna arrays and intelligent radio surfaces.
    - Led by Arman Shojaeifard (IDE).
- WP4 considered the design and implementation of AI/ML-based radio interface technologies.
    - Led by Stephan ten Brink (UST).
- WP5 considered enabling frameworks and algorithms for AI-based RAN intelligence and automation.
    - Led by Rui Inacio (Vilicom).
- WP6 focused on the building of standards-compliant testbeds for assessing and demonstration of the technical solutions.
    - Led by Milan Zivkovic (NBLS).

This structure of the work packages was designed to maximise interaction between different work areas while maintaining each package with a clearly defined goal and output.

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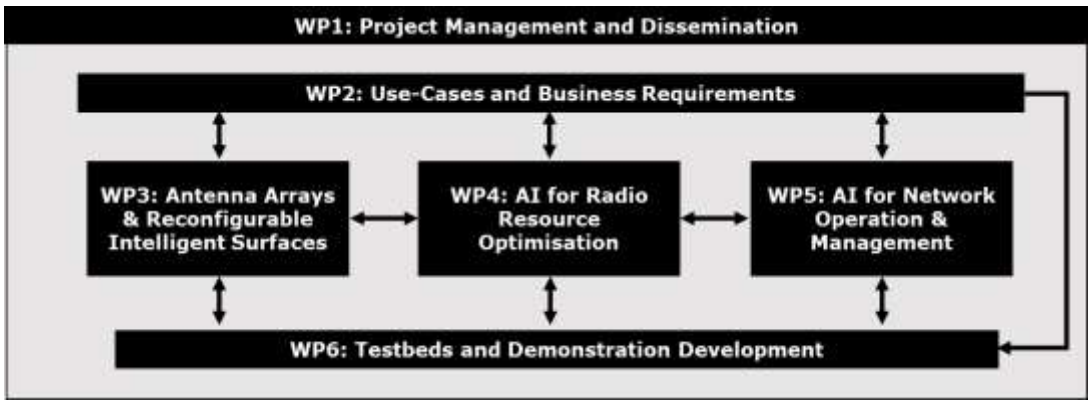

Fig. 1: AIMM project work-package structure.

The areas of interaction between the AIMM technical work packages are presented in Figure 2 as shown below:

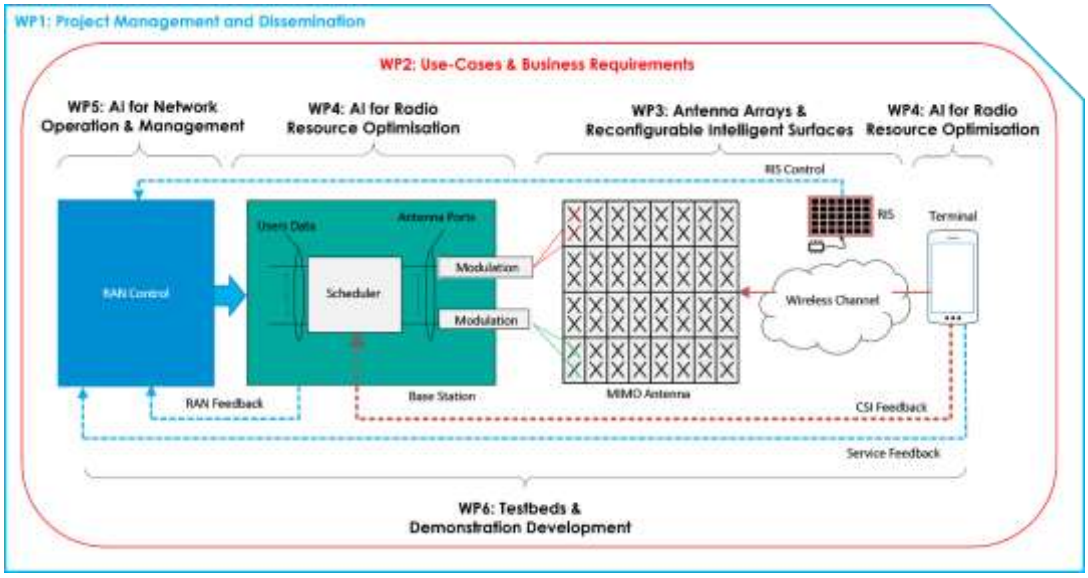

Fig. 2: AIMM work-package structure relationships.

1.2. Project Management Roles & Responsibilities

The AIMM Management Team comprised of the "Project Coordinator" and the "Work Package Leads". In addition, there were "Local Country Partner Leads" who were responsible for interactions and meeting reporting requirements/reviews determined by the individual local funding bodies.

Project Coordinator Responsibilities:

- Supervised the overall technical progress of the project.
- Organised and chaired monthly WP leadership meetings, plenaries, and quarterly reviews.
- Maintained project work space (on OnlyOffice), AIMM website, dissemination, and database for IPR control.
- Reviewed project deliverables and acted as the main contact to CELTIC Office including raising any PCR's.
- Quality sign-off on all work package deliverables.

Work Package Lead Responsibilities:

- Created and maintained a WP execution plan and risk register:
  - Tracked and update tasks, milestones and deliverables.
  - Responsible for the directing of the WP participants.

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- Coordination:
  - Organised regular calls with the participants (biweekly or monthly as appropriate).
  - Overall co-ordination of deliverables.
  - Track WP progress and update Execution plan and risk register as appropriate.
- Reporting:
  - Produced a short monthly report for the WP Leadership meetings.

Country Partner Lead Responsibilities

- Led on fulfilling the reporting/review requirements determined by the local country funding bodies.
- Raising any PCR's if required with the local funding bodies.

1.3. Milestones & Deliverables (all work packages)

The following tables outlines the key deliverables and milestones across all work packages in the CELTIC-NEXT AIMM project. All final deliverables are publicly available online.

WP	WP ID:	Deliverables Title and short description Month	Planned Month	Planned Date	Status
WP1		**Project management and dissemination**			
	IR1.1	Project description	1	Oct-20	
	IR1.2	PCA - Project Cooperation Agreement	5	Feb-21	Issued
	D1.1	Project presentation (public project description)	4	Jan-21	Issued
	D1.2	Public project website	5	Feb-21	
	D1.3	Interim activity report	12	Sep-21	Issued
	D1.4	Interim dissemination report	12	Sep-21	Issued
	D1.5	Final activity report	24	Sep-22	Issued
	D1.6	Final dissemination report	24	Sep-22	Issued
WP2		**Use-cases and business requirements**			
	M2.1	Interim material for D2.1	6	Mar-21	Issued
	D2.1	Business requirements, techno-economics, and security covers T2.1, T2.2	9	Jun-21	Issued
	M2.2	Interim material for D2.2	13	Oct-21	Issued
	D2.2	Background to AI-enabled 5G networks covers T2.3, T2.4	15	Dec-21	Issued
	M2.3	Interim material for D2.3	18	Mar-22	Issued
	D2.3	Final reviewed document with additional section covering technology dissemination recommendations and advising on the use of the developed technology to tackle real world practical problems.	24	Sep-22	Issued
WP3		**Antenna arrays and reconfigurable intelligent surfaces**			
3	M3.1	Interim material for D3.1.	6	Mar-21	Issued
	D3.1	Antenna array geometries, reconfigurable intelligent surfaces, and power amplifier enhancements (preliminary results). Covers all WP3 tasks; interim internal report.	12	Sep-21	Issued
	M3.2	Interim material for D3.2.	18	Mar-22	Issued
	D3.2	Antenna array geometries, reconfigurable intelligent surfaces, and power amplifier enhancements. Covers all WP3 tasks; final public deliverable.	24	Sep-22	Issued
WP4		**AI for radio resource optimisation**			
4	M4.1	Interim material for D4.1	6	Mar-21	Issued
	D4.1	AI for Radio Resource Optimisation – Initial Results. Covers all WP4 tasks; interim internal report.	13	Oct-21	Issued
	M4.2	Interim material for D4.2	18	Mar-22	Issued
	D4.2	AI for Radio Resource Optimisation. Covers all WP4 tasks; final public deliverable.	24	Sep-22	Issued
WP5		**AI for network operation and management**			
5	M5.1	Interim material for D5.1.	6	Mar-21	Issued
	D5.1	AI for network operation and management – Initial Results. Covers all WP5 tasks; interim internal report.	13	Oct-21	Issued

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	M5.2	Interim material for D5.2.	18	Mar-22	Issued
	D5.2	AI for network operation and management – Final Results. Covers all WP5 tasks; final public deliverable.	24	Sep-22	Issued
WP6		**Testbed and Demonstration Development**			
6	M6.1	Successful design of a flexible network architecture.	7	Apr-21	Issued
	M6.2	Successful development of the centralized testbed.	13	Oct-21	Issued
	D6.1	Report on development of centralized testbed and baseband modules design for cell-less testbed. Covers WP6 Tasks 1-2; interim internal report.	14	Nov-21	Issued
	M6.3	Successful development of the cell-less testbed.	17	Feb-22	Issued
	D6.2	Successful evaluation and demonstration of the AIMM testbeds and capturing real-data set information. Final public report.	24	Sep-22	Issued

2. AIMM Dissemination Activities

An AIMM dissemination tracker is maintained by the Project Coordinator. The tracker was reviewed in the leadership team meetings and updated as an when dissemination activities took place.

A project website was created and served as a key tool for public dissemination- https://www.celticnext.eu/project-aimm/. The website is managed by WP1 with contributions being provided across the AIMM project community.

The project utilised additional external methods for dissemination effort, based on research output provided by the project partners, in different forms such as patent applications, paper publications, publication of over-the-air channel datasets, simulation codes, standards participation and contributions, newsletters, press releases, workshops, and industry talks/panels. In what follows, the dissemination activities of AIMM are listed under different categories.

2.1 Standards Participation and Contributions

The Standardization Activities Section reports on activities related with the key SDOs for beyond 5G such as 3GPP, O-RAN, and ETSI. These activities included monitoring/tracking these SDOs as well as participation through submitting technical contributions.

3GPP

As captured in the following table, 3GPP WGs within the scope of AIMM were RAN1 (Radio Layer 1 – Physical Layer), RAN2 (Radio Layer 2 and Radio Layer 3 Radio Resource Control), RAN3 (UTRAN/E-UTRAN/NG-RAN architecture and related network interfaces). Moreover, in the table, 3GPP topics which fall within the scope of AIMM and relevant deliverables have been highlighted.

3GPP WG	Topic	In-Scope Study / Work Items	Relevant AIMM Deliverable
RAN1/RAN2	MIMO	Rel-17, Rel-18	D3.2, D4.2, D6.2
	AI/ML for NR Air-Interface	Rel-18	D4.2, D6.2
	NCR	Rel-18	D3.2
RAN3	NR SON/MDT enhancements	Rel-17, Rel-18	D5.2
	AI/ML for NG-RAN	Rel-18	D5.2

Overall, there has been a strong mapping between the research work that was defined and executed in the AIMM project and what has been included in the 3GPP work in Release 18 (first 5G-Advanced release).

On the topic of AIML applied to air-interface and RAN (work-packages 4 and 5), these topics have for the first time entered 3GPP RAN in Release 18, where some of the use cases defined in AIMM such as enhancements to CSI, beam management, and positioning are prioritized as part of these study/work items.

On the topic of RIS (reconfigurable intelligent surfaces), there were multiple company proposals as part of the Release 18 discussions, and ultimately it was decided not to bring RIS into the work of 3GPP in Release 18. The discussions however led to a SI (and as of the writing of this report WI) on

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NCR, which can be viewed as a stepping-stone for RIS. As will be discussed in the subsection on ETSI below, AIMM project partners were instrumental in founding a first ISG on RIS, to streamline pre-standards research efforts on this beyond 5G topic.

Industry partners in the project, including Nokia, BT, and InterDigital actively engage in 3GPP standardization activities, both in terms of participation in meetings, and producing technical contributions. Several individuals involved in the AIMM project from these companies were involved in the preparations of contributions of these companies as part of the 3GPP pre-Release 18 discussions, and furthermore the Release 18 ongoing work. The contributions for companies (t-docs) can be accessed via the 3GPP portal: https://portal.3gpp.org/#/55931-tdocs.

O-RAN

One of the initial decisions of AIMM was the adoption of the RAN architecture being developed through the O-RAN alliance as the mechanism for realising the technical proposals of AIMM. Within this structure it is principally the RIC function that is of particular interest to AIMM. The relevant working groups within the O-RAN Alliance are WG2 “Non-real time RAN Intelligent Controller and A1 interface work group” and WG3 “Near real time RIC and E2 interface work group”, which are primarily considered in WP5 of AIMM where the application of AI/ML techniques to realise solutions for deployment on the RIC have been worked on. Some aspects of the work of WP3, particularly relating to future cell-free architectures, will also potentially place requirements on the open fronthaul interface considered by WG4 “Open fronthaul interfaces work group”.

BT is an active participant in the O-RAN, monitoring WG2 and WG3 where individuals in the BT team working on AIMM are also the attendees in these work groups that define, among other things, the standard data sets that can be measured and communicated to the RIC across the E2 interface. The work carried out in AIMM WP5 has informed the requirements for the granularity and periodicity required for this data transfer. BT is also involved in WG1 “Use cases and overall architecture work group” and some of the use cases of AIMM, identified in WP2, are also part of the Telecom Infra Project (TIP) RAN Intelligence and Automation workstream of which BT is a co-chair. Finally BT attend the “Security work group”, WG11, although this has not been explicitly considered as part of AIMM.

ETSI

AIMM project partners, notably InterDigital and BT, were instrumental in establishing a new ISG on RIS at ETSI, the very first pre-standards group on a 5G-Adv/6G topic aiming to bridge the gap between research and standards. This group provided the means for disseminating the results of the AIMM project, on RIS and paving the way for all other collaborative projects working on these topics, onto future standards (notably 3GPP).

Since the launch of the group in September 2021, significant progress has been made by the group through regular ISG meetings on identifying and documenting relevant RIS use cases, architectures, channel models, deployment scenarios, and standardization impact. There has been more than 35 contributions to date made to ISG RIS from AIMM project work.

There are currently 38 Members/Participants in the group, including operators, vendors, SMEs, and a large number of research institutes and universities. The latest list of members can be found here: https://portal.etsi.org/TB-SiteMap/RIS/List-of-ISG-RIS-Members-and-Participants.

In addition, AIMM project partners, notably InterDigital, were part of the founding member group for establishing of a new ISG on Terahertz modelling (ISG THz) at ETSI. The group, anticipated to launch in December 2022, will prepare systematic output on channel models, system parameters, and evaluation assumptions, for subsequent evaluation of THz communications systems by 3GPP.

2.2 Intellectual Property Creation

AIMM consortium developed a number of technologies based on the outcome of the R&D activities conducted. In what follows we highlight a selection of these patent applications (note this is not an exhaustive list of IP generated from the AIMM project activities):

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- Shojaeifard et al., *"Adaptive Reference Signal Configuration"*, EP application 21178929.2, Filed 11 June 2021.
- Y. Chen et al.; *"Enhanced DMRS-Based Channel Estimation With Machine Learning Aided Universal Interpolation For Ultra High Mobility,"* Patent Application Number: PCT/EP2021/077728, Filed 7 October 2021.
- Shojaeifard et al., "Methods for Multi-resolution CSI feedback for Wireless Systems", 2021P00302 US, Filed 3 November 2021.
- Zhang et al., *"Precoding for Beamforming",* GB Application GB2203385.6, Filed 11 March 2022.
- Hemadeh et al., *"Multi-directional Fully Connected Design for Reconfigurable Intelligent Surfaces",* 2021P00161 US, Filed 25 May 2022.
- Shojaeifard et al., *"Methods for UE specific CSI codebook design"*, 2022P00102 US, Filed 5 April 2022.

2.3 Paper Publications

Project partners produced a number of conference and journal papers based on the work of AIMM. A selected list of paper submissions/publications is provided below:

- F. Euchner, Ph. Stephan, M. Gauger, S. Doerner, S. ten Brink, *"Improving Triplet-Based Channel Charting on Distributed Massive MIMO Measurements"*, IEEE SPAWC conference, Oulu, July 2022 (in special session "Machine Learning for Communications").
- F. Euchner, M. Sueppel, M. Gauger, S. Doerner, S. ten Brink, *"Deep Learning for Uplink CSI-based Downlink Precoding in FDD massive MIMO Evaluated on Indoor Measurements"*, EUSIPCO, Belgrade, Aug. 2022.
- F. Euchner, Ph. Stephan, M. Gauger, S. ten Brink, *"Channel Sounder with Over-the-Air Antenna Synchronization: Absolute Phase and Timing Calibration using Known Transmitter Locations"*, EuCNC, Grenoble, June 2022.
- "F. Euchner, M. Gauger, S. Doerner, S. ten Brink, *"A Distributed Massive MIMO Channel Sounder for Big CSI Data"-driven Machine Learning",* IEEE/ITG WSA 2021, Eurecom, Nov. 2021.
- Yejian Chen; Jafar Mohammadi; Thorsten Wild; *"Turbo AI, Part III: Facilitating Wireless Massive Access for Next Generation PRACH,"* in Proc. 25th Int. ITG Workshop Smart Antennas (WSA 2021), Nov. 2021.
- Yangyishi Zhang, Minglei You, Gan Zheng, Anas Al Rawi, Anvar Tukmanov; *"Downlink Cell-Free Fixed Wireless Access: Architectures, Physical Realities and Research Opportunities"*, IEEE Wireless Communications Magazine, June 2022.
- Li, Peizheng et al., *"RLOps: Development Life-cycle of Reinforcement Learning Aided Open RAN"*, IEEE Access, submitted 2022.
- T. Chen, M. You, G. Zheng, and S. Lambotharan, *"Graph Neural Network based Beamforming in D2D Wireless Networks,"* the 25th International ITG Workshop on Smart Antennas (WSA), Nov. 2021, EURECOM, French Riviera.
- Shojaeifard et al., *"Deep Learning-based DMRS Configuration for MIMO Channel Estimation",* in Proc. 25th Int. ITG Workshop Smart Antennas (WSA 2021), Nov. 2021.
- M. Zivkovic, F. Schaich, "A Real-Time testbed for AI/ML-enhanced RAN", EuCNC, Grenoble, June 2022.
- A. Ahmad, R. Inacio, H. Erdol, *"Multi-Vendor multiple Open-RAN Technology Analytics platform - Centralized & Federated AI applications"*, EuCNC, Grenoble, June 2022.
- K. Briggs, *"A system-level simulator for AI/ML-enhanced network design"*, EuCNC, Grenoble, June 2022.
- M. You, T. Chen, and G. Zheng, "Towards Distributed Cell-Less MIMO Testbed: An RFNoC Implementation," EuCNC, Grenoble, June 2022.
- Kapoor, S., Li, P. *"Variational Autoencoder Assisted Neural Network Likelihood RSRP Prediction Model"*, 2022 IEEE 33rd Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC).
- Yejian Chen; Jafar Mohammadi; Stefan Wesemann; Thorsten Wild; *"Turbo AI, Part IV: Estimating Uplink Channels for Ultra High Mobility with Sparse Pilots,"* 2022 Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'22), September 2022.
- Z. Ren, A. Doufexi, and M. Beach, *"Lattice quantization for centralized and scalable Cell-Free massive MIMO with realistic fronthaul,"* in 2022 IEEE International Mediterranean

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Conference on Communications and Networking (MeditCom) (IEEE MeditCom 2022), Athens, Greece, Sep. 2022.
- Hakan Erdol, Xiaoyang Wang, Peizheng Li, Jonathan D. Thomas, Robert Piechocki, George Oikonomou, Rui Inacio, Abdelrahim Ahmad, Keith Briggs, Shipra Kapoor, *"Federated Meta-Learning for Traffic Steering in O-RAN"*, submitted 2022.
- Peizheng Li, Hakan Erdol, Keith Briggs, Xiaoyang Wang, Robert Piechocki, Abdelrahim Ahmad, Rui Inacio, Shipra Kapoor , Angela Doufexi, Arjun Parekh, *"Transmit Power Control for Indoor Small Cells: A Method Based on Federated Reinforcement Learning"*, submitted 2022.
- A. Shojaeifard et al., *"MIMO Evolution Beyond 5G Through Reconfigurable Intelligent Surfaces and Fluid Antenna Systems,"* in Proceedings of the IEEE, doi: 10.1109/JPROC.2022.3170247.
- Tapio, V., Hemadeh, I., Mourad, A. et al., *"Survey on reconfigurable intelligent surfaces below 10 GHz*", J Wireless Com Network 2021, 175 (2021). https://doi.org/10.1186/s13638-021-02048-5.
- V. Tapio, A. Shojaeifard, I. Hemadeh, A. Mourad and M. Juntti, *"Reconfigurable Intelligent Surface for 5G NR Uplink Coverage Enhancement,"* 2021 IEEE 94th Vehicular Technology Conference (VTC2021-Fall), 2021, pp. 1-5, doi: 10.1109/VTC2021-Fall52928.2021.9625081.
- Jagyasi et al., *"Unsupervised Learning-Aided Discrete RIS Configuration Estimator"*, IEEE VTC-Spring, 2022.
- V. Tapio, *"SNR-based configuration for RIS-integrated NR"*, IEEE VTC-Spring, 2022.

2.4 Press releases and newsletters

At the start of the project, a number of press releases were issued by the project partners, including:

- *InterDigital Announces Participation in AIMM Project to Improve 5G Performance through AI and Massive MIMO* Press Release – https://www.globenewswire.com/news-release/2020/11/23/2131475/0/en/InterDigital-Announces-Participation-in-AIMM-Project-to-Improve-5G-Performance-through-AI-and-Massive-MIMO.html.
- *AIMM Leverages Reconfigurable Intelligent Surfaces Alongside Machine Learning* Press Release – *https://www.6gworld.com/exclusives/aimm-leverages-reconfigurable-intelligent-surfaces-alongside-machine-learning/.*
- *Vilicom, BT, UK academia gain funding to spearhead 5G and AI research* Press Release – https://www.computerweekly.com/news/252491910/Vilicom-BT-UK-academia-gain-funding-to-spearhead-5G-and-AI-research.

A series of public newsletters were published through the lifespan of the project in order to inform and engage with the external stakeholders. These are listed below:

- *Use Cases* Newsletter – https://aimm.celticnext.eu/2021/06/06/newsletter-aimm-use-cases-defined/.
- *AI for Network Operation & Management* Newsletter – https://aimm.celticnext.eu/2021/07/07/newsletter-ai-for-network-operation-and-management/.
- *Antenna Arrays and Reconfigurable Intelligent Surfaces* Newsletter – https://aimm.celticnext.eu/2021/08/31/newsletter-antenna-arrays-reconfigurable-intelligent-surfaces/.
- *AI for Radio Resource Optimisation* Newsletter – https://aimm.celticnext.eu/2021/09/30/newsletter-ai-for-radio-resource-optimisation/
- *Testbeds & Platforms* Newsletter – https://aimm.celticnext.eu/2021/12/16/newsletter-aimm-testbeds-and-platforms/.
- *Business Benefits and Ethical Considerations* Newsletter – https://aimm.celticnext.eu/2022/03/28/newsletter-business-benefits-ethical-considerations/.
- *AIMM System Simulations* Newsletter – https://aimm.celticnext.eu/2022/07/13/newsletter-aimm-system-simulations/.

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2.5 Publication of public datasets and simulation code

UST, an AIMM project partner, completed the development of a massive MIMO channel sounder called Distributed Channel Sounder by University of Stuttgart (DICHASUS). DICHASUS is used to capture very large Channel State Information datasets, which are suitable for machine learning applications. In contrast to previous channel sounders, DICHASUS can be deployed in a distributed fashion, i.e., with antennas scattered over a facade or across several buildings. Measured DICHASUS datasets were freely provided to the scientific community under a permissive license. Datasets can be downloaded from: https://dichasus.inue.uni-stuttgart.de/.

Further, within AIMM a simulator that emulates a cellular radio system roughly following 5G concepts and channel models was developed. The intention was to have an easy-to-use and fast system written in pure Python with minimal dependencies. It is especially designed to be suitable for interfacing to AI engines such as *tensorflow* or *pytorch*. AIMM simulator documentation was made available to the scientific community (https://aimm.celticnext.eu/simulator/) and the intention is to release the code post project completion.

2.6 Workshops, industry talks and panels

A number of workshops, industry talks, and panels were also targeted as part of AIMM project dissemination. These are listed below:

- Shipra Kapoor, Online Technical Lecture, *"Application of Machine Learning in 5G and beyond Wireless Networks*", in Department of Electrical and Electronics Engineering Science, University of Johannesburg, 30 September 2022.
- Stephan ten Brink, Online Tutorial, *"Channel Charting - Mapping the Radio Environment", https://dichasus.inue.uni-stuttgart.de/tutorials/tutorial/channelcharting/*.
- N. Süppel, F. Euchner, Online Tutorial, *"FDD Massive MIMO: Infer Downlink CSI from Uplink CSI"*, https://dichasus.inue.uni-stuttgart.de/tutorials/tutorial/downlinkcsi/.
- G. Zheng, Presentation, *"Spectrum-efficient Beamforming beyond 5G: Model-driven AI Algorithms and SDR Testbed",* 16 September 2021.
- F. Burton, Presentation, *"Network Operator requirements and use-cases for Reconfigurable Intelligent Surfaces"*, IEEE PIMRC, September 2021.
- K. Briggs, Presentation, *"Simulating 5G mobile networks with AI control"*, KLAIM2021, Fraunhofer Institute for Industrial Mathematics.
- A. Shojaeifard, Presentation *"AI for Massive MIMO" Cambridge Wireless "Is your radio smarter than you? Applying AI to radio communications"*, November 2021.
- A. Shojaeifard, Workshop, ICT'21 RIS "Joint Ariadne, RISE-6G, and AIMM Projects Workshop on RIS Technology", June 2021.
- A. Shojaeifard, Workshop, PIMRC'21 RIS "Joint Ariadne, RISE-6G, and AIMM Projects Workshop on RIS Technology", September 2021.
- C. Element, Presentation, Ottawa Product Management Association - Share - Learn - Grow Event *"What does AI mean to you"*, March 2022.
- C. Element, Presentation, IoT Canada, Things Happen Podcast, *"Managing and Assuring Radio Spectrum"*, April 2022.
- K. Briggs, Presentation, Maths4DL, University of Bath, *"Interfacing AI algorithms with a 5G network simulator"*, April 2022.
- Stephan ten Brink, Keynote, *"Deep Learning Applications in Wireless Communications based on Distributed Massive MIMO Channel Sounding Data"*, Design, Automation and Test in Europe (DATE) conference, March 2022.
- C. Element, Presentation, CAV - 2021 - Canadaian Autonomous Vehicle Conference.
- Shipra Kapoor, Presentation, *"An Introduction to Reinforcement Learning"*, Bristol Data Week, University of Bristol, June 2022.
- M. Zivkovic, Workshop, *"AIMM Project Testbeds and Platforms"*, EuCNC, June 2022.

3. Conclusions

The deliverable presented here provides a summary of the dissemination activities undertaken within the AIMM project. It has been shown that the project partners have been very active in disseminating the results of the 24 month project in a variety of ways, including patent applications, paper publications, publication of over-the-air channel datasets, simulation codes, standards participation and contributions, newsletters, press releases, workshops, and industry talks/panels.

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