Deliverable 6.4
Final report of ARIADNE Standardization activities

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Abstract

This deliverable includes the work conducted within Task 6.2 “Standardization”. The main objective of this task is to promote project results in standardization bodies. In this task, ARIADNE has proceeded in a 3-step approach for the coordination and planning of the contribution strategy. Firstly, Standardization Bodies (SB) relevant to the project, have been identified. Consequently, SB have been monitored so as to ensure the alignment of the project technical work with standards evolution and the achievement of high-level interactions, based on the progress and maturity of the work to be done. Finally, the project partners have proceeded to actual contributions, where and to the extent possible. Such activities aim at identifying the gap between the technical research and the standardization bodies work items, fostering potential ARIADNE’s outcome.

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Impressum

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Executive summary

This document provides a summary of standardization activities that have been carried out by Ariadne partners during the project.

The results are presented in three main activity areas:

(1) Standardization bodies relevant to and followed by ARIADNE partners, which includes brief description of the activities of that organization, interest for Ariadne and outlook to future.

(2) Activities towards existing relevant SDO's, where their most important activities and alignment toward these activities are presented.

(3) New ISG groups, including recently introduced ETSI ISG groups, where Ariadne partners have been involved/contributed as founding members.

Deliverable 6.4 is created at the end of the project. It will summarize planned activities, contributions and achievements towards standardization made during ARIADNE project.

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Abbreviations

2D	Two dimensional
3GPP	3rd Generation Partnership Project
5G	Fifth Generation (mobile cellular networks)
5G PPP	5G Public Private Partnership
AI	Artificial Intelligence
AP	Access Point
B5G	Beyond 5G
BBU	Baseband Unit
BEP	Bit Error Probability
BTS	Base Transceiver Station
E2E	End-to-end
eCPRI	Enhanced Common Public Radio Interface
EM	Electromagnetic
eMBB	Enhanced Mobile Broadband
ETSI	European Telecommunications Standards Institute
FD	Full-Duplex
FDMA	Frequency Division Multiple Access
HD	Half-Duplex
ISG	Industry Specification Group
ITU	International Telecommunication Union
KPI	Key Performance Indicator
LOS	Line of Sight
LTE	Long Term Evolution
ML	Machine Learning
mMTC	Massive Machine Type Communications
mmWave	Millimeter Wave
MW	Microwave
mWT	Millimeter Wave Transmission
NLOS	Non Line Of Sight
NOMA	Non-Orthogonal Multiple Access
P2MP	Point-to-Multipoint
P2P	Point-to-Point
RF	Radio Frequency
RIS	Reconfigurable Intelligent Surface
RRH	Remote Radio Head
RX	Receiver
TX	Transmitter
uRLLC	Ultra Reliable Low Latency Communications
UE	User Equipment
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
WP	Work Package
XPIC	Cross-Polar Interference Cancelation

1 Introduction to the project

This deliverable reports the progress and summarizes activities of the Ariadne project during the 45 months. This includes a 9-month extension needed to complete other work package activities where covid-19 had affected the implementation schedule. Despite the change in schedule, planned activities were performed and as a remarkable additional achievement, Ariadne partners were co-founders of two new ETSI ISG groups.

1.1 Objectives of the ARIADNE

The ARIADNE project has the core objective to enable efficient high-bandwidth wireless communications by developing three complementary but key new technologies for beyond 5G networks in an integrated and innovative way:

- ARIADNE will develop new radio technologies for communications using the above 100GHz D-band frequency ranges (Pillar 1)
- ARIADNE will exploit the opportunities emerging for advanced connectivity based on metasurfaces where objects in the environment can become tunable reflectors for shaping the propagation environment in D-band (Pillar 2)
- ARIADNE will employ Machine Learning and Artificial Intelligence based management techniques necessary for the high-frequency communications and dynamic assignment and reconfiguration of the metasurfaces, in order to provide continuous reliable High Bandwidth connections in the Beyond 5G scenario (Pillar 3).

To realize this novel system concept, ARIADNE partners has been working with the following advanced technology enablers:

- A novel Communication Theory framework beyond the Shannon paradigm
- Intelligent surfaces (metasurfaces) used to enable tunable or switchable reflections and overcome limitations resulting from obstructed links and NLOS scenarios
- Propagation characterization in the D-band for indoor/outdoor, LOS and NLOS
- Highly integrated D-band transceiver RF-frontend architectures and spectral efficient baseband processing, energy-efficient carrier aggregation, and D-band MIMO antenna design
- Waveform design, wireless access, tracking and resource allocation based on the pencil beamforming principle, and
- ML-based approaches for ultra-reliable connectivity, optimal and adaptive RRM and E2E network optimization (resource allocation, routing, etc.).

See reference [1].

1.2 Objectives of the task standardization

The highly innovative nature of the project has provided the great potential to generate inputs for standardization. Objective of task by active follow-up, participation and contributions to relevant interest groups and standardization bodies based on the work addressed in the project are envisaged.

It was anticipated that some of the ARIADNE work can be integrated into relevant standards, in the 5G-PPP and maybe in other bodies as well.

Presenting the results of the project to standardization bodies was a high priority for the ARIADNE consortium. Therefore a 3-step approach planned has been followed for the coordination and planning of the contribution strategy.

- Firstly, Standardization Bodies (SB) or Interest Groups (IG) relevant to the project, to be identified
- SB's or IG's identified to be relevant should be monitored so as to ensure the alignment of the project technical work with standards evolution and the achievement of high-level interactions, based on the progress and maturity of the work to be done
- Project partners to proceed to actual contributions, where and to the extent possible. Such activities aim at identifying and bridging the gap between the technical research and the standardization bodies work items, fostering and promoting potential ARIADNE's outcomes.

ARIADNE's effort on standardization activities should be driven by participation of the project partners in related standardization bodies and interest groups.

There are two deliverables related to the standardization:

- D6.3 (M12) (NOK) - Standardization activities: Regularly updated list of standardization activities of the project
- D6.4 (M36) (NOK) - Standardization activities: Regularly updated list of standardization activities of the project.

Deliverable 6.3 has presented a plan for activities and also the outcome of preliminary standardization contributions / investigations after 12 months from the project start. It was a snapshot of standardization bodies or interest groups proposed to be followed. Information on which of the partners are following activities and work of those groups was also provided.

Deliverable 6.4 is created at the end of project (M36+9). It will summarize all activities, contributions, achievements and alignment towards standardization within ARIADNE project.

1.3 Presentation of the task result

The results of standardization activities are presented in three main activity areas:

(1) Standardization bodies followed by ARIADNE partners, which includes a brief description of the activities of that organization, interest for ARIADNE and outlook to future.

(2) Activities towards existing SDO's, where alignment toward relevant standardization organizations is described.

(3) New ISG groups, i.e. recently introduced ETSI ISG groups, where ARIADNE partners have been contributing as founding members.

2 Standardization bodies followed by ARIADNE partners

2.1 Findings and future vision from standardization bodies or interest groups

2.1.1 3GPP

Website: https://www.3gpp.org/

3GPP is an umbrella term for a number of organizations concentrated on developing mobile communication protocols. It consists of seven national or regional standards organizations as primary members ("organizational partners") and a variety of other organizations ("market representation partners"). Organizational partners define the scope, content and resourcing of standardization work and act as the primary decision-making body. Market representation partners primarily offer advice and insight into the market requirements to support the standardization work.

3GPP standards are divided into releases. The releases consist mainly of Technical Specification and Technical Report documents, each of which may undergo many revisions over several releases.

Specification work is done in specification groups, where the most relevant working groups for ARIADNE are radio layer 1 (RAN1) and radio layer 2 (RAN2) working groups. 3GPP RAN1 working group is responsible for specifications for physical layer of the radio interfaces for user equipment especially the development of specifications dealing with 5G new radio (5G NR) physical layer aspect. While 3GPP RAN2 working group is in charge of radio interface architecture and protocols including the specification of radio resource control protocol and radio resource management procedures.

3GPP Rel 18 is the first release for 5G advanced. In Feb 2022, Rel-18 stage-2 has been released with the content definition and prioritization of study items. The study items in Rel-18 are based on new requirements for 5G advanced.

Some example of study items based on new Rel-18 requirements which are relevant to ARIADNE are as follows:

- Study on System Support for AI/ML based services: This study aims to provide intelligent transmission support for AI/ML based use-cases specific, e.g., AI/ML based CSI compression and prediction, AI/ML beam management and AI/ML positioning prediction
- Study on system architecture for next generation real-time communication services
- Study on Architecture enhancements for vehicle mounted relays: this study aims to support the operation of base station relays possibly mounted on vehicles, using 5GNR for wireless access towards the UE and for self-backhauling.

The timeline for 3GPP standardization is shown below.

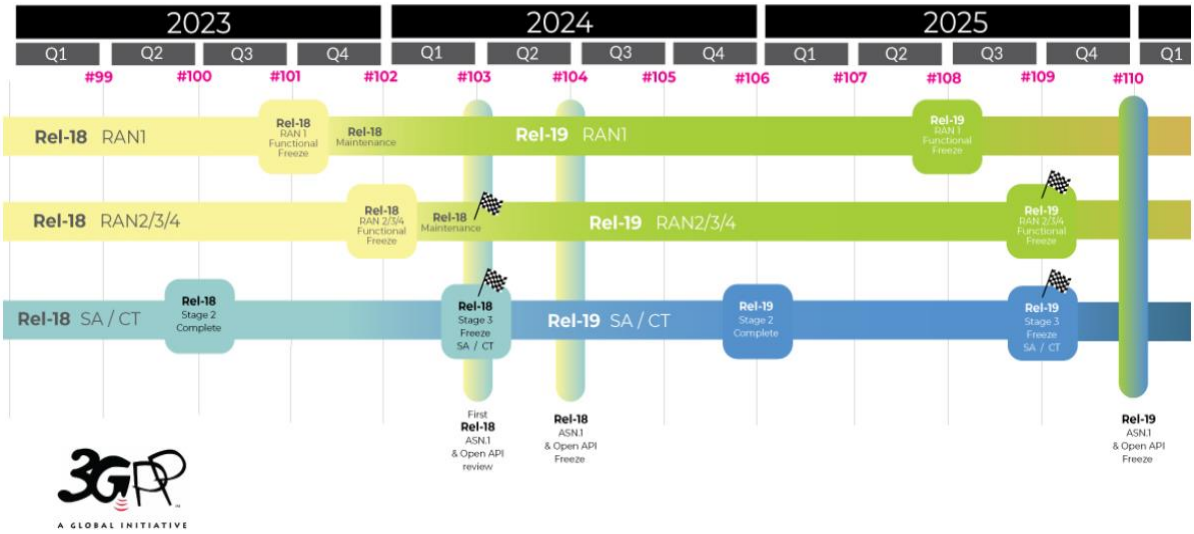

Figure 1: 3GPP standardization timeline for Rel18 and Rel19

The upcoming 3GPP Rel-19 is starting from beginning of 2024. ARIADNE outputs could be contributed to 3GPP Rel-19 especially AI/ML based air interface and RIS related topics.

There are multiple proposals from many companies supporting RIS to be one of the study items in 3GPP Rel-19 under network control repeater (NCR) topic.

- The support of RIS is that the RIS can act as a relay to change the radio environment in a controllable manner and thus significantly improving the link quality of wireless communications with low power consumption, and low cost
- In coverage extension scenario, RIS relay can enhance certain paths between base station and UE, in this scenario, the RIS panels can be seen as the extension of base station antennas. The reflection array of RIS can be controlled and coordinated by base station to form a multiple layers transmission.

2.1.2 US mmWave Coalition

Website: https://mmwavecoalition.org/

mmWave Coalition is a US based group of companies that focuses on advocating opening up regulations that govern the use of frequencies between 95 GHz and 450 GHz. Specific aims (from the coalition website):

- Create large contiguous blocks of spectrum by proposing service rules, including Part 101 and Part 30, that span existing Fixed Service (FS), Mobile Service (MS) bands, and present passive (US 246) bands, *e.g.* 102-130 GHz facilitating speeds comparable with fiber optics technology
- Update present US Allocation Table US246 to enable controlled sharing of passive above 90 GHz spectrum under strict conditions that protect the passive uses of them — which is much easier at these frequencies than at lower bands
- Extend quantitative RF safety limits above present 100 GHz to decrease regulatory uncertainty.

mmWave Coalition consist of members from universities and companies like Oklahoma State University, University of Arizona, Northeastern University, Qualcomm, National Instruments, Nokia, NYU Wireless, Keysight technologies and others.

From the coalition website there can be found the latest interest towards to support research and development activities for wireless devices above 95GHz and needed suitable regulatory framework for their eventual use. Some areas as example are mentioned to foster investments and commercial success at this spectral area:

- U.S. allocations extend up to 275 GHz as of 2021, but before March 2019, service rules stopped at 95 GHz (FCC claims jurisdiction up to 3 THz).
- Use of technology above 95 GHz is governed by FCC ET Docket 18-21 in the United States
- ITU rules call for protection of primary passive spectrum by prohibiting “all emissions” in some bands. The mmWave coalition fully supports protecting all passive receivers and their spectrum. However, the ITU has made little progress in its WRC-2000 call for studies of possible sharing feasibility. If fundamental physics and engineering solutions offer fool-proof ways to share these passive bands with terrestrial users, these possibilities should be explored. Also, it is vital to understood the out-of-band emissions (OOBE) sensitivity that passive users face in the spectrum above 95 GHz near the protected ITU bands
- Worldwide, there is uncertainty regarding service rules in 95-275 GHz
- No provisions for terahertz spectroscopy exist today despite products on US market for domestic and foreign firms.

Frequencies above 95 GHz present new opportunities for 6G. 5G New Radio (NR) addressed many of the beam-based air-interface challenges. FCC U.S. Spectrum Horizons opens sub-THz. 21 GHz of new discontinuous unlicensed spectrum has been divided into contiguous bands of 7.2, 7, 5 and 2 GHz.

New type of experimental license for trialing new services. Open to band 95 GHz to 3 THz. 10-year non-renewable experimental license would provide an ability to sell devices to non-license holders.

CEPT ECC approved two recommendations for Fixed Service (FS) above 92 GHz:

- W Band ECC Recommendation ECC/REC/(18)02 on frequencies 92-114.25 GHz
- D Band ECC Recommendation ECC/REC/(18)01 on frequencies 130-174.8 GHz.

ITU RR.340 Bands limit the contiguous bandwidth available.

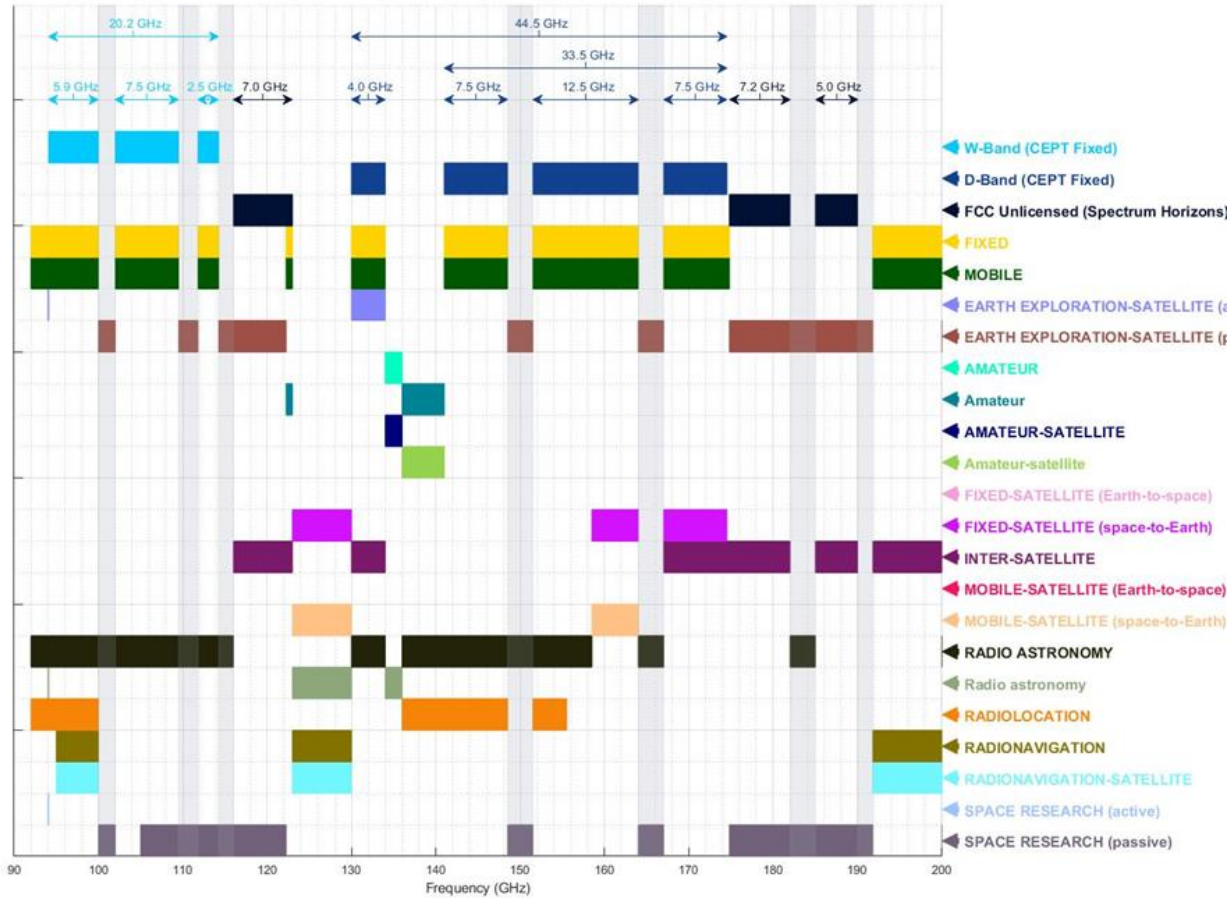

Figure 2: Sub-Terahertz overview at US

2.1.3 ITU-R

The origins of the International Telecommunication Union (ITU) (http://www.itu.int) date back in 1865, when the International Telegraph Union was founded in Paris. The ITU is a specialized agency of United Nations with its based in Geneva, Switzerland. Currently the ITU is formed by 193 Member states and more than 700 organizations from the private sector and academia. Since 1992 the ITU has been structured into three sectors:

- **Telecommunication Standardization Sector** (**ITU-T**). The ITU-T assembles experts from around the world to develop international standards known as ITU-T Recommendations which act as defining elements in the global infrastructure of information and communication technologies (ICTs)

- **Telecommunication Development Sector** (**ITU-D**). The ITU-D fosters international cooperation and solidarity in the delivery of technical assistance and in the creation, development and improvement of telecommunication and ICT equipment and networks in developing countries

- **Radiocommunication Sector** (**ITU-R**): The mission of the ITU-R is, inter alia, to ensure rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including those using satellite orbits, and to carry out studies and adopt recommendations on radiocommunication matters, by:

- holding World and Regional Radiocommunication Conferences and Seminars to expand and adopt Radio Regulations and Regional Agreements covering the use of the radio-frequency spectrum;
- approving ITU-R Recommendations, developed by ITU-R Study Groups (SG) in the framework set by Radiocommunication Assemblies, on the technical characteristics and operational procedures for radiocommunication services and systems;
- coordinating activities to eliminate harmful interference between radio stations of different countries;
- maintaining the Master International Frequency Register (MIFR); and
- offering tools, information and seminars to assist national radio-frequency spectrum management;
- carrying out studies and adopting recommendations on radiocommunication matters.

The ITU-R is the most relevant Sector for Wireless Technologies. Organized by the ITU-R, the most important events regarding the regulation of the use of the spectrum are the **World Radiocommunication Conference**s (WRC) that are held every three to four years and that are presented in Section 2.1.4. The next WRC-23 will take place in Dubai, United Arab Emirates from 20 November to 15 December 2023.

The **Radiocommunication Assemblies** (**RA**) are responsible for the structure, programme and approval of radiocommunication studies. They are normally convened every three or four years and may be associated in time and place with WRCs. The next RA will be held from 13 to 17 November 2023 in Dubai, immediately preceding WRC-23, The RA:

- assign conference preparatory work and other questions to the Study Groups;
- respond to other requests from ITU conferences;
- suggest suitable topics for the agenda of future WRCs;
- approve and issue ITU-R Recommendations and ITU-R Questions developed by the Study Groups;
- set the programme for Study Groups and disband or establish Study Groups according to need.

The ITU-R Study Groups develop the technical bases for decisions taken at World Radiocommunication Conferences and develop global standards (Recommendations), Reports and Handbooks on radiocommunication matters. More than 5000 specialists, from administrations, the telecommunications industry as a whole and academic organizations throughout the world, participate in the work of the Study Groups on topics such as efficient management and use of the spectrum/orbit resource, radio systems characteristics and performance, spectrum monitoring and emergency radiocommunications for public protection and disaster relief.

There are six Study Groups (SGs) specializing in the following areas:

- SG 1 Spectrum management (www.itu.int/ITU-R/go/rsg1)
- SG 3 Radiowave propagation (www.itu.int/go/ITU-R/rsg3)
- SG 4 Satellite services (www.itu.int/ITU-R/go/rsg4)
- SG 5 Terrestrial services (www.itu.int/go/ITU-R/rsg5)
- SG 6 Broadcasting service (www.itu.int/ITU-R/go/rsg6)
- SG 7 Science services (www.itu.int/ITU-R/go/rsg7).

Subgroups, known as Working Parties (WPs) and Task Groups (TGs) are established to study the questions assigned to the different Study Groups.

2.1.3.1 ITU-R Study Group 3 – Radiowave propagation

ITU-R SG 3 deals with the propagation of radio waves in ionized and non-ionized media and the characteristics of radio noise, for the purpose of improving radiocommunication systems. The technical work is carried out in the following four Working Parties:

- WP 3J – Propagation fundamentals. WP 3J provides information and develops models describing the fundamental principles and mechanisms of radiowave propagation in non-ionized media. Such material is used as the basis of propagation prediction methods developed by the other Working Parties
- WP 3K – Point-to-area propagation. WP 3K is responsible for developing prediction methods for terrestrial point-to-area propagation paths. In the main, these are associated with terrestrial broadcasting and mobile services, short-range indoor and outdoor communication systems (e.g. radio local area networks, RLAN), and with point-to-multipoint wireless access systems
- WP 3L - Ionospheric propagation and radio noise. WP 3L studies all aspects of radiowave propagation in and through the ionosphere
- WP 3M - Point-to-point and Earth-space propagation. WP 3M addresses radiowave propagation over point-to-point terrestrial paths and Earth-space paths, both for wanted and unwanted signals.

Meetings of the four WPs of SG3 are jointly organized once per year, usually in Spring. The last one was held at Geneva, Switzerland, in May-June 2023. The WP meetings have a technical orientation and produce proposals of changes of ITU-R Recommendations or additions of new ones as well as other technical documents (Handbooks, Reports, Fascicles). They are followed in some years by a general SG3 meeting, where the ITU-R Recommendations are approved.

Interest for ARIADNE

The topic of radiowave propagation is related to the activity of ARIADNE WP1. The proposals studied at the WP 3J, 3K and 3M meetings can be of interest, and the documents released can be of application for the ARIADNE activity. However, at the moment the number of documents discussed related to the D-band is limited.

In the last meetings, several proposals to modify current Recommendations on gas attenuation, cloud attenuation, rain specific attenuation, attenuation by vegetation, and

others were discussed. They can affect the D-Band. In particular, a revision of Rec. P.676 on gas attenuation has been published in 2022. A newer version could follow in the short term. Also, a revision of Rec. P.840 on cloud and fog attenuation may be published in the near future.

Technical work is in same cases originated by Liaison Statements (LS) coming from other SG of ITU or from other entities. Currently there is a LS on Propagation Issues in the range 116-260 GHz issued by CEPT WG on Spectrum Engineering and related to the protection of radioastronomy services. Because of the frequency range, some results could be of application to ARIADNE.

2.1.3.2 ITU-R Study Group 5 –Terrestrial Service

This Study Group focuses on systems and networks for fixed, mobile, radiodetermination, amateur and amateur satellite services.

Four Working Parties (WPs) carry out the studies on questions assigned to Study Group (SG) 5 and one Task Group (TG) which conducts studies on WRC-19 Agenda item 1.13.

- WP 5A: Land mobile service above 30MHz (excluding IMT), wireless access in the fixed service, amateur and amateur-satellite services
- WP 5B: Maritime mobile service including the Global Maritime Distress and Safety System (GMDSS), the aeronautical mobile service and the radiodetermination service
- WP 5C: Fixed wireless systems, HF and other systems below 30 MHz in the fixed and land mobile services
- WP 5D: IMT systems.

WP 5D is responsible for the overall radio system aspects of International Mobile Telecommunications (IMT) systems, comprising the IMT-2000, IMT-Advanced and IMT for 2020 and beyond. For the last 30 years, ITU has been coordinating efforts of governments and the industry in the development of a global broadband multimedia international mobile telecommunications system, known as IMT. Since the year 2000, the world has seen the introduction of the first family of standards derived from the IMT concept: IMT-2000. There are currently several billions IMT subscribers in the world and these systems are continuing to expand and evolve. IMT provides a global platform on which to build the next generations of mobile services – fast data access, unified messaging and broadband multimedia – in the form of exciting new interactive services.

Study Group 5 and its Working Parties maintain a number of Recommendations (www.itu.int/pub/R-REC) and Reports (www.itu.int/pub/R-REP) relating to the fixed, mobile, radiodetermination, amateur and amateur-satellite services. Study Group 5 is also responsible for the development of IMT, as illustrated in the following figure.

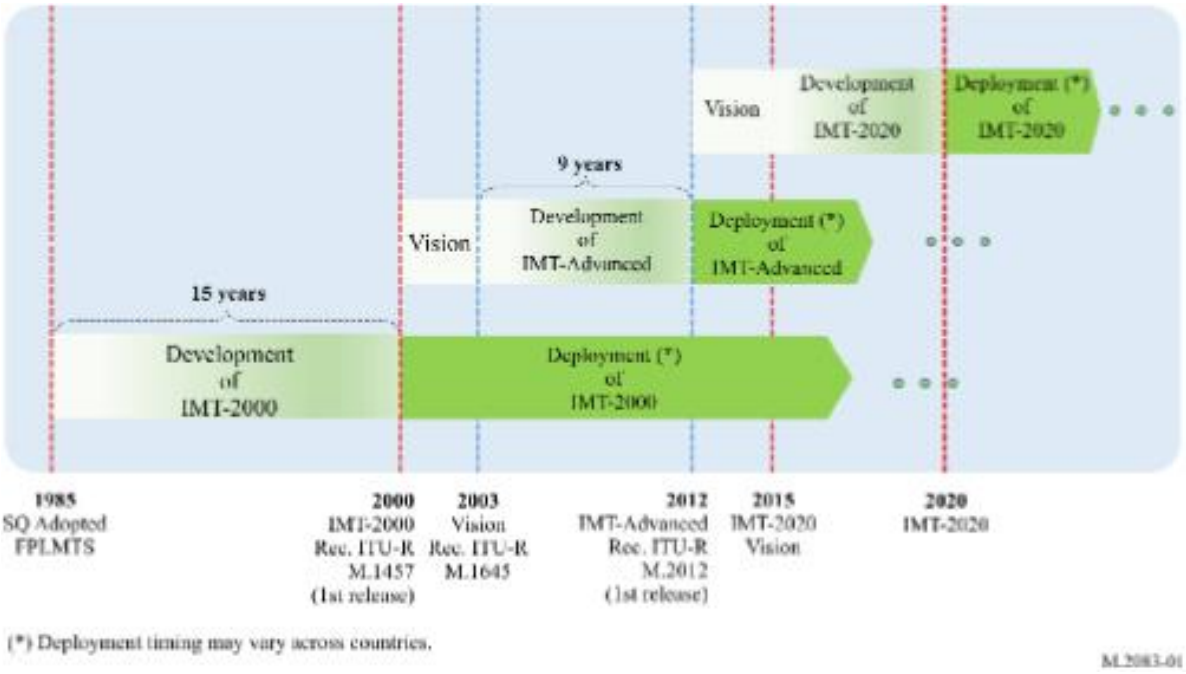

Figure 3: Development of IMT

IMT-2020 Evaluation Process

ITU-R has commenced the process of developing ITU-R Recommendations for the terrestrial components of the IMT-2020 radio interface(s). This work is guided by Resolution ITU-R 65. Resolution ITU-R 65 on the "Principles for the process of future development of IMT for 2020 and beyond" outlines the essential criteria and principles, which will be used in the process of developing the Recommendations and Reports for IMT-2020, including Recommendation(s) for the radio interface specification.

Report ITU-R M.2410 describes key requirements related to the minimum technical performance of IMT-2020 candidate radio interface technologies. It also provides the necessary background information about the individual requirements and the justification for the items and values chosen. Provision of such background information is needed for a broader understanding of the requirements. This Report is based on the ongoing development activities of external research and technology organizations.

Report ITU-R M.2411 deals with the requirements, evaluation criteria and submission templates for the development of Recommendations and Reports on IMT-2020, such as the detailed specifications of IMT 2020. It provides the service, spectrum and technical performance requirements for candidate Radio Interface Technologies (RITs)/Set of Radio Interface Technologies (SRITs) for IMT 2020.

Report ITU-R M.2412 provides guidelines for the procedure, the methodology and the criteria (technical, spectrum and service) to be used in evaluating the candidate IMT-2020 radio interface technologies (RITs) or set of RITs (SRITs) for a number of test environments. These test environments are chosen to simulate closely the more stringent radio operating environments. The evaluation procedure is designed in such a way that the overall performance of the candidate RITs/SRITs may be fairly and equally assessed on a technical basis. It ensures that the overall IMT 2020 objectives are met.

The first invitation for submission of proposals for candidate radio interface technologies (RITs) or a set of RITs (SRITs) for the terrestrial components of IMT-2020 was issued by WP5D in March 2016. This Circular Letter invitation also initiated an ongoing process to evaluate the candidate RITs or SRITs for the terrestrial components of IMT-2020 and invited the formation of independent evaluation groups (IEGs) and the subsequent submission of evaluation reports on these candidate RITs or SRITs.

In February 2017, WP5D announced the availability of Report ITU R M.2410 – Minimum requirements related to technical performance for IMT 2020 radio interface(s).

In July 2017, WP5D announced the availability of two new Reports ITU R M.2411 – Requirements, evaluation criteria and submission templates for the development of IMT 2020 and ITU-R M.2412 – Guidelines for evaluation of radio interface technologies for IMT 2020.

In December 2019, the successful closure for all IMT-2020 candidate technology submissions was announced (Step 3).

In March 2020, WP5D provided information on the completion of IMT 2020 evaluation process (Step 4) and announced the availability of the final evaluation reports from registered Independent Evaluation Groups (IEGs) as well as a consolidated summary.

ITU-R has determined that the IMT-2020 candidate technology submission proposals listed below have successfully completed Step 7 and all preceding Steps of the evaluation process, and thus are accepted for inclusion as IMT-2020 technologies in the standardization phase for IMT-2020 (Step 8). Candidate technology submissions accepted for first release of Recommendation ITU-R M. [IMT-2020.SPECS] are:

- Candidate SRIT submission from 3GPP proponent
- Candidate RIT submission from 3GPP proponent
- Candidate RIT submission from China (People's Republic of)
- Candidate RIT submission from Korea (Republic of)
- Candidate RIT submission from TSDSI.

In December 2020, this Recommendation was submitted for simultaneous adoption and approval by correspondence (PSAA), following the procedure of Resolution ITU-R 1/8 (§ A2.6.2.4). In February 2021, ITU-R has published the new Recommendation ITU-R **M.2150** '**Detailed specifications of the radio interfaces of IMT-2020**'. Following the successful evaluation of various radio technology candidates for IMT-2020 at the end of last year, the newly published Recommendation represents a set of terrestrial radio interface specifications which have been combined into a single document.
During 2021, further radio interface technologies (RIT) candidates have been undergoing the evaluation process by ITU-R (a.k.a. "IMT-process") and have been checked against the given requirements and worldwide compatibility of operation and equipment. As the outcome, a new RIT has been included in the draft revision: "**ETSI DECT 5G-S**RIT". ITU-R Study Group 5 adopted the 1st revision of ITU-R M.2150 (December 2021, www.itu.int/rec/R-REC-M.2150/en).
Further info on the developments in the IMT-2020 specification can be found on www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020.

IMT-2030

The work and discussions on a new timeline for IMT towards the year 2030 and beyond started in WP 5D #37 and during its meeting #41 (June 2022), ITU-R WP 5D agreed on the overview timeline for IMT towards the year 2030 and beyond.

ITU-R WP 5D held a full-day Workshop on "IMT for 2030 and beyond" in June 2022, with total 348 participants in an integrated physical and remote participants arrangement. The objective of the Workshop was to provide WP 5D delegates with an overview of ongoing worldwide research activities, initiatives, and views related to future mobile communications targeting 2030 and beyond. In this workshop a presentation was delivered by the technical manager of ARIADNE. (Details on the workshop can be found in https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/Pages/wsp-imt-vision-2030-and-beyond.aspx)

As one of the targets at the beginning of the process, ITU-R WP 5D developed a new ITU-R Report on "Future Technology Trends". At the meeting of the parent ITU-R SG5 in November 2022, this document has been agreed and was published as Report ITU-R M.2516.

In parallel to the Future Technology Trends, 2 other documents were developed within ITU-R as part of the IMT 2030 works:

- ITU-R Recommendation on a new "IMT-2030 Framework" (in former generations named "IMT-Vision")
- ITU-R Report on "Technical feasibility of IMT in bands above 100 GHz".

At its June 2023 meeting, ITU-R WP 5D has agreed the draft new Recommendation "Framework and overall objectives of the future development of IMT for 2030 and beyond" (for approval under Res. ITU-R 1-8), which can be considered as the basis for the standardization fora to develop the next generation of IMT standards. This draft Recommendation addresses:

- Trends of IMT-2030
- Usage scenarios of IMT-2030
- Capabilities of IMT-2030
- Considerations of ongoing development.

At the same meeting in June 2023, WP 5D agreed to elevate the report on "Technical feasibility of IMT in bands above 100 GHz" to a Preliminary Draft New Report (PDNR).

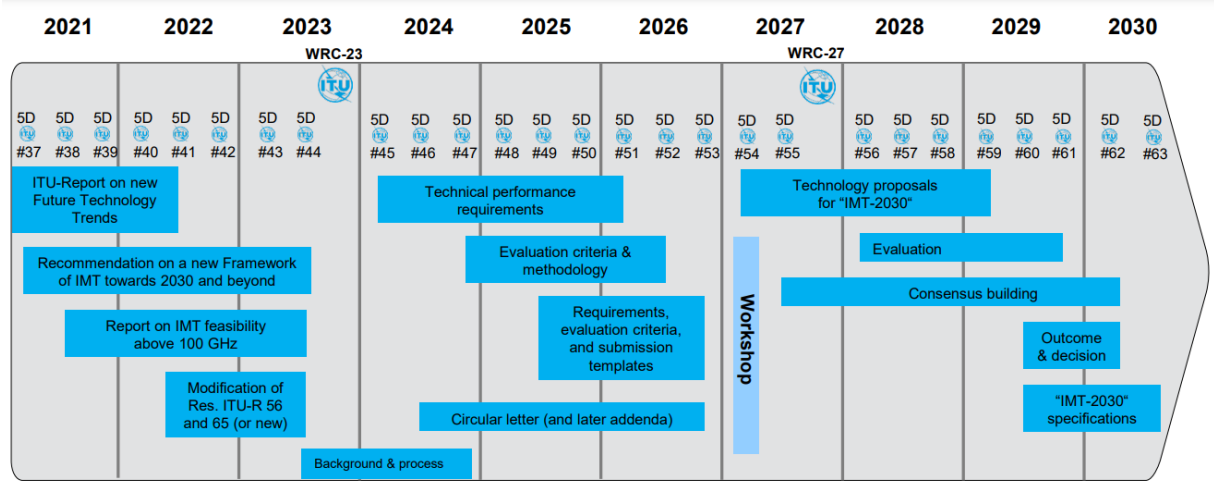

Figure 4: IMT-2030 and WRC Timeline

Interest for ARIADNE

The 3 documents are the results of a long process of elaboration of numerous contributions from ITU member organizations. Many ARIADNE concepts and ideas have been contributed during this process through UPRC technical contributions as part of the WWRF sector member submissions to WP5D meetings over the last 3 years along the ARIADNE project duration.

Moreover, the development within the ITU-R IMT-2030 process is of great significance for ARIADNE work and longer-term impact, since technical directions, trends and requirements agreed in ITU-R will shape the design of 6G systems.

2.1.4 ITU WRC-23

Organized by the ITU-R, the most important events regarding the regulation of the use of the spectrum are the **World Radiocommunication Conference**s (WRC) that are held every three to four years. It is the job of WRC to review, and, if necessary, to revise the **Radio Regulations** (RR), the international treaty governing the use of the radio-frequency spectrum and the geostationary-satellite and non-geostationary-satellite orbits. The last Conference (WRC-19) took place in Sharm el-Sheikh, Egypt in October-November 2019. The following one (WRC-23) will be held in Dubai, United Arab Emirates, from 20 November to 15 December 2023. The works to prepare the next WRC start immediately after the closure of the precedent one, within the ITU and other regulatory bodies such as CEPT in Europe.

The use of the spectrum is defined in the Article 5 of the Radio Regulations by the **Allocations** of the frequency bands. An allocation is officially defined as an "Entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more radio communication services or the radio astronomy service under specified conditions." The allocations are defined for the three ITU-R regions and complemented by notes that allow the incorporation of particular situations affecting some countries. Region 1 comprises Europe, Africa and part of Asia, Region 2 includes America and Region 3 the rest of the world.

Interest for ARIADNE

The future implementation and deployment of wireless systems in the D band will make use of the frequency bands allocated for the services of interest. It is relevant to know the current

situation of the allocations (already taken into account in the work of WP3) and their likely evolution in the future.

The Final Acts of WRC-19 do not change substantially the allocations in the range 100-200 GHz. Only the following changes are made to Art. 5 of the RR and published in the subsequent version of 2020.

- In the frequency bands 105-109.5 GHz, 111.8-114.25 GHz and 217-226 GHz, the use of this allocation is limited to space-based radio astronomy only
- The frequency band 155.5-158.5 GHz is allocated to the following services: FIXED, MOBILE and RADIOASTRONOMY for the three ITU Regions.

Additionally, Resolution 731 of WRC-19 invites the ITU-R to conduct studies the conditions for frequency sharing between active and passive services in several frequency bands above 71 GHz, some of them within the range of interest of ARIADNE.

Resolution 811 of WRC-19 defines a proposal of agenda for the next Conference WRC-23, including several urgent items. None of them is explicitly defined for the frequency bands of interest of ARIADNE.

Resolution 812 defines a preliminary agenda for the following Conference WRC-27, to be held in 2027. Again, none of the items make explicit reference to the frequency bands of interest for ARIADNE.

The conclusion that can be drawn is that a need to modify the current frequency allocations in the 100-200 GHz range has not been identified. The current allocations published in the 2020 edition of the Radio Regulations are not expected to change within the next decade.

More recently, the ITU has published a “Report of the CPM on technical, operational and regulatory/procedural matters to be considered by the World Radiocommunication Conference 2023”, with CPM meaning Conference Preparatory Meeting. The document, with more than 1000 pages, reflects the results of the meeting held in Geneva from 27 March to 6 April 2023. After careful analysis of the document, the conclusion described in the previous paragraph is confirmed. No modification of the current frequency allocations in the 100-200 GHz range has been proposed for consideration at WRC’23.

See references [2] [3] and [16].

2.1.5 ITU-T SG13

One of the three sectors under ITU is ITU-T, which coordinates and facilitates the establishment of ICT recommended standards for the telecommunications. These may impact the management, interoperability and reliable delivery of services in an efficient manner.
In order to come up with recommendations, various study groups (composed of expert members from private, public or related bodies) operate under ITU-T. There are three areas for which standards have been devised by the ITU-T, namely for cybersecurity, machine learning (ML) and video compression.

For ARIADNE, the Study Group 13 (SG 13) of the ITU-T, which deals with the application of machine learning in telecommunication networks, is particularly relevant.

As part of SG13, a focus group on machine learning for future networks including 5G (shortly FG-ML5G) was established in November 2017 [4]. In nearly 3 years of its activity, the FG-ML5G recommended 10 technical specifications. These serve as recommendations to address machine learning in future networks regarding interfaces, network architectures, protocols, algorithms and data formats. Some of the specifications published by this group are well aligned with the work in ARIADNE especially the specification on "Architectural framework for machine learning in future networks including IMT-2020" (codenamed as ITU-T Y.3172 and completed rather recently on January 2020). Some key aspects on the relevance of the Y.3172 specification to ARIADNE are presented below.

Interest for ARIADNE

The specification Y.3172 (Architectural framework for machine learning in future networks including IMT-2020" (ITU-T Y.3172) is arguably one of the most impactful of FG-ML5G specifications. Hence, it was of interest for ARIADNE. It proposes a reference architecture, which highlights far reaching measures that need to be planned and put in place before machine learning models are trained and operationalized. The specification addresses the potential challenges of decentralization to train the models at the core and edge of the networks. This is undoubtedly an under-addressed area - not just in telecommunication but other industries and businesses, as recent market surveys and studies found that deployment of ML models in production remains low [5]. This is partly due to the lack of guidelines and standards.

The Y.3172 specification further addresses the use of containers for managing large-scale orchestration of ML models and functions. At the heart of the proposed reference architecture is the concept of ML pipelines, which serve as a discrete unit of work that may encapsulate a specific functionality like fetching heterogeneous data from diverse sources, pre-processing data, training a model, triggering retraining or model updates, making predictions on incoming data, triggering an action in regards to a run time event, and scaling up the resources to maintain QoS performance levels. With ML pipeline as a loose-coupling artefact, various network layers can be integrated together. This enables the development of contextually aware, advanced AI and ML functions, which on one hand, harness cross modular information for making improved automated decisions in real time and on the other hand, can be realized in a common approach which eases long term maintenance. However, it cannot be ignored that these design recommendations are yet to be broadly adopted and tested so ML related guidelines ought to be applied rather pragmatically.

Relating with Y.3172 recommendations

As far possible, work in ARIADNE has been shaped along several standardization concepts proposed in Y.3172 if not all. ARIADNE does not aim at a unifying software technology stack because the focus was on solving hard problems in multiple tiers of beyond 5G wireless architecture. Nevertheless, the recommendations in Y.3172 are of interest as there are several areas, especially concerning the application of Machine Learning, where they may be beneficial to future-proof our work. One possible means of compliance is to abide by and adopt the pipeline-based design of Y.3172 standard. Towards this, we sketch out the following highlights:

- One of the foundational concepts in Y.3172 is to develop data processing and machine learning functionality as a pipeline. A typical pipeline consists of nodes that perform

ETL (Extract Transform Load) operations. Pipelines can extract data from diverse sources, perform transformations on data and store the updated data in the required sinks). Training ML models, updating them, measuring their performance and applying them to get predictions on new unseen data in real time, should also be developed as pipelines. The basic reasoning behind pipeline design is re-usability of a modular unit of work and its unifying capability to integrate disparate sub-systems, which are prevalent in telecommunication networks

- The Altair RapidMiner approach to build ETL and ML functionality is also pipeline based, with the ease to create pipelines visually. This approach proved of interest and was leveraged for ARIADNE. Moreover, Altair RapidMiner pipelines are not limited to any particular implementation language or execution environment and can integrate many native environments and disparate sources by exposure as web-service endpoints.
- The Y.3172 specification argues for an ecosystem or management tooling around the pipelines to manage large-scale deployment and orchestration of ML and AI functions across different layers of the network (both at core and edges with restrained resources). These recommended capabilities exist in Altair RapidMiner platform, which can be used to benefit any future work based on ARIADNE outcomes.

Other industrial standards in ML and their current standing in the market

- PMML [6]
  - The Predictive Model Markup Language (PMML) is an XML-based model interchange format, that can be used to describe a predictive model (e.g. a machine learning model) using the XML schema provided by the standard. The PMML models may be reconstructed at different systems and hence allow for inter-operable exchange. It has been developed by the Data Mining Group (DMG) [7], which is an independent vendor-led consortium that develops data mining standards.
- PFA [8]
  - The Portable Format for Analytics is a JSON-based interchange format, that can also be used (much like PMML) to describe a predictive model. The PFA has also been developed by the Data Mining Group.
- De-facto standards
  - Although the DMG standards are gradually becoming more popular in AI/ML tools, the scientific and industrial landscape regarding the AI/ML methods and technologies is changing very actively. This has resulted in niche and agile players to surface as market leaders when it comes to developing AI/ML products. This is because these products have demonstrated technical depth and rapid innovation expected by different verticals and market segments - earning them a strong position in the AI/ML industry. For instance, the Gartner magic quadrant reports for Data Science and Machine Learning platforms [9] for the last 6 years, placed RapidMiner and of course some other vendors of AI/ML software as industrial leaders. This has led to the recognition of some vendor-specific approaches as de-facto standards in their own rights. Therefore, such state-of-the-art approaches and products are arguably leading the industrial adoption of AI/ML by making these complex methods easier to use, which delivers their customers a competitive edge through value-added enterprise ready services.

The study group SG13 continued the work of the previous focus group FG-ML5G on applying machine learning to 5G communications and the automation of the networks. However, these groups also continue to evolve themselves. The work direction of the new group(s) aligns well with ARIADNE in terms of objectives. This direction includes autonomous networks and ARIADNE has been following this group for key outcomes that complemented project objectives.

2.1.6 ETSI ISG mWT

The ETSI Industry Specification Group (ISG) on Millimeter Wave Transmission (MWT) is focused on the frequency spectrum 6-42 GHz and 50-300 GHz for backhaul and fronthaul applications [ETSI-0], [ETSI-1]. Tracking the activities and upcoming meetings can be best achieved through their main web site [ETSI-0], while [ETSI-1] provides a more descriptive summary of the work.

Huawei Technologies in the UK chairs the group currently. The ARIADNE partner Nokia participates actively in this group through their colleagues in Italy. As the name of the group indicates, it is a mostly industry driven organization. Members comprise major 5G / mobile network stakeholders, including operators world-wide and suppliers, e.g. Vodafone, Deutsche Telekom, BT, Huawei, NEC etc. However, it is possible for non-member organizations to participate by technical contributions and attend meetings without having voting rights.

The group releases white papers and Group Reports that consider contributions from industry participation in research projects and direct funded industrial research and development work. The most significant recent publication for ARIADNE is [ETSI-2], which analyses and proposes the use of current D-band spectrum, based on the ITU-R Radio Regulation from 2016. As of today, this is probably still the most comprehensive summary of the industrial state of the art and latest transmission experiments. Also, of high interest for ARIADNE is the Group report on the 5G Wireless Backhaul / X-Haul [ETSI-3]. During the year ISG mWT continued its regular liaison with ETSI's Technical Committee ATTM TM4 on antenna and equipment, in particular for systems operating in the so-called D-Band frequency range (130-174,8 GHz) and W-band frequency range (92−114,25 GHz). This demonstrates the high interest in this field and opens up the opportunity to actively contribute with the achievements by the Ariadne project.

Interest for ARIADNE

Since ETSI ISG mWT started to focus on the evolution of 5G and Fixed Wireless Access beyond 2020 in recent years, considering also more and more the spectrum above 100 GHz, ARIADNE can perfectly contribute with its work to those activities through the industrial partners. Both Group Reports on the D-band spectrum show that ETSI ISG mWT may be a very relevant platform to interact with and present the results of ARIADNE. The next meetings are scheduled for February and May 2021 [ETSI-0]. Although, so far, the focus of the released reports was mostly on radio technologies and propagation / transmission aspects [ETSI-4], which are rather topic to WP1 and WP3, it is expected that all technical work packages WP1, WP2, WP3, WP4 and WP5 may contribute in the future. E.g., one can easily anticipate that the considerations on SDN related to microwave and millimeter wave transmission can be extended by new AI-based and RIS-based ideas arising from the work of WP2 and WP4.

See References [10] - [14].

2.1.7 ECC SE19

The Electronic Communications Committee (ECC) is one of three business committees of the European Conference of Postal and Telecommunications Administrations (CEPT).

The Electronic Communications Committee (ECC) brings together 48 countries to develop common policies and regulations in electronic communications and related applications for Europe, and to provide the focal point for information on spectrum use. Its primary objective is to harmonize the efficient use of the radio spectrum, satellite orbits and numbering resources across Europe. It takes an active role at the international level, preparing common European proposals to represent European interests in the ITU and other international organizations. ECC works with all stakeholders, the European Commission and ETSI to facilitate the delivery of technologies and services for the benefit of society.

Two of the ECC's main outputs are "Decisions" and "Recommendations" on major harmonization issues. ECC Reports and CEPT Reports are studies which respectively inform ECC Decisions and Decisions of the European Commission; the latter are binding on EU Member States.

WG SE (Spectrum Engineering) is one of the Working Groups supporting ECC and specifically SE19 is dedicated to Fixed Services (FS).

The main objectives of ECC SE19 are to:

- Prepare harmonized frequency plans and guidelines for introducing novel broadband applications in the FS;
- Study developments in new FS technology;
- Study compatibility/sharing issues involving traditional FS (such as radio relay links) as well as broadband FS applications;
- Co-ordinate the relevant activities in ITU-R;
- Liaise/contribute to ETSI ATTM/TM4 in accordance with the CEPT/ETSI MoU.

Two deliverables of the group, related to D-band and publicly available are:

- ECC/REC/(18)01 - Radio frequency channel/block arrangements for Fixed Service systems operating in the bands 130 - 134 GHz, 141-148.5 GHz, 151.5-164 GHz and 167 - 174.8 GHz (April 2018)
- ECC Report 282 - Point-to-Point Radio Links in the Frequency Ranges 92-114.25 GHz and 130-174.8 GHz (September 2018).

Interest for ARIADNE

The group has already published work on D-band which is important. Moreover, the group accepts contributions from new participants after following a certain procedure. Under these conditions, there is ground to interact with ECC SE19 which cooperates with ETSI TM4.

During ARIADNE life, NCSRD was registered to ECC SE19 and was following the activities of the group. Through NCSRD, ARIADNE proposed to contribute regarding D-band channel

measurements and modeling. However, the forthcoming meetings of the group were dedicated to Fixed Services with strict deadlines to complete the workplan. ARIADNE will continue to interface with the group and seek for opportunities to contribute in the near future, exploiting the project results on D-band channel characterization.

2.1.8 WWRF - Wireless World Research Forum vision and activities

The Wireless World Research Forum, (http://www.wwrf.ch/) is an influential forum and a place to promote new ideas for advanced technologies and novel system concept that define wireless evolution. WWRF organizes two meetings a year, following the format of technical workshops where research contributions are invited by members and non-members and proceeding are made available to the meeting attendees and to WWRF members. The forum organizes workshops and special sessions at international conferences and regular seminars and webinars on cutting-edge wireless research and innovation topics. Furthermore, it produces “Outlooks” (white papers) and various edited books and magazine publication series, as means for disseminating innovative visions and discuss technology evolution trends.

The work within WWRF is organized in a number of working groups illustrated in the following figure. Additional to the plenary WWRF meetings, the working groups hold separate meetings focusing on specific research and technology topics.

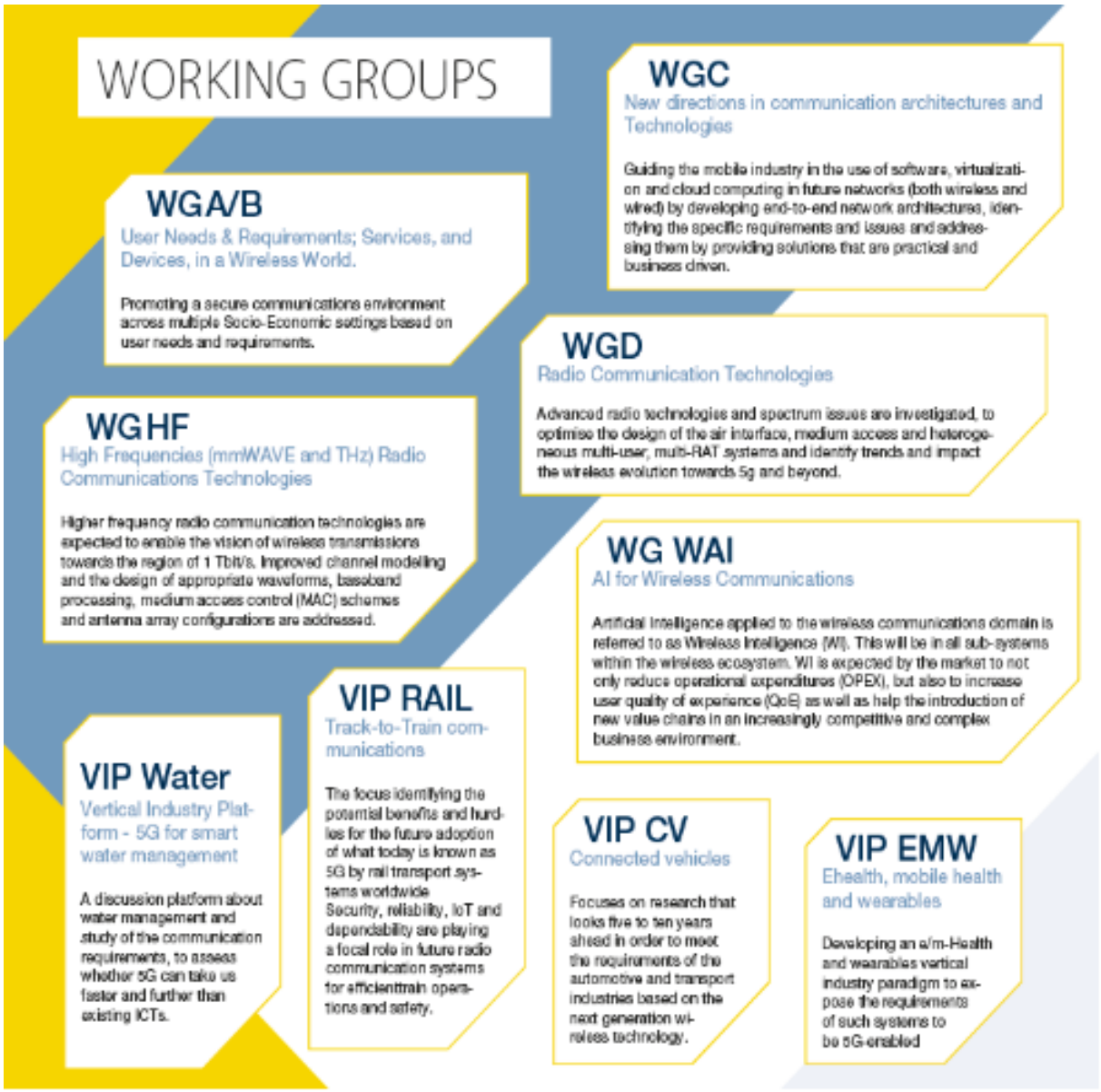

Figure 5: The structure of WWRF in working groups

The UPRC group in ARIADNE project has been an active member of the WWRF, assuming several leadership roles over the last 20 years, with main focus on the WWRF Working Group D on Radio Communication Technologies and on the Working Group on High Frequencies Radio Communications. The latter has been established in 2016 and aims at studying and building consensus around enabling technologies for the mmWave and THz bands.

Working Group D (WGD) on Radio Communication Technologies addresses research aspects focusing on the air interface for wide-area and local-area wireless communication systems, spectrum issues and other distributed resource sharing for future wireless systems. In particular, WGD covers topics such as multi-carrier air interfaces, smart antenna and MIMO technologies, cooperative communications, interference management, cross-layer design, overhead signaling and complexity issues. Physical-layer security of wireless systems is also covered in this working group.

As wireless networks evolve beyond IMT-2020, challenging requirements resulting from the ever-decreasing cell size along with the explosive increase in the number of cells and the number of users and devices to be connected, breaking the interference barrier and maintaining the per user/node capacity will need powerful PHY/MAC cross-layer design and emphasis on the optimization of performance versus complexity/overhead trade-off. New technology enablers (e.g. massive MIMO, Reconfigurable Intelligent Surfaces etc.) and new extreme resources opportunities (e.g. THz communications) are attracting a great amount of interest in this WG. These activities have - from time to time and when it was considered appropriate - resulted in the creation of more focused WWRF working groups, such as the Working Group on High Frequencies.

The vision of the WG on High Frequencies is to provide a discussion platform/thinktank, by engaging a critical mass of experts from industry, regulators and academia, in order to investigate the trends, requirements, enablers and challenges in the specification, design, optimization and adoption of high frequencies radio technologies in future wireless networks. The main objectives of this WG are to

- Study the requirements and research and technology challenges for high frequencies radio communications
- Report of the advances on channel modeling, physical layer and wireless access issues
- Facilitate collaborations and consensus building among various experts and actors
- Organize workshops to encourage dissemination and interactions
- Follow/participate/contribute to research/technology/regulatory/ standardization fora (e.g. NGMN, 5G-PPP, ITU-R, IEEE, etc.).

Over the last ten years, WWRF has championed several cross-working group activities focused on the wireless evolution to and beyond 5G, including workshops and special sessions, presentations, white papers and journal special issues. The ongoing effort to roll out 5G technologies, and the ongoing debate on how to meet the requirements of the various vertical industries that will make use of 5G are being studied within WWRF and publications such as Outlook series are a good guide to them. But the mission of WWRF is to look beyond current technology and businesses to identify the key research trends that will impact wireless world in the next 5-10 years.

As an example, the Vertical Industry Platform (VIP) programme of working groups focuses on vertical industry requirements, including connected vehicles, e-health, rail networks and the water industry, while new technical working groups have been set up to address key technology questions, such as the impact of AI technologies on communication networks.

ARIADNE project results could be disseminated within the Working Groups on High Frequencies and AI for Wireless Communications. ARIADNE vision, system concept and architecture could provide input to the beyond 5G discussions within WWRF.

WWRF and IMT-2020 evaluation process

WWRF has been very supportive of the ITU's evaluation process for IMT-2020 and participated as an independent evaluation group (IEG). A group of interested members was formed in 2018 to investigate how WWRF could implement the evaluation procedure. Available resources dictated that WWRF was not able to provide a complete evaluation in all use cases but has

concentrated on those of most importance to our members, in particular those working on developing IMT-2020 in emerging and developing markets.

Based on the individual studies of the IEG members and the discussions and consensus reached, the WWRF IEG decided to focus their evaluation on the proposals submitted to ITU-R by Nufront [1] and TSDSI respectively [2] and a small project team was formed to progress this work.

A WWRF working group ('ITU EVAL') and dedicated sessions within the WWRF conferences were organized. The WWRF IEG has studied the various features and technologies proposed and provided an assessment by inspection, analysis and based on simulation results, where it was deemed necessary. The assessment was submitted to the ITU WP5D in time for the February 2020 Meeting #34 in the form of a document entitled: "FINAL EVALUATION REPORT FOR RIT SUBMISSIONS FROM TSDSI (IMT-2020/19) AND NUFRONT (IMT-2020/18)" (Document noted by ITU WP5D as 5D/120). The team participated in the face-to-face Meeting #34 held in Geneva, during 19-26th February 2020, where it supported the evaluation outcomes.

The official IMT-2020 evaluation process was planned to be completed in June 2020. However, as the evaluation of two of the proposals was not conclusive, an extension has been granted targeting the complete evaluation of the two pending proposals, namely Nufront and ETSI DECT proposals. The WWRF IEG was involved in the further evaluation of these proposals, which was completed in October 2021 (WP5D meeting #39). The WWRF IEG was further involved in the follow up evaluation process "after year 2021" that was completed in October 2022.

WWRF and IMT-2030 process

WWRF as a sector member of ITU has been heavily involved in the IMT 2030 works and the development of the 3 reports, namely

- "Future technology trends of terrestrial International Mobile Telecommunications systems towards 2030 and beyond"
- ITU-R Recommendation on a new "IMT-2030 Framework" (in former generations named "IMT-Vision")
- ITU-R Report on "Technical feasibility of IMT in bands above 100 GHz".

UPRC through its participation/leadership role in WWRF has contributed many ARIADNE innovations to this work.

2.1.9 THz Interest Group within IEEE (IEEE 802.15.3d)

The IEEE standards are mostly familiar to public from the various 802.11 based wireless local area network (WLAN) standards. The IEEE also has close proximity (short range communications) standards, such as 802.15 wireless personal area network (WPAN) standards. Among the .15 family of standards, we can find one of the first standards for +100 GHz bands. The 802.15.3d standard [15] is developed for the lower THz band from 252 to 325 GHz. This is part of the high rate WPAN standards (.15.3) and formally supports data rates of +100 Gbps.

The 802.15.3d has been developed by IEEE 802.15 WPAN Terahertz Interest Group (IGthz) led by Thomas Kürner. The 802.15.3d supports two different physical layer (PHY) techniques; **THz on-off keying** mode PHY (THz-OOK PHY), and **THz single carrier** mode PHY (THz-SC PHY). The former is meant to be simplified version of the standard for simple devices whereas the single carrier mode offers the full data rate via carrier-based modulations (pi/2 BPSK, pi/2 QPSK, pi/2 8-PSK, pi/2 8-APSK, 16-QAM, and 64-QAM).

Both PHY techniques rely on the same channeling formed of various possible bandwidths (2.16, 4.32, 8.64, 12.96, 17.28, 25.92, 51.84, and 69.12 GHz). The number of sub-bands for the whole 252 – 325 GHz band depends on the chosen bandwidth. The total throughputs vary greatly depending on the bandwidth, coding and modulation, and pilot words. The THz-OOK PHY has a throughput range from 1.29 Gbps to 59.14 Gbps. The THz-SC PHY has a throughput range from 1.13 Gbps to 315.39 Gbps. It should be noticed that the maximum data rates herein require very high receiver sensitivities up to -32 dBm.

Given the specifications above and in the standard itself, similar channeling and data rates would be possible to utilize at the D band (110 – 170 GHz). The D band is more fragmented due to reserved bands. But in principle the 802.15.3d could be partially realized on the D band as well. The IEEE 802.15.3d can be better benchmarked against the ARIADNE channel models when those are ready to find out how the .15.3d would work in the D band.

The future proposals for 802.15.3d based on the ARIADNE results as well as new project activities will be considered. Particularly interesting, would be the inclusion of the D band in the standard. The future proposals will be up to the research activities after the ARIADNE, but in the case of the potential proposals, the ground work done in ARIADNE is very valuable background for the proposals considering particularly physical layer methods at the D band.

2.2 ETSI ISG RIS

The ISG-RIS was established in September 2021 for a duration of two years. It was recently extended for another two years. During the first two years, five work items were identified and discussed. Two work items, one on "Use Cases, Deployment Scenarios and Requirements" and another on "Communication Models, Channel Models, and Evaluation Methodology" were recently finalized and approved. The second work item was led by CNRS as Rapporteur. Recently, other work items were proposed and are under discussion on hardware implementation, multi-function RIS, and the analysis of the diversity and spatial multiplexing tradeoff of RIS. The ISG is composed of 44 members and 4 participants.

The ETSI ISG RIS group was formed as a platform for ETSI members to look into pre-standardization of RIS technologies. ISG RIS looks into various aspects of RISs, including usage scenarios, RIS models, and channel models. This group also studies potential gaps in research in existing standards in SDOs and networking architectures. The goal of the ISG RIS in the end is to produce pre-standardization reports for

1) RIS use cases, deployment scenarios and requirements,
2) RIS technological challenges, architecture and impact on standardization, and
3) RIS communication models, channel models, and evaluation methodology.

Further information on the ETSI ISG RIS terms of reference, work programme, planned deliverables, and other documentations are available through the ISG portal, https://www.etsi.org/committee/1966-ris.

Interest for ARIADNE

Three ARIADNE partners are part of this group and among the founding members: CNRS, UOULU, and UPRC. These groups have also participated in the work and proposals for usage scenarios, communication models and system models. The work of this group is ongoing and will continue beyond ARIADNE project with the above partners continuing to participate and produce proposals for the ISG RIS group.

This is very important activity for ARIADNE as the metasurfaces and RISs are in the focal point of the ARIADNE project. Hence, the work in the ARIADNE has and will have impact on the pre-standardization work in ISG RIS. The existing participating ARIADNE partners will continue the work in this group in the future.

2.3 ETSI ISG THz

ETSI Industry Specification Group (ISG) THz provides the opportunity for ETSI members to share their pre-standardization efforts on THz technology resulting from various collaborative research projects and being extended with relevant global initiatives, towards paving the way for future standardization of the THz technology. The group concentrates on establishing the technical foundation for the development and standardization of THz communications (0.1 - 10 THz).

The scope of the ISG THz contains the definition of target scenarios and frequency bands of interest; the analysis of specific radio propagation aspects for THz communication, such as molecular absorption, effect of micro-mobility, specific considerations for scattering, reflections, and diffractions, and considerations for near-field propagation; the analysis of data from earlier measurement campaigns published in relevant literature; the performance of channel measurements for the selected scenarios and frequency bands; the development of channel models for the selected scenarios and frequency bands; the establishment of baseline for THz technology fundamentals, including antenna assumptions, simulation assumptions, and deployment strategies; the assessment of the state-of-the-art materials for THz communication e.g., electronics, photonics, plasmonics; the study of the feasibility of different channel bandwidths considering component technologies, circuits and systems; the study of the effects of RF hardware; the characterization of RF/analog impairments based on simulations/measurements and obtain suitable RF impairment models in THz frequency range; the study of the low complexity large antenna array and packaging technologies; assessment of overall device complexity and cost impact; the study of the state of art for RF subsystems (transceiver, front end, antenna) in the THz frequency range; the study the energy efficiency of state-of-the-art materials and RF subsystems on transmission and/or reception.

The four initial Work Items approved are:

- Identification of use cases for THz communication systems
- Identification frequency bands of interests for THz communication systems
- Channel Measurements and modeling in THz Bands
- RF Hardware Modeling.

ISG THz prepares systematic output on channel models, system parameters, and evaluation assumptions for the evaluation of THz communication systems. ISG THz encourages a continual exchange with relevant standardization groups/bodies (either inside or outside of ETSI) to ensure they are informed and consider the work of ISG THz in their further relevant technology specifications developments.

Further information on the ISG THz terms of reference, work programme, planned deliverables, and other documentations are available through the ISG portal, www.etsi.org/committee/2124-thz.

Interest for ARIADNE

Three ARIADNE partners are part of this group and among the founding members: UPRC, UOULU, and CNRS. These groups have also participated in the work and proposals for the work items in progress. The work of this ISG is ongoing and will continue beyond ARIADNE project with the above partners continuing to participate and produce proposals for the ETSI ISG THz group.

2.4 Working list

It has been important to follow ongoing standardization activities at different standardization bodies, interest – or working groups. The main target has been to identify bodies or groups most relevant to ARIADNE work and start to follow them up on subjects which are relevant to ARIADNE. When ARIADNE outputs has been available, the idea has been to share those with targeted bodies or groups to synchronise with related standardization activities.

To observe relevant standardization bodies, a list of bodies of potential interest to the project has been created. In this working document, information on who shall be following, and later also who will be contributing, to specific standardization bodies is included. This document has been saved to ARIADNE working directory at Onlyoffice.

3 Activities, contributions and alignment with standardization

3.1 Contribution to ITU-R WP 3J

Results of the work carried out in ARIADNE WP1 have been contributed to several meetings of ITU-R SG3 Working Party 3J on Propagation fundamentals. The documents contributed and the results of the discussions are briefly described in the following.

Document 3J/136-E "Variability of rain specific attenuation evaluated from drop size distributions" was presented in the meeting of June 2021 and described the general results of WP1 on this topic. These results were novel and opened a line of study not considered before.

Document 3J/198-E "Draft of a proposed revision of Recommendation ITU-R P.838-3" proposed the incorporation of a new Annex on the variability of rain specific attenuation at 80-200 GHz, developed on the results of WP1 of Ariadne. It was presented at the meeting of May 2022. The proposal was kept as a working document for future meetings. The discussion was generally positive, the main concern being the fact that the data supporting the model came from a single site: Madrid (Spain) and this was considered not sufficient to propose a model of general applications.

In the recent meeting of May 2023 a new document 3J/294-E "Rain attenuation of millimeter waves investigated from drop size distributions" was presented with more advanced results on the topic. Interestingly, Korea presented in document 3J/265-E "Proposed revision to Recommendation ITU-R P. 838-3. Attenuation model proposal for rain at 240-300 GHz the results of some analysis carried out with the inspiration of our 3J/198-E of the previous meeting. These results are largely coincident with ours, so they are a good confirmation of our procedures and conclusions.

As a continuation of this work beyond the time allocated to this project, access has been gained to new data from two other sites, one in Europe and the other in South-Western Asia. The results obtained from the analysis of the new data, together with the contribution of Korea, will eventually be supporting a new proposal of modification of ITU-R Rec. P.838-3 to be presented at the WP3J meeting of Spring 2024.

3.2 Participation in 6G-IA Pre-Std WG

6G-IA Pre-Std Work Group is a cross project WG where participants are coming from ongoing 6G IA or 5G PPP projects. Purpose and target of group is defined at Terms of Reference as for all other 6G IA and 5G PPP groups. Purpose has been defined at following way: "The purpose of the WG is to facilitate impact creation by the running research projects, in particular towards relevant standardization bodies (e.g. 3GPP, ETSI, IETF, IEEE, ITU-T, ITU-R), pre-standardization bodies and industry fora, alliances, associations or consortia (e.g. GSMA, NGMN, 5GAA, 5G-ACIA, UIC, O-RAN, TIP, PSCE, IALA, ECHA, EBU/5G MAG, ESOA, a.o.). This is achieved by fostering activities serving as a bridge between research projects and standardization. The activities should provide indications to research projects on the expected standardization trends and requirements and should provide standardization bodies with insight on objectives and results of research projects."

The main objective of WG is to share relevant information about standardization trends, requirements, and activities. It should facilitate the dissemination of research projects objectives and results to interested standardization, pre-standardization bodies and industry

for a, associations or consortia. WG should also track and disseminate the standardization and pre-standardization activities performed by research projects.

Main activities of WG are to collect and broadcast relevant information by questionnaires, information meetings, workshops, webinars, maintaining and promoting web databases etc. [17].

Ariadne has been participating regularly to 6G Pre-Standardization WG work. Work Group activities have been versatile and providing extensively information relating to standardization activities performed by other projects, sharing information about all proceedings, fairs, workshops, etc. and collecting and reporting activities performed by participating projects toward Standardization Organizations (SDO).

Information sharing has been playing important role of WG's daily work. Participating projects have been introducing and sharing their activities and experiences related to standardization. There have been interesting presentations from participants from multiple area and subjects. Some have been regular activities or alternatively individual updates. Regular updates have been covering issues like 3GPP plenaries, ETSI workshops, etc. Individual presentations have been covering fairs (e.g., EUCNC 6G Summit or Special sessions), multiple stardardisation related or future oriented different kind of webinars. Also, presentation content has been covering many workshops like ETSI, Hexa-X 2, ISO Initiative, SNS phase 1, etc and fair session reports.

One important role of Pre-standardization WG has been to collect 6G-IA and 5GPPP project activities regularly. Projects have been reporting their activities quarterly and from that information a summary report of activities toward SDO organizations has been created.

3.3 Alignment with 3GPP

To support a new AI/ML-enabled radio interface for the next cellular systems, 3GPP started in 2022 a new study item (RP-213599) for Release 18. Beam management is one of the different pilot use cases for applying AI/ML model in the NR radio interface. The different pilot use cases will also serve to identify a common AI/ML framework, including functional requirements of AI/ML architecture, which could be used in subsequent releases and will pave the way for the design of native AI/ML 6G networks.

The Rel18 beam management use case is studied for spatial and/or time beam prediction (see figure below). The scope of spatial beam prediction (BM-Case1) is to predict the best DL Tx beam and/or DL Tx/Rx beam pairs in different spatial locations. Conversely, time-domain beam predictions (BM-Case2) aim to predict the best DL Tx beam and/or DL Tx/Rx beam pairs beam to use for next time instants. *The primary motivation for supporting AI/ML-based beam management in the standard is overhead savings and latency reduction*. It has been shown that ML algorithms enable predicting the serving beam for different UE locations and time instances, thus avoiding measuring the actual beam quality and saving those resources to be employed for data transmission and/or for the UE to increase the length of DRX. On the other hand, beam scanning operations like those performed in P1, P2 and P3 are time inefficient and not scalable when the size of antenna arrays increases which is clearly the trend of mobile network evolution. Therefore, ML algorithms can replace sequential beam scanning by recommending a reduced set of beams likely to contain the best beam index of the full scan.

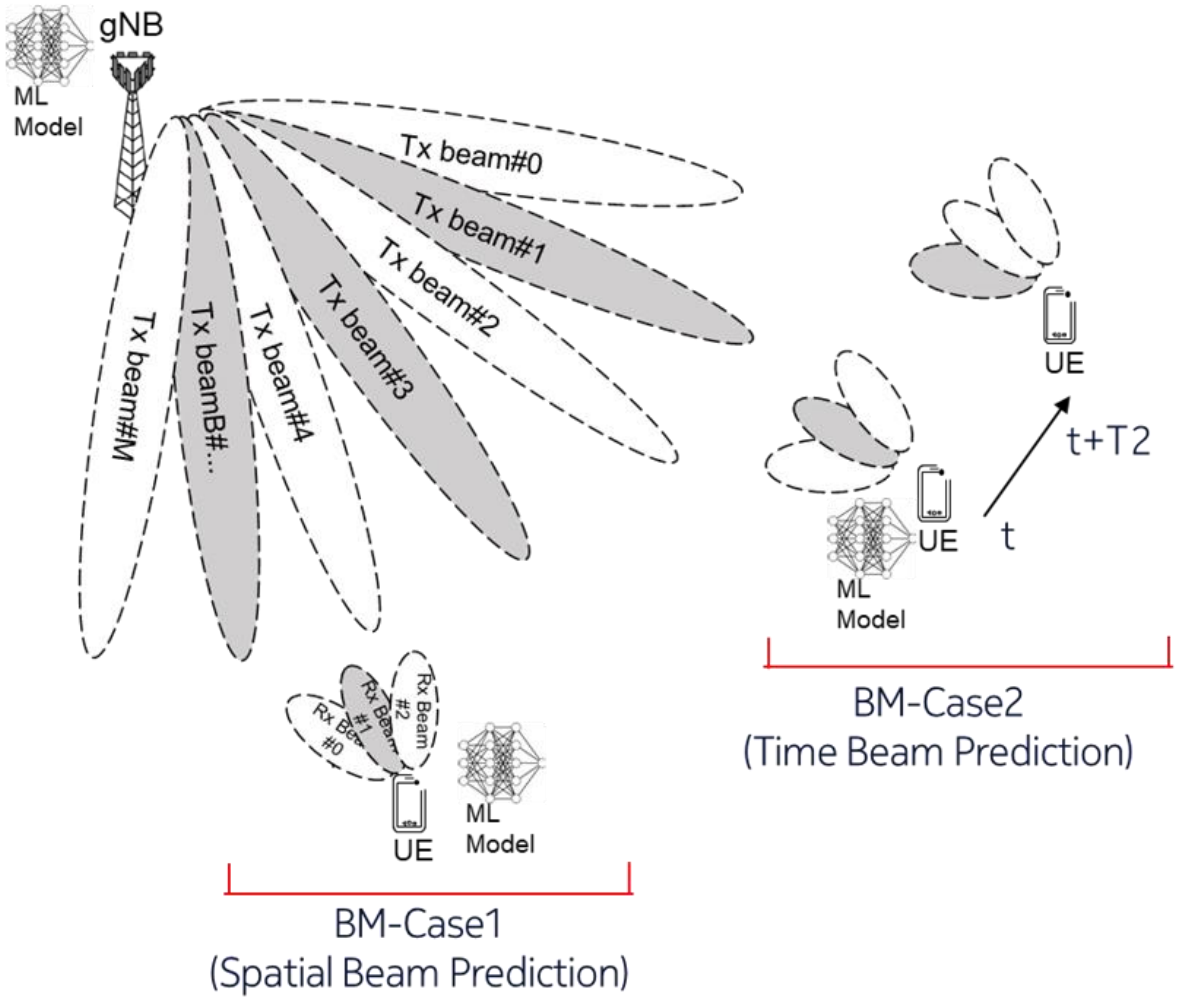

Figure 6: Beam prediction

This 3GPP case is a good example of subjects that are covered by ARIADNE and supporting work done towards 3GPP. Study subjects of ARIADNE have been selected a forward-looking attitude to support issues expected to be addressed in the future.

3.4 Contributions to ITU-R IMT-2030 works

As mentioned in the previous chapter, UPRC as lead participant of WWRF sector member participation/involvement in ITU-R WP5D, has been extensively contributing to the works of WP5D towards IMT-2030 Vision and Future Technology trends. In these contributions reference to ARIADNE system concept, technologies and usage scenarios has been made. Some representative examples of these contributions are provided below.

- A contribution (by WWRF, prepared by UPRC) [ITU-R WP5D Document 5D/635-E, 38th WP5D Meeting, May 2021] proposes the ARIADNE system concept, technologies and architecture. This contribution was submitted for consideration in the draft new Report ITU-R M.[IMT.FUTURE TECHNOLOGY TRENDS TOWARDS 2030 AND BEYOND]

- A contribution (by WWRF, prepared by UPRC) [ITU-R WP5D Document 5D/822-E, 39th WP5D Meeting, October 2021] proposes 3 (out of 4) usage scenarios inspired by the ARIADNE usage scenarios. This contribution was submitted for consideration in the draft new Recommendation ITU-R M.[IMT.VISION 2030 AND BEYOND].

A text contribution was submitted (by WWRF, prepared by UPRC) on Beam Tracking, Massive MIMO and Beam Steering vs Beam Focusing [ITU-R WP5D Document 5D/1442-E, 42nd WP5D Meeting, October 2022]. This contribution was submitted for consideration in the draft new Report ITU-R M.[IMT.ABOVE 100GHz].

3.5 New ETSI ISG groups created

During the ARIADNE project time t two new Industry Specification Groups (ETSI) have been established, where ARIADNE partners has been heavily involved. These groups are newly founded and many ARIADNE partners are having a driving role in their creation and daily works. Also, we can say that these new ETSI ISG groups are at the core of ARIADNE research focus.

3.5.1 Participation/contribution to ETSI ISG RIS

One of the main activities in ARIADNE has been RISs, modelling those and the channel losses, and deriving algorithms to control the RISs in various scenarios. We have also presented quite extensive number of performance evaluations for RISs via simulations and theoretical models. Hence, the works in ARIADNE have been very well aligned with the ETSI ISG RIS focusing on pre-standardization and exploring the opportunities for RISs. As mentioned in the previous chapter, there are three organizations within ARIADNE that participate in ISG RIS: CNRS, UOULU, and UPRC. The goals for research and standardization of the ETSI group were given above as 1) RIS use cases, deployment scenarios and requirements, 2) RIS technological challenges, architecture and impact on standardization, and 3) RIS communication models, channel models, and evaluation methodology. Particularly item 3 has been under thorough investigation in ARIADNE even if the work in ARIADNE also addresses items 1 and 2.

The three ARIADNE participants have been giving inputs (as a part of their respective organizations) for the work and these have been considered in the first set of published work reports. Those are given below per work item listed above, respectively, and can be found in https://www.etsi.org/committee/1966-ris.

1. ETSI GR RIS 001 V1.1.1 (2023-04) Reconfigurable Intelligent Surfaces (RIS); Use Cases, Deployment Scenarios and Requirements
2. ETSI GR RIS 002 V1.1.1 (2023-08) Reconfigurable Intelligent Surfaces (RIS); Technological challenges, architecture and impact on standardization
3. ETSI GR RIS 003 V1.1.1 (2023-06) Reconfigurable Intelligent Surfaces (RIS); Use Cases, Deployment Scenarios and Requirements.

Currently, ETSI ISG RIS is continuing the work in studying and standardizing RIS technologies and communication methods. ARIADNE participants are well represented with Marco di Renzo (CNRS) acting as a vice chair of ETSI ISG RIS in present activities.

The ISG-RIS was established in September 2021 for a duration of two years. It was recently extended for another two years. During the first two years, five work items were identified and discussed. Two work items, one on "Use Cases, Deployment Scenarios and Requirements" and another on "Communication Models, Channel Models, and Evaluation Methodology" were recently finalized and approved. The second work item was led by Marco Di Renzo (CNRS) as Rapporteur. Recently, other work items were proposed and are under discussion on hardware implementation, multi-function RIS, and the analysis of the diversity and spatial multiplexing tradeoff of RIS.

3.5.2 Participation/contribution to ETSI ISG THz

The ISG-THz was established at the end of 2022 for a duration of two years. As of today, four work items are under discussion:

- "Identification of use cases for THz communication systems",
- "Identification of frequency bands of interest for THz communication systems",
- "Channel measurements and modeling in THz bands", and
- "RF Hardware Modeling".

The three ARIADNE participants have been providing input (as a part of their respective organizations) on the work in progress. The corresponding reports and deliverables of this ISG will be finalized in the following months. Further information on the works of ISG THz can be found in www.etsi.org/committee/2124-thz.

4 Conclusion

In early stage of the project life time, the ARIADNE project consortium identified a number of standardization bodies, which might be relevant for the project, in order to follow up their activities and provide relevant inputs from the project side if appropriate. On one side, it was very important to follow up ongoing work of the standardization bodies and their adopted visions on the future developments, to align the ARIADNE's research and innovation activities accordingly. On the other side, selected standardization bodies have been approached by the project consortium by providing relevant inputs and discussion points for further development of standards in discussion. For this, the consortium established a particular follow-up process.

The identified and followed bodies are:

- 3GPP
- US mmWave Coalition
- ITU-R
    - ITU-R Study Group 3 – Radiowave propagation
    - ITU-R Study Group 5 –Terrestrial Service
- ITU WRC-23
- ITU-T SG13
- ETSI ISG mWT
- ECC SE19
- WWRF
- THz Interest Group within IEEE (IEEE 802.15.3d)
- ETSI ISG RIS
- ETSI ISG THz

Concretely, the ARIADNE contributed to the following ITU-R WP 3J documents:

- Document 3J/136-E "Variability of rain specific attenuation evaluated from drop size distributions",
- Document 3J/198-E "Draft of a proposed revision of Recommendation ITU-R P.838-3" proposed the incorporation of a new Annex on the variability of rain specific attenuation at 80-200 GHz, based on the ARIADNE results,
- Document 3J/294-E "Rain attenuation of millimeter waves investigated from drop size distributions ".

ARIADNE has been regularly participating in the 6G-IA Pre-Standardization WG work. The Work Group activities have been versatile and providing extensively information relating to standardization activities performed by other 5G-PPP projects, sharing information about all proceedings, fairs, workshops, etc. and collecting and reporting activities performed by participating projects toward Standardization Organizations (SDO).

In respect to 3GPP activities, the ARIADNE consortium was active in discussions on AI/ML based beam management. Here, the study subjects of the ARIADNE project have been selected as forward-looking to consider the issues expected to be addressed in the future by the 3GPP.

Furthermore, in the scope of the project activities related to ITU-R IMT-2030, ARIADNE provided contributions to the following documents:

- ITU-R WP5D Document 5D/635-E, 38th WP5D Meeting, May 2021, proposes the ARIADNE system concept, technologies and architecture
- ITU-R WP5D Document 5D/822-E, 39th WP5D Meeting, October 2021 proposes 3 (out of 4) usage scenarios inspired by the ARIADNE usage scenarios
- [ITU-R WP5D Document 5D/1442-E, 42nd WP5D Meeting, October 2022, on Beam Tracking, Massive MIMO and Beam Steering vs Beam Focusing

Finally, several ARIADNE partners (CNRS, UOULU, UPRC) have been involved in the establishment of two new ETSI ISG at the core of the project research pillars, namely ETSI ISG RIS and ETSI ISG THz and are among the ISGs founding members.

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