MINOAS
Machine learning aided optical wireless networks

Deliverable 1.1: Project Administrative, Technical & Data Management Handbook

Editor	**Alexandros-Apostolos A. Boulogeorgos**	
Deliverable nature	**Document, Report (R)**	
Dissemination level	**Public (PU)**	
Date: Planned | Actual	**22 February 2024**	**22 February 2024**
Version | No. of pages	**1.0**	**49**
Keywords		
Status	**Final**	

Abstract

This deliverable, titled "D1.1: Project administrative, technical & data management handbook", includes part of the work that is conducted within work package (WP) 1 "Project management, innovation, dissemination, and communication management". The main objective of WP1 is to deal with the project management, the coordination activities, the technical management, and the quality assurance of the project results, as well as the financial and administrative management, while applying a risk management procedure. In particular, WP1 defines the following activities: i) Overall coordination of the project; ii) Financial administration of the project; iii) Risk management and mitigation of the project; iv) Technical and scientific management of the project; v) Innovation management and added value provisioning of the project results; and vi) Data knowledge handling & Intellectual Property Rights (IPR) management. Moreover, WP1 encloses all dissemination and impact creation activities. Specifically, WP1 defines the required actions to ensure that MINOAS solutions and results will be properly disseminated and communicated to academic & industrial parties as well as to the general public. MINOAS's results will be distributed by the project's consortium to internal and external collaborators (researchers, companies, similar projects and individuals).

Motivated by this, the deliverable D1.1 presents an overview of the project administration processes, describes the technical management tools and approaches that are followed, and provides data management guidelines. In more detail, the handbook encloses all procedures and guidelines for the administrative and management requirements of the project. The innovation strategy is defined in D1.1 in terms of ensuring the project excellence. It reports the required processes and procedures for assessing the quality and the guidelines and risk assessment plans of the project. Finally, it addresses the lifecycle and public availability of research data generated by the project.

Disclaimer

The research project MINOAS is implemented in the framework of H.F.R.I call "Basic research Financing (Horizontal support of all Sciences)" under the National Recovery and Resilience Plan "Greece 2.0" funded by the European Union – NextGenerationEU (H.F.R.I. Project Number: 15857).

HELLENIC REPUBLIC MINISTRY OF DEVELOPMENT
H.F.R.I. Hellenic Foundation for Research & Innovation
Greece 2.0 NATIONAL RECOVERY AND RESILIENCE PLAN
Funded by the European Union NextGenerationEU

Impressum

Project number	15857
Call	Sub-action 1. Funding New Researchers – RRF: Basic Research Financing (Horizontal support for all Sciences)
Scientific area	SA2. Engineering Sciences & Technology
Full project title	Machine learning aided optical wireless networks
Short project title (Acronym)	MINOAS
Number and title of work package	WP1-Project Management, Innovation, Dissemination & Communication Management
Number and title of related task(s)	Task 1.1-Administrative & Financial Coordination Task 1.2-Technical, Scientific & Innovation Management
Document title	Project Administrative, Technical & Data Management Handbook
Editor(s)	Alexandros-Apostolos A. Boulogeorgos, UoWM
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Executive summary

The MINOAS project envisions the design of reliable and flexibly scalable wireless system that supports high-speed communication (in the order of 100 Gbps to 1 Tbps) with almost zero-delay by taking advantage of the optical spectrum for medium access and communication with the core network, pioneering technological approximations, such as meta-surfaces for ensuring uninterrupted communication in obstacle riddled environments, and machine learning based design of medium access, resource allocation and network administration techniques. For the realization of this vision, a novel system model will be developed and analyzed that will contain physical, medium access control (MAC) and resource management (RM) layer design considering the particularities of the optical band, a pioneering beyond Shannon theoretical framework will be extracted, and network machine learning methodologies will be proposed. These results are expected to “open the road” for the realization of novel highly capable beyond fifth generation (B5G) and sixth generation (6G) networks.

The MINOAS project defines three (3) main pillars that will be the basis for the work to be carried out and allow it to achieve its main goal. The pillars are the following:

• **Pillar I: Beyond Shannon optical wireless communications (OWCs)** for high-data rate, by exploiting mature optical transceivers and novel optical materials as well as cell free access mechanism designs, in order to significantly improve the radio resource usage by introducing novel strategies for range expansion, by supporting of novel use cases and killer apps, and by commercializing the underutilized spectrum.

• **Pillar II: AI-based optical wireless network orchestration** to maximize the system’s energy efficiency, to support ultra-high availability and applications with diverse requirements, to optimize network topology and management, to enable device collaboration, and to transform B5G backhaul/midhaul/fronthaul networks into intelligent platforms.

• **Pillar III: “Almost-zero latency” and high-computational capabilities at the edge** by means of grant-free and semi-grant free access, caching and task offloading to transform the B5G network into a “zero response time” computing platform.

To achieve its technical objective, all the project processes need to be documented in order for all the members of the consortium to be aware in order to maximize the everyday administrative management efficiency. Motivated by this, thework package (WP) 1 that is titled “Project Management, Innovation, Dissemination & Communication Management”, deals with the project management, the coordination activities, the technical management, and the quality assurance of the project results, as well as the financial and administrative management, while applying a risk management procedure. In particular, WP1 defines the following activities:

i) Overall coordination of the project;
ii) Financial administration of the project;
iii) Risk management and mitigation of the project;
iv) Technical and scientific management of the project;
v) Innovation management and added value provisioning of the project results; and
vi) Data knowledge handling & Intellectual Property Rights (IPR) management.

Moreover, WP1 encloses all dissemination and impact creation activities. Specifically, WP1 defines the required actions to ensure that MINOAS solutions and results will be properly disseminated and communicated to academic & industrial parties as well as to the public. MINOAS’s results will be distributed by the project’s consortium to internal and external collaborators (researchers, companies, similar projects, and individuals).

The first deliverable of WP1 with title "Project Administrative, Technical & Data Management Handbook" presents an overview of the project administration processes, describes the technical management tools, and approaches that are followed, and provides data management guidelines. In more detail, the handbook encloses all procedures and guidelines for the administrative and management requirements of the project. The innovation strategy is defined in this deliverable in terms of ensuring the project excellence. It reports the required processes and procedures for assessing the quality and the guidelines and risk assessment plans of the project. Finally, it addresses the lifecycle and public availability of research data generated by the project.

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AUTH	Georgios Chondrogiannis	Proofreading and review of v0.2
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Abbreviations

3D	Three dimensional
5G	Fifth generation
6G	Sixth generation
AI	Artificial intelligence
AP	Access point
B5G	Beyond the fifth generation
BS	Base station
CoMP	Coordinated multipoint
DoW	Description of Work
DSP	Digital signal processing
GF	Grant free
HW	Hardware
ID	Identifier
IPR	Intellectual Properties Rights
KPI	Key performance indicator
LoS (NLoS, OLoS)	Line-of-sight (non-LoS, obstructed LoS)
MAC	Medium access control
ORIS	Optical Reconfigurable Intelligent Surface
OWC	Optical wireless communications
PHY	Physical layer
PI	Prime investigator
RC	Research committee
RF	Radio frequency
RX	Receiver
SDMA	Space-division multiple access
TX	Transmitter
WP	Work package
WPL	Work package leader

1. Introduction to the project and the deliverable

1.1. Project motivation and rationalization

As the wireless world moves towards the commercialization of the fifth generation (5G) systems, the demand for innovative technological developments that will become the pillars of beyond 5G (B5G) or six generation (6G) systems, is evident. In more detail, Cisco has foreseen that the global mobile data-traffic will increase more than 10 times (from 7.2 to 77.5 EB/month) from 2017 by the end of 2022 with an exponential increasing trend in 2020s accompanied by a similar growth of the number of networked devices that by the end of 2022 is expected to reach 28.5B [Cisco2017]. Additionally, the next generation networks are envisioned to inherently support a huge dynamic and diverse range of novel usage scenarios and applications that require, except from extremely high-data rates, agility, flexibility, availability, reliability, zero response time and artificial intelligence (AI) under a security and privacy umbrella. Virtual/artificial/extended reality, three-dimensional (3D) printing, self-driven cars, and generally cyber physical systems for intelligent transportation, smart traffic, Industry 5.0 and e-health are only a few indicative examples of several highly anticipated use cases. Despite the adaptation of several game changing design principles by the 5G, such as network densification, virtualization, and orchestration, which aim at enhancing the scalability, flexibility as well as efficient resource management, it has been proven that the envelop of its capabilities is defined by the available bandwidth, transmission and processing delay, as well as spectral and energy efficiency [Andrew2015].

To overcome the aforementioned limitations, B5G networks need to focus on the vast unutilized and largely unallocated higher frequency resources in the optical band, where more than 500 GHz of continuous and exploitable bandwidth exists. This is expected to open the door to 1 Tbps connectivity by combining the large available bandwidth with spectrally efficient transmission and access schemes. However, optical wireless links suffer from severe path and penetration losses that originate from the interaction and energy absorption by the molecules (mostly water) of the propagation medium in this band and result in low-transmission range and blockage. To enable a connectivity range of some tens of meters and support mesh topologies via midhaul/fronthaul and nomadic connectivity scenarios, high-direction connectivity is employed in both the transmitter (TX) and receiver (RX) side. This also allows the utilization of space-division multiple access (SDMA); thus, it can support a massive number of connected devices, and since solitary line-of-sight (LoS) links can be established, it provides an additionally inherent physical layer (PHY) security. On the other hand, it comes with the challenge of designing innovative low-latency device discovery and beam tracking for moving and mobile nodes. Moreover, to deal with blockage and to enable range expansion, coordinated multipoint (CoMP), relaying, and optical reconfigurable intelligent surface (ORIS)-aided approaches may be employed. Another particularity of wireless systems that operate in the optical band is due to the ultra-wideband extremely directional nature of the communications links and the non-uniform user's spatial distribution, which results in inefficient user association when the classical minimum-distance criterion is employed. To counterbalance this, user association should be designed to meet the dominant key performance indicators (KPIs) of each user's application. As a consequence, users may not be associated with the geographically closest base-station (BS)/access point (AP), since a better directional link may exist for a further away BS/AP. In other words, we need to rethink the conventional notion of hexagonal cell and transform it into "dynamic cell" that will not have a predefined share, and it will be established through the solution of multivariety optimization problems. Of note, the solution of such problems may require the use of sophisticated artificial intelligence (AI) approaches. Finally, B5G networks need to support ultra-low latency applications. In this direction, grant-free (GF) or semi-GF access protocols need to be utilized as well as novel AI-based social-aware caching mechanisms.

To further extend the connectivity range into hundreds of meters in order to support midhaul/backhaul connectivity and wireless fiber extension, highly directional links can be established. Of note, wireless fiber extension is an application scenario of much hype, since it contributes to bridging the connectivity gaps that exist between the radio frequency (RF) access network and the fiber optic-based backbone network in a cost-efficient and easy deployment manner. This application scenario is expected to be employed in developing countries, harsh and urban environments, where there may not be much of a fiber optic structure and hence to increase its reach and bandwidth to the last mile, without requiring a huge number of economic resources to dig up the current brown-field. In such scenarios, TXs are placed in high buildings; as a consequence, they may experience beam misalignment degradations, due to environmental phenomena, such as wind, small earthquakes, etc. A possible solution to this is the design of hybrid systems that by simultaneously establishing lower frequency links (e.g., millimeter wave or microwave), they can guarantee seamless communication (availability probability > 99.999%). Another challenge is the lack of efficient transceiver designs in this band, which makes the system sensitive to optical chain related hardware (HW) imperfections, such as in-phase and quadrature imbalance, phase noise, amplifiers non-linearities, and antenna coupling. To counterbalance their effect, new low-cost transceiver designs, and advanced digital signal processing (DSP) have to be developed.

1.2. Project challenges and objectives

Challenges: In the light of the aforementioned remarks, the following challenges are identified:

• Provide ubiquitous connectivity and practically infinite network capacity for new services and business models, by means of advanced energy-efficient transmission schemes and optical reconfigurable intelligent surface (ORIS) designs that will allow the use of the optical band;

• Mathematically model the particularities of ORIS and create the interface between the optical and the signal processing communities;

• Identify the performance envelop of advanced optical wireless communication (OWC) systems and provide future directions to the photonics society;

• Support ultra-dense low-latency connectivity by exploiting the nowadays underutilized spectrum, introducing novel system architectures based on extraordinary materials, designing grant-free or semi-grant free access mechanism, and presenting novel caching policies;

• Enable NLoS/obstructed LoS (OLoS) smart and reliable connectivity by creating reconfigurable wireless environments by means of AI-assisted ORISs, which are able to mitigate or even cancel propagation impairments and topology constraints, as well as energy and complexity limitations;

• Support uninterrupted connectivity for mobile users by exploiting innovative AI methodologies,

Overall approach and objective: Recognizing the main requirements for the development of B5G networks, MINOAS proposes a novel complete solution. Concerning the availability of new resources, the optical spectrum is regarded as the main contender for backhaul and fronthaul applications due to their high-speed and increased network capacity.

Moreover, in the optical band, there is more than 500 GHz continuous available bandwidth. As far as the development of new technologies for maximizing the resource utilization, evolutions in the field of optoelectronics, in particular manufacturing of light emitting diodes (LED), lasers, and photodiodes (PD) functioning in the infrared (IR) with high sampling frequency, highly integrated circuits that enable highly complex digital signal processing (DSP) calculations in real time, and the development of meta-surfaces that enable adapting the wireless link on the fast-changing environment is combined for designing novel B5G network systems and architectures under the MINOAS project.

Overall objective: Following the aforementioned approach, MINOAS envisions the design of a reliable and flexibly scalable wireless system that supports high-speed communication (in the order of 100 Gbps to 1Tbps) with almost zero-delay by taking advantage of the optical spectrum for medium access and communication with the core network, pioneering technological approximations, such as meta-surfaces for ensuring uninterrupted communication in obstacle-riddled environments, and machine learning based design of medium access, resource allocation and network administration techniques. For the realization of this vision, a novel system model will be developed and analyzed that will contain physical, medium access control (MAC) and resource management (RM) layer design considering the particularities of the optical band, a pioneering beyond Shannon theoretical framework will be extracted, and network machine learning methodologies will be proposed. These results are expected to open the road for the realization of novel highly capable B5G networks.

1.3. Deliverable goal and relation to other deliverables in MINOAS

The first deliverable of WP1 with title "Project Administrative, Technical & Data Management Handbook" presents an overview of the project administration processes, describes the technical management tools, and approaches that are followed, and provides data management guidelines. In more detail, the handbook encloses all procedures and guidelines for the administrative and management requirements of the project. The innovation strategy is defined in this deliverable in terms of ensuring the project excellence. It reports the required processes and procedures for assessing the quality and the guidelines and risk assessment plans of the project. Finally, it addresses the lifecycle and public availability of research data generated by the project.

As presented in Figure 1, D1.1 provides inputs to all the deliverables in the project. In more detail, this deliverable provides the MINOAS innovations to all the other deliverables as well as the data management guidelines.

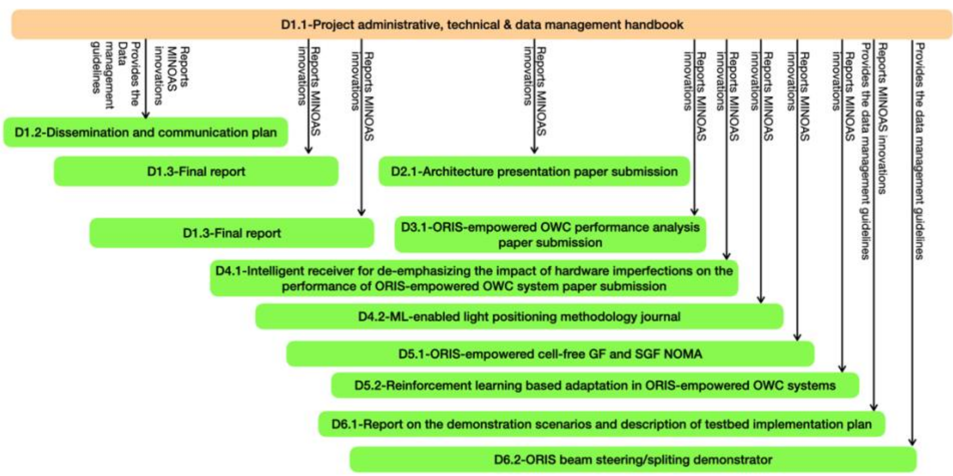

Figure 1: Relation to other deliverables.

2. Project management

2.1. Overview

The management of the project has the following goals:

• To ensure that the project is conducted in accordance with HFRI rules,
• To reach the objectives of the project within the agreed budget and time scales,
• To coordinate the work of the partners, and ensure effective communication between them,
• To maximize the potential for exploiting results and active involvement of industry via External Advisors
• To set the quality policy, including quality objectives for the project as well as for Deliverables
• To manage properly Foreground and IPR matters,
• To ensure that decisions are made on the basis of data and factual information,
• To solve any problem or conflicting situation,
• To set the quality policy, including quality objectives for the project,
• To ensure that an infrastructure is set up in order to support the above.

At the project outset, the D1.1 is prepared, which establishes the rules of project management. The D1.1 sets the day-to-day rules of the project: documents and deliverables handling, project planning and manpower, meeting organization, internal reporting and information management, external information management, list of personnel with corresponding responsibilities. It describes, among others, the composition, decision-making procedures and responsibilities of the project coordinator and the general assembly (GA); it will also provide clear guidelines to govern the IPR questions and Knowledge Management amongst the consortium members. Finally, it will provide details, beyond the terms of the grant agreement, on the internal project rules and guidelines concerning the daily management of foreground and IPR.

All the deliverables, the work and resources effort for the internal project management are covered and described in WP1.

2.2. Milestones and technical decision to be taken

Milestones are control points in the project that help in the progress monitoring. Milestones correspond to the completion of a key deliverable, allowing the next phase of the work to begin, to the fulfillment of contractual obligations, or even to dissemination points. They may also be needed at intermediary points so that, if problems have arisen, corrective measures can be taken. A milestone may be a critical decision point in the project, where, for example, the consortium must decide which of several technologies to adopt for further development. Table 1 below shows all milestones of MINOAS in the table, indicates means of milestone verification.

Table 1: MINOAS Milestones

Milestone Number	Milestone Name	Related WP	Due Date (in months)	Means of Verification
MS1.1	Availability of MINOAS's public profiles	WP1	M02	Publicly available website, and social media profiles
MS1.2	Availability of D1.1	WP1	M03	D1.1
MS3.1	Availability of the initial version of the optics-signal interface	WP3	M03	Internal report

MS1.3	Availability of vision video at YouTube	WP1	M04	YouTube video
MS1.4	Availability of D1.2	WP1	M05	D1.2
MS2.1	Availability of requirements and specifications	WP2	M05	Internal report
MS2.2	Availability of MINOAS system architecture	WP2	M07	Internal report
MS1.5	Availability of special issue	WP3	M12	Special issue webpage
MS6.1	Availability of D6.1	WP6	M13	D6.1
MS2.3	Availability of D2.1 as a preprint to ArXiV	WP2	M18	ArXiV
MS4.1	Availability of D4.1 as a preprint to ArXiV	WP4	M19	ArXiV
MS3.2	Availability of the final version of the optics-signal interface	WP3	M20	Internal report
MS4.2	Availability of D4.2 as a preprint to ArXiV	WP3	M20	ArXiV
MS5.1	Availability of D5.1 as a preprint to ArXiV	WP5	M21	ArXiV
MS3.3	Availability of D3.1 as a preprint to ArXiV	WP3	M22	ArXiV
MS1.6	Availability of demonstration video at YouTube	WP3	M23	YouTube video
MS1.7	Availability of D1.3	WP1	M24	D1.3
MS5.2	Availability of D5.2 as a preprint to ArXiV	WP5	M24	ArXiV
MS6.2	Availability of D6.2	WP6	M24	D6.2

2.3. Project management structure and governance scheme

This section offers a thorough overview of the project management structure. The researchers that are involved in MINOAS project are summarized in Table 2.

Table 2: MINOAS researchers.

Researcher	Organization	Expertise	Role in the project
Alexandros-Apostolos A. Boulogeorgos	University of Western Macedonia (UoWM)	Senior Researcher	• P.I. • Leads WP1 and WP5 • Contributes to all WPs
Afroditi Papadopoulou	UoWM	Financial officer	• Contributes to WP1
Emmanouil E. Kriezis	Aristotle University of Thessaloniki (AUTH)	Senior Researcher	• Leads WP6 • Contributes to WP2
Nestor Chatzidiamantis	AUTH	Senior Researcher	• Leads WP3 and WP4 • Contributes to WP4 and WP5
Alexandros Pitilakis	UoWM	Senior Researcher	• Leads WP2 • Contributes to WP1-WP6

Evangelos Koutsonas	UoWM	Early-stage researcher	• Contributes to WP1-WP6
Georgios Chondrogiannis	AUTH	Early-stage researcher	• Contributes to WP1-WP6

The light project management structure shown in Figure 2 has been agreed among the partners. It has been adapted to the project size, and already implemented with success in similar projects in the past.

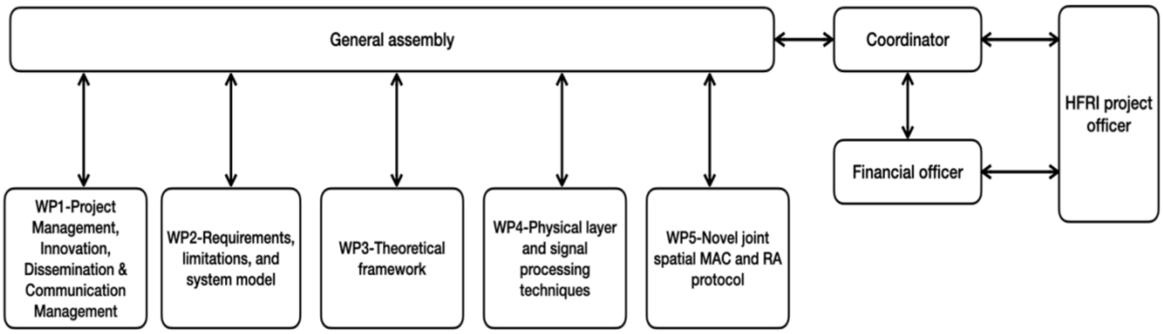

Figure 2: MINOAS project management structure.

The rest of the section is organized as follows:
- Section 2.3.1 presents the general assembly's role and responsibilities, as well as its composition and meeting schedule;
- Section 2.3.2 presents the project's Advisory Board and outlines its role;
- Section 2.3.3 outlines the workgroups in each WP;

2.3.1. General assembly

Role and responsibilities: The general assembly (GA) responsibility is to monitor MINOAS formal and technical follow-up and make important decisions. The decisions that are expected to be taken by this body may refer to:
- Contract and consortium agreement (CA) amendment;
- Termination of the contract of underperforming participant;
- Budget follow-up and transfers; and
- Decisions on major variations from the grant agreement technical roadmap.

Composition: All the members of the research team can participate at the GA. However, only the WP leaders and the coordinator have voting rights. In more detail, Table 3 summarizes the role of each member of the research team at the GA.

Table 3: GA composition.

Researcher	Organization	Role and rights in the GA
Alexandros-Apostolos A. Boulogeorgos	UoWM	• GA chair • Organizes GAs • Informs the GA about the progress of WP1 and WP5 • Voting rights
Emmanouil Kriezis	AUTH	• GA deputy chair • Informs the GA about the progress of WP6 • Voting rights
Nestor Chatzidiamantis	AUTH	• Informs the GA about the progress of WP3 and WP4

		• Voting rights
Alexandros Pitilakis	UoWM	• Informs the GA about the progress of WP2 • Voting rights
Evangelos Koutsonas	UoWM	• Participates at the GA
Georgios Chondrogiannis	AUTH	• Participates at the GA

Meetings: A bi-weekly GA is organized in MINOAS project to enable efficient coordination of all the project activities. GA meetings can be held by teleconference to save on travel expenses. The following table presents an initial GA meeting plan. Note that the academic calendar was accounted for in the preparation of the GA meeting plan.

Table 4: GA meetings for the first year of the project.

Project month	Date	Event
M01	November 22, 2023	Project start
	December 04, 2023 (15.00-17.00)	Kick-off meeting
	Christmas holidays	
M02	January 10, 2024 (15.00-16.00)	GA meeting
M03	January 31, 2024 (15.00-16.00)	GA meeting – Submission of D1.1 for internal review
	February 14, 2024 (15.00-16.00)	GA meeting – Discussion concerning D1.1
M04	February 28, 2024 (15.00-16.00)	GA meeting
	March 13, 2024 (15.00-16.00)	GA meeting
M05	March 27, 2024 (15.00-16.00)	GA meeting
	April 3, 2024 (15.00-16.00)	GA meeting
	April 17, 2024 (15.00-16.00)	GA meeting
M06	May 1, 2024 (15.00-16.00)	GA meeting
	May 15, 2024 (15.00-16.00)	GA meeting
M07	May 29, 2024 (15.00-16.00)	GA meeting
	June 12, 2024 (15.00-16.00)	GA meeting
M08	June 26, 2024 (15.00-16.00)	GA meeting
	July 10, 2024 (15.00-16.00)	GA meeting
M09	July 24, 2024 (15.00-16.00)	GA meeting
	Summer Holidays	
	August 21, 2024 (15.00-16.00)	GA meeting
M10	September 4, 2024 (15.00-16.00)	GA meeting
	September 18, 2024 (15.00-16.00)	GA meeting
M11	October 2, 2024 (15.00-16.00)	GA meeting
	October 16, 2024 (15.00-16.00)	GA meeting
M12	October 30, 2024 (15.00-16.00)	GA meeting
	November 13, 2024 (15.00-16.00)	GA meeting
M13	November 27, 2024 (15.00-16.00)	GA meeting
	December 11, 2024 (15.00-16.00)	GA meeting
	Christmas holidays	

2.3.2. Advisory board

In addition to project partners, the Consortium will form an External Advisory Board. The advisory board will be chaired by the project coordinator and will consist of minimum 3 influential experts from academia or industry, with proven track record in transferring advanced technologies from research labs to the market. Advisory board members will supervise the technical directions and provide feedback on the relevance and focus of the work as well as on maximisation of potential impact. At the project start, the advisory board consists of people from PureLiFi, Cambridge University (UK), AMO (Germany), and Northeastern University (USA). Table 5 presents the names of the advisory board. Composition of Advisory Board might be changed by the decision of GA – in this case, all partners can propose substitute/additional candidates.

Table 5: Members of the advisory board.

Organization	Country	Name	Expertise
PureLiFi/Cambridge University	UK	Harald Hass	Visible light communications
Amo	Germany	Stephan Suckow	Photonics, Optical surface design
Northeastern University	USA	Josep Jornet	Optical wireless communications

2.3.3. WP technical groups

Composition: Each WP Technical Group is composed of all the members of the considered WP and chaired by the WP Leader (WPL). In practice, the following operational work of the project is performed in the WP Technical Groups, under the responsibility of the WP Leaders (see Table 6). In its tasks, it may ask for the help of the Project Coordinator.

Role and responsibilities: WPL responsibility is to plan, manage, co-ordinate and follow-up the work within the work package; the WPL ensures the work is done in full accordance with the description of work (DoW) and proposes proper actions when required. He/She represents the WP interests and interfaces with other WPs through the GA meetings. Work packages are further broken down into tasks; Task Leaders are appointed and coordinated by the WPL. Note that WP1 does not have its own WP Technical Group since the Project Office treats WP1 matters.

Meetings: WP Technical Groups meetings occur at least at the same time and location as the GA meetings. They are convened just before the GA meeting to enable reporting and resolution of issues there upon. In addition, WP meetings can be called and organised by each WPL when needed to achieve the technical work. In between, teleconferences are organised on a regular basis or on request.

Table 6: WPLs.

WP No.	Leading partner	WPL
1	UoWM	A.-A. A. Boulogeorgos
2	UoWM	A. Pitilakis
3	AUTH	N. Chatzidiamantis
4	AUTH	N. Chatzidiamantis
5	UoWM	A.-A. A. Boulogeorgos
6	AUTH	E. Kriezis

2.4. Main management roles

2.4.1. Project coordinator

The Project Coordinator chairs the GA, performs the financial management of MINOAS project, and provides the H.F.R.I with relevant technical, managerial, and financial information. In this role, he is supported by the Project Office of the Host Institution (UoWM). The Project Coordinator will be Prof. Alexandros-Apostolos A. Boulogeorgos (UoWM). His major tasks are:

- Supervision of the overall administrative and technical project progress;
- Organisation and chairing the GA;
- Preparation with the support of the GA of the deliverables, reports, cost statements and project documents required by the H.F.R.I (quarterly, annual and final activity reports);
- Confirmation and approval of periodic reports for the H.F.R.I.;
- Financial coordination of the project;
- Performing of contract amendments when necessary;
- Organisation of H.F.R.I review meetings;
- Follow up of implementation of corrective actions;
- Representative of the consortium to periodical matchmaking and dissemination events organized by H.F.R.I;
- Coordination of IPR and knowledge management,
- Coordination of the dissemination and communication activities of the project.

Finally, the project coordinator will act as the focal point for contacts and coordination with the H.F.R.I., and with other relevant EU, national, and international projects, and for external relationship with relevant bodies and other related activities.

2.4.2. Financial officer

The financial officer appointed by the UoWM research committee (RC) is Ms Afroditi Papadopoulou, and she is responsible for the following tasks:

- Communication with UoWM research committee;
- Communication with the H.F.R.I. financial officers;
- Assisting the project coordinator to perform administrative monitoring of the project;
- Preparation of all the financial documents that need to be submitted by MINOAS to the UoWM RC and H.F.R.I.

2.4.3. WPL

Each WP is led by the corresponding WPL, Table 6. The WLP is responsible for the following tasks:

- Arrange meetings with the task leaders and members of the WP in order to organize the work within the WP;
- Monitor the everyday progress of WP tasks;
- Achieve the technical objectives of each WP; and
- Identify WP-related risks and report them to the risk manager and project coordinator.

2.5. Operations and Communication Tools

2.5.1. Planning

Drafting coherent plans for the MINOAS work packages is an essential prerequisite to enable the work to progress. The current document only presents a high-level overview of the project, setting out the ground rules on which the project will proceed in terms of objectives, technical approach and time scales.

From day 1 of the MINOAS project, a consolidated planning has been produced and maintained by the Project Office. A detailed work plan is produced at the beginning of each task at a sub-WP level to avoid redundancy in activities, to ensure all objectives, deliverables and milestones are on-track, and to allow an efficient follow-up of progress. The detailed work plan can be revisited only with the approval of the GA.

2.5.2. Meetings and travel management

Meetings are organised at a frequency defined above. In order to minimise travel costs and guarantee maximum efficiency, the partners agree to meet one (1) day every four (4) months in joint = meetings (physical or virtual). In these meetings, the various bodies will convene; at a minimum, the WP Technical Groups meetings and a GA meeting will take place. Ad-hoc meetings for integration, testing, or solving special issues can be organised. At the start of the project, the GA defines a provisional planning for meetings and teleconferences. The calendar (time and place for one year) of the various meetings (physical and virtual) is defined in Table 4, and it may be revised during the second year of the project.

2.5.3. Deliverables

Deliverables consist of reports, white papers, documents, laboratory models, demonstrations, field trials, paper submissions, etc. Deliverables are approved first by the WP Leader, then by appointed reviewers, and, finally, by the Project Coordinator. Reviewers are named by the GA and are usually internal to the project. In special occasions, external reviewers can be consulted after appropriate confidentiality measures have been taken.

2.5.4. Documentation

All project documentation will be stored electronically in a dedicated MINOAS electronic repository. Well-known tools (e-mail, web collaborative tools, audiovisual teleconference systems) are used for the exchange of documents/information. The template of all the documents types of MINOAS will be provided in D1.2.

2.5.5. Reporting process

Internal (within Consortium): The Host Institution, UoWM, commits to write a report every six (6) months to the GA. It will describe the technical, scientific, and management project work done, listing effective time spent on the project. It will mention difficulties, milestones and deliverables (or contributions to deliverables in case of joint deliverables) that have been reached, patents, publications, travel, and visits.

External (to H.R.F.I.): The Project Office coordinates and consolidates the annual and final technical reports, as well as the management and financial reports; the Project Office submits the reports for GA approval, after which it delivers them to the H.R.F.I.

2.5.6. MINOAS website, public electronic profiles, and collaborative platforms

Table 7 summarizes the MINOAS official public electronics profiles. These profiles enable the consortium to manage the large dissemination of the project results, as well as the events and information related to its scope of interests. More information about the MINOAS dissemination strategy and tools will be provided in D1.2.

Table 7: MINOAS public profile.

Logo	
Website	https://minoas-project.gr
LinkedIn page	https://www.linkedin.com/company/project-minoas/
Facebook page	https://www.facebook.com/profile.php?id=61552919412515
YouTube channel	https://www.youtube.com/@minoas-project

For its internal communication, the consortium uses an interactive web collaborative platform. In more detail, for teleconferences and repository, it uses Microsoft Teams and SharePoint, respectively. The Microsoft SharePoint website of MINOAS is secured and enables the consortium:

- to manage the limited diffusion of private information;
- to monitor resources and allow easy exchanges between partners.

It can be made accessible to the H.F.R.I. and/or to external reviewers with personal level of access rights.

3. Quality management

3.1. Quality control principles

Quality shall not only be addressed for the deliverables but also for the project process itself. Thus, the management process and developments of the project will be subject to periodical reviewing with respect to:

1. Staying focused on project objectives of focusing on end-user requirements, high quality technical outputs, market proximity and openness;
2. Adequacy of the project management plan and how the work performed complies with it, including intellectual properties rights (IPR) management and results dissemination;
3. How well the project processes are synchronized and inter-linked;
4. Identification and evaluation of activities and results that would adversely affect the achievement of the project objectives;
5. Process improvement in the project by identifying deviations and changes.

Quality assurance is the joint responsibility of all participants and is applied at all levels of the project's activities.

Management will continuously monitor and control (i.e. taking corrective actions) expenses, resources, and will schedule "versus plans" (i.e. technical and financial annexes to the Grant Agreement). Root causes for deviations, be it shortages or excesses, in costs, resources and schedules shall be identified, recorded, and used as input for continual improvement. Possible impacts of schedule changes on the budget and resources of the project and on the quality of the results should be determined.

3.2. Quality management process

The quality management is the process of continually assessing and quantifying the quality of all activities and taking corrective actions (if and when needed) until the research team achieves the desired result. In more detail, the quality management process contributes to:

- Costs control;
- Selection of standards to aim for; and
- Determination of the procedure to achieve standards.

Another important benefit that effective quality management brings is lowering the project risks. Motivated by this, in MINOAS we define a quality plan that from the one hand allows continuous monitoring of the project outcomes quality, while on the other does not compromise the workload of the research team.

A good quality management plan is essential for the successful completion of the project. It starts with a clear definition of the goal of the project and then it defines the deliverables and outcomes of the project. In this phase, a clear definition of each deliverable, including its goal, structure, role within the project as well as the plan that need to be followed to achieve the result is presented. Moreover, possible risks and mitigation measures are defined in this phase. Finally, the methods and tests to achieve, control, predict, and verify success are presented for each deliverable in this phase.

4. Technical and scientific management

4.1. MINOAS objectives, challenges, and means to achieve them

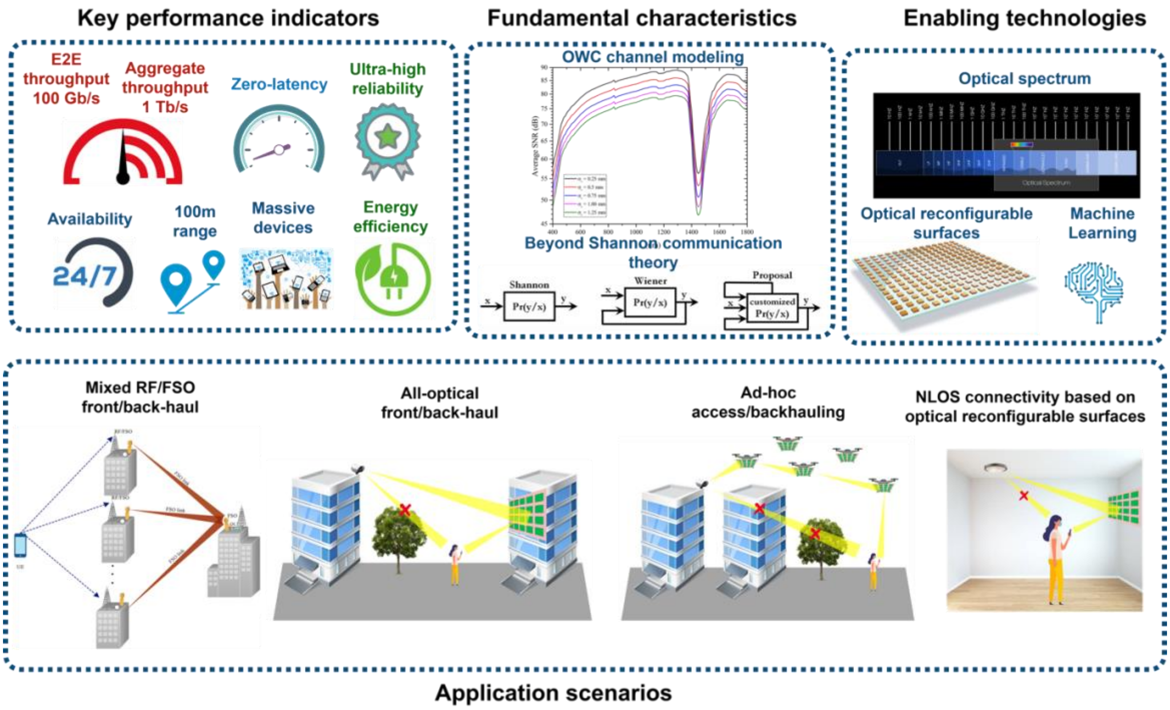

Figure 3: A nutshell of the MINOAS concept.

Figure 3 depicts the MINOAS system concept in a nutshell, where the principal elements of the project are presented, i.e., the KPIs, the optical wireless fundamental characteristics, the main enablers modules as well as the usage scenarios. In MINOAS, we envision that ORIS fueled by AI will enable extremely high level of flexibility and adaptability to OWC systems without compromising either reliability or robustness. On the contrary, a pervasive transformation will be realized, towards an intelligent and widely reconfigurable system with practically infinity bandwidth. In addition to adaptability and flexibility, other decisive attributes are necessary to cope with game-changing applications: These include low-latency, ultra-high reliability, and energy-efficiency. MINOAS accounts for the wireless applications and attributes and focuses on four (4) carefully selected representative use cases.

Mixed RF/FSO front/back-haul: Following the trends of the cellular industry, mixed access and backhaul (MAB) at optical frequencies are possible. Two options for backhaul/fronthaul wireless connectivity exist, namely, mixed RF/FSO front/back-haul and all-optical front/back-haul. In the mixed RF/FSO front/back-haul case, an OWC system is utilized to carry aggregated RF links, and, thus, the major challenges are low-complexity setup, high flexibility, and low total cost of ownership when compared to the fiber deployment. However, the very high directivity links, that enable such long-range communication, require precise beam alignment at all times.

All-optical front/back-haul: On the other, an all-optical MAB system combines the challenges of both optical wireless backhaul and fronthaul, i.e. in addition to the need for a high-gain directional links and, thus, precise beam alignment, the mobility of the users of the network can lead to blockage and frequent disconnects. However, it also opens the door to simplified hardware architectures and the possibility to dynamically adapt or trade resources between fronthaul and backhaul services.

Advanced OLoS ad-hoc access/backhauling: Moving nodes, such as nomadic base stations, can serve as access points that offer backhaul solutions for ultra-high data rate connectivity (in excess of 10 Gb/s) over comparatively shorter distances than fixed backhaul (up to hundreds of meters) in cases of irregular traffic increase, ultra-dense connectivity demands, and mobile environments. Mobile ad hoc backhauls can enable and support point-to-point, point-to-multipoint, and mesh architectures with ORIS-enabled multi-hop connectivity in outdoor scenarios, including campuses, outdoor shopping malls, and areas of towns and cities, among others. In addition to the need for highly directional links and, thus, precise beam alignment, the mobility of both the network nodes and the users of the network can lead to blockage and frequent disconnects. Moreover, the need to support low-latency applications calls for the design of new access schemes and resource management (RM) policies.

NLOS connectivity based on ORISs: It is often the case of wireless communication networks operating in the high frequency bands, that the line-of-sight link is obstructed by objects and/or even by channel impairments, e.g., rain, fog, foliage, etc. We could therefore consider the case where the environment itself is made reconfigurable and can assist the communication between two end-points. For example, randomly distributed environmental objects are coated with reconfigurable intelligent surfaces, e.g., tunable reflectors, which sense the system's response to the optical waves and feedback the relevant information. Based on the sensed data, the input and the operation of the object coated with intelligent electromagnetic material are jointly optimized and configured through a software controller. This approach has several applications in scenarios where the line-of-sight may not be available or may be readily obstructed.

Bringing to fruition the notion of AI-aided B5G optical wireless networks calls for a flexible, scalable, and powerful network information theory approach that will go beyond the limitations of Shannon, a revolutionary ML-based transmission and reception framework that will be supported by cutting edge technology components, and a novel universal resource management methodology, which includes cell-free radio access mechanisms, ML-assisted mobility management and blockage avoidance schemes, AI-based resource and network orchestration. Additionally, MINOAS will identify the critical technology gaps and invent, optimize, and assess the key enablers for the B5G optical wireless networks. MINOAS approach is built upon three well-defined pillars:

• **Pillar I: Beyond Shannon Optical wireless communications for high-data rate**, by exploiting mature optical transceivers and novel optical materials as well as cell free access mechanism designs, in order to significantly improve the radio resource usage by introducing novel strategies for range expansion, supporting of novel use cases and killer apps, and commercializing the underutilized spectrum.

• **Pillar II: AI-based optical wireless network orchestration to maximize the system's energy efficiency**, support ultra-high availability and applications with diverse requirements, optimize network topology and management, enable device collaboration, and transform B5G backhaul/midhaul/fronthaul networks into intelligent platforms.

• **Pillar III: "Almost-zero latency" and high-computational capabilities at the edge** by means of grant-free and semi-grant free access, caching and task offloading to transform the B5G network into a "zero-response" computing platform.

In Table 8, the corresponding MINOAS research and technical objectives (O) are presented, along with the challenges that are expected to be addressed, the technological means to achieve them, as well as the associated goals and measurable criteria of success.

Table 8: Objectives, challenges, and means to achieve/address them.

VISION 3 Pillars	Objective / Challenges	Means to Achieve/Address them
	O-1: “To create the interface between optical theory and signal modeling”	
“ Optical wireless communications for high-data rate and high-security connectivity”	*Challenges:* • New more realistic ORIS models that map the ORIS particulates into simplified/ tractable signal models • Provide guidelines for the design of ORIS • New models that map stochastic characteristics, like weather conditions, misalignment, disorientation, blockage and hardware imperfections	•Use geometric/Fourier optics theory to develop new optical channel and propagation models •Characterize based on accurate simulations the key particularities of ORIS. •Use stochastic geometry and random based theory to create generalized blockage models •Use optical theory to analyze the impact of misalignment and disorientation for the three defined use cases and combine the results with stochastic models that capture the motion characteristics of network nodes and end-users. •Identify the hardware imperfections of optical transceivers and ORIS and develop accurate signal models that capture their characteristics
	Goals/Measurable Criteria: •Accuracy of ORIS models >99% •1 novel and tractable blockage model •1 novel and generalized disorientation/misalignment model •ORIS hardware imperfections models	
	O-2: “To design and develop advanced optical wireless access and backhaul networks”	
	Challenges: •New channel and interference models •Limits of classical information and performance analysis theories to provide efficient performance evaluation metrics, new fundamental performance limits need to be devised •Advanced system concept and architecture definition	•Development of new interference model based on optical beam focusing and derived channel model •Derivation of novel fundamental performance limits of ORIS-assisted OWC system that characterize the performance envelop of the next generation OWC systems •Development of deterministic network information theoretic framework for link-level and network-level.
	Goals/Measurable Criteria: •Tbit/s aggregate throughput of optical wireless links •At least a 100x increase in area spectral efficiency over 5G systems	

“ AI-based optical wireless network orchestration to maximize the system’ s energy efficiency”	•Bandwidth saving up to 35% and 40% traffic reduction •‘Always’ available connectivity of ‘infinite’ devices	•‘Zero’ latency connectivity
	O-3: “To analyze the feasibility of ORIS-empowered OWC systems and determine their performance envelop”	
	Challenges: • Identify the role of OWC systems in the B5G era •Determine the capability of OWC systems to enable B5G killer-applications •Experimentally verify the feasibility of ORIS-empowered OWC systems.	•Identify B5G killer-applications that are expected to be fueled by advanced OWC systems and document their requirements. •Use probability and random matrix theories in order to extract closed-form expressions, approximations, and bounds of key performance metrics, such as the bit error rate (BER), outage probability, throughput, and capacity, as a function of the SNR, the network nodes characteristics (transceivers, ORIS) and the propagation conditions. •Design and utilize two in-lab testbeds that demonstrate the key functionalities of ORIS.
	Goals/Measurable Criteria: •A theoretical framework that analyze the performance of advanced OWC systems •Two in-lab pilots that demonstrate the functionalities of ORIS.	
	O-4: “To reach the Pareto optimal performance in advanced OWC systems”	
	Challenges: •User association in cell-free networks that exploit fixed or mobile ORIS and the spatial distribution of the users is not spatial •Network node placement optimization •Extreme densification •Massive number of devices, “competition” to transmit •High congestion of the backhaul network	•Design novel association policies that maximize the overall network or user individual throughput without compromising either the systems/users energy efficiency requirements or the backhaul network constraints. •Design novel association policies that maximize the energy efficiency without compromising each user’s throughput demands. •Provide solution to ORIS placement and mobile network nodes root optimization problems •Design of novel approaches in optimization theory and machine learning for achieving optimal single-/multi-hop system performance •Development of a reinforcement learning empowered highly adaptable framework

		for almost real-time optimal resource management in OWC systems
	Goals/Measurable Criteria: •Tbit/s aggregate throughput of optical wireless links •Bandwidth saving up to 35% and 40% traffic reduction	•'Always' available connectivity of 'infinite' devices •At least a 100x increase in area spectral efficiency over 5G systems
" Almost-zero latency and high-computational capabilities at the edge"	**O-5:** "To deliver intelligence at the end-user and support high levels of reconfiguration in a flexible and adaptable manner"	
	Challenges: •Ultra-Dense Networks •AdHoc, dynamically changing topology •Harsh and volatile environmental conditions •Complexity growing dramatically, due to large scale networks and large data volumes	•ML to perform resource allocation with minimum complexity and side-information requirements •ML techniques to optimize and refine channel models and / or adapt to volatile environmental conditions •ML techniques to optimize energy efficiency (Joule-per-bit) •ML-based optimization of user-cell association (or node pairing), i.e., a discrete resource allocation problem (or •classification problem) •Model-based optimization with ML to improve on known analytical models of limited accuracy •Data-driven optimization with ML to improve network deployment and management •Design of cell-free GF and SGF multi-user/device medium access protocols for OWC systems and suitable new device discovery algorithms •Create pro-active beam tracking mechanisms that ensure high-level of adaptation in indoor and outdoor mobile environments •Build a OWC-oriented caching overlay based on user's social interests and channel status
	Goals/Measurable Criteria: •E2E throughput •Energy efficiency •'Always' available connectivity of 'infinite' devices (Reliability approaching 100%)	•Bandwidth saving and traffic reduction •Complexity/overhead reduction

The work in MINOAS is performed in order to

- Experimentally validate on software and hardware the theoretical findings and technological developments.
- Qualitatively and quantitatively assess the practical limitations and obstacles of ORIS-empowered OWC systems; and
- Assess the feasibility of the proposed architecture and individual components/functionalities integration.

4.2. MINOAS research results and workplan

Table 9 briefly presents the research result of the project MINOAS as well as their connections to the project pillars.

Table 9: MINOAS research results.

ID	MINOAS Research advances	Pillars I	Pillars II	Pillars III
R-1	Creating the interface between the optical and wireless communication worlds through modeling optical wireless communications systems in direct and indirect LOS scenarios via ORIS and NLOS scenarios	✓		
R-2	Stochastic channel modeling	✓		
R-3	Novel beyond Shannon communications theoretical framework	✓		
R-4	Beam tracking and transmission techniques for environments with ORISs			✓
R-5	MAC and resource allocation techniques		✓	
R-6	ML techniques for the control and orchestration of ORIS aided optical wireless networks		✓	✓

To deliver the aforementioned results, the MINOAS work is organized in four (4) technical work-package (from WP2 to WP5), as described in the following Tables 10-13.

Table 10: WP2 DoW.

WP Number: 2	Title: Requirements, limitations, and system model
The objectives of WP2 include: • the identification of the requirements and limitations of OWC systems and their applications; • the definition of appropriate KPIs accompanied by their targeted values; • modeling of transceivers' and ORIS hardware imperfections (i.e., non-linear behavior of amplifiers, ORIS stacked pixels or groups of pixels, etc.); • the identification and modeling of the movement of transceivers, ORIS, interferers, and obstacles; • modeling of ORIS; • extraction of optical channel particularities, interference, and noise in ORIS aided systems; and • Definition of the complete system architecture and the individual systems models.	
Task 2.1 Requirements and Specification Definition: A careful identification of the requirements is the foundation for the successful completion of MINOAS. During this phase, the use cases of OWC-enabled B5G networks will be described, with emphasis on fronthaul/backhaul scenarios that use wireless all-optical or hybrid (optical and RF) technologies, OWC backhauling, and ORIS aided NLOS links. The requirements, such as performance requirements for optical wireless links and system design requirements (i.e., device size and cost, energy consumption, resilience in interference and noise, etc.), as well as limitations will be extracted for these use cases. Furthermore, safety limits (i.e., transmission power) for the communication will be set in order to abide with state-of-the-art standards (i.e., IEC Laser Safety Standards, IrDA, JEITAC Cp-1223, European COST 1101, etc.), as well as variables, such as the magnitude of transceiver misalignment. **Task 2.2 Overall system architecture definition:** Task 2.2 identifies baselines architectures and designs MINOAS's novel architecture that ensures uninterrupted connectivity, scalability and adaptability, through AI and optical materials technologies. The proposed architecture will be in-	

line with the open radio access network (O-RAN) framework. This is translated into possible early adaptation into B5G systems. The key hardware and software technology enablers (i.e., transceivers, ORISs, etc.) building blocks (transmission and reception schemes) and modules (AI, resource orchestrator, etc.) will be identified, defined and explained in this task and their advantages and disadvantages will be documented. This will allow us to early identify research and technology gaps and provide technical solutions and/or guidelines. **Task 2.3 System modeling:** Task 2.3 aims to define all the network elements and create the mathematical framework that accurately captures their operation and limitations. In this direction, we will identify the key transceivers' and ORIS imperfections that may affect the overall performance of the system. In addition, ORIS will be modeled alongside their limitations using Fourier optics approaches and the results will be validated through simulations in commercial software (CST, Comsol Multiphysics, Matlab, Python, or similar). Key metrices that will be derived, include but not limited to directivity, reflectivity, scattering pattern, beamwidth. Channel models will be presented for each of the use cases that will take into consideration the particularities of optical links, the behavior of ORIS, and the characteristics of interference and noise. Finally, a simulation-driven feasibility study fueled by the specification and requirements of Task 2.1, as well as the system architecture defined in Task 2.2, and incorporated the characteristics of ORIS will be conducted. These simulations will provide an early insight of the performance envelop of MINOAS architecture.

Table 11: WP3 DoW.

WP Number: 3	**Title: Theoretical framework**
The objectives of WP3 include: • the development of a generalized channel model that accounts for different atmospheric conditions and network nodes mobility states and captures the key characteristics and functions of ORIS. In other words, the creation of the interface between optics and signal modeling. • Extraction closed-form expressions, approximations, and bounds of theoretical KPIs, such as the BER, outage probability, throughput, and energy efficiency, which quantifies the performance of OWC systems; and • Develop the information theoretic framework that quantifies self-information and entropy of ORIS-empowered OWC systems.	
Task 3.1 Optics-Signal modeling interface development: The key objective of Task 3.1 is to bridge optics and signal processing by creating the interface between the two types of analysis. In particular, Fourier optics will be employed in order to model the characteristics of the optimal materials and ORIS. Building upon the Fourier optics tailored models and to the fundamentals of multiple-input multiple-output theory, i.e., matrix theory, a new generalized and tractable from the signal modeling and analysis point of view model, will be developed. The model will account for the macroscopic characteristics of the ORIS, such as size, beam patterns, reflection capabilities, ORIS imperfections, etc. The validation of the accuracy and the limitations of this model will be also a topic of study for this task. To achieve this goal commercial simulation tools, such as CST studio, will be used. Another objective of this task is to combine the aforementioned model with stochastic models that capture the characteristics of different optical wireless channels, such as weather conditions, ORIS or other network node mobility, beam misalignment, etc. In this direction, first, we will identify the different stochastic models that accommodate these characteristics. Next, we will explain the correlation of the intermediate (source-ORIS and ORIS-destination) channels and stochastically characterize the end-to-end (source-ORIS-destination) channel distribution. Finally, we will extend our analysis for the case of multiple ORISs. These results will enable the performance analysis of a number of ORIS-empowered OWC systems. **Task 3.2 Performance analysis:** Signal-to-noise-ratio (SNR) and signal-to-interference-and-noise (SINR) will be used to quantify the quality-of-service (QoS) and the transmission windows. The	

reliability of the link will be evaluated based on the outage probability, while the support for transmission schemes will be based on the throughput. In addition, the energy consumption as well as energy and spectral efficiency will be calculated. Furthermore, statistical analysis, and probabilistic methods will be used for the extraction of closed-form expressions that will be used in the design of OWC system architectures. Next, the impact of system and environmental variables on the system's performance will be investigated (i.e., user's movement, stationary and moving obstacles, transceiver misalignment, etc.). **Task 3.3 Beyond Shannon Information Theoretic Framework:** The challenge of performance evaluation and bound definition is critical for every communication system. Towards this end, MINOAS provides a new ORIS-OWC IT framework that takes into account the optical channel characteristics and models as well as the LoS, OLoS and reflected non-LoS nature of the links. This becomes the fundamental analysis for several application scenarios. MINOAS proposes novel fundamental performance bounds for the OWC systems and characterises the information theoretic implications imposed by the new disruptive characteristics of the channel. In more detail, the OWC channel characteristics requires for MINOAS to go beyond the classical Shannon theory by rethinking the fundamental limit in a harsh propagation environment with super-wideband channels, ultra-low SNR links, distance-dependent bandwidth and high-directional reconfigurable links. To achieve this, information theoretic tools are employed. Finally, to deal with the harsh propagation environment of the OWC systems, where it is difficult to establish a direct LoS link, MINOAS leverages ML approaches together with ORIS in order to make the environment itself reconfigurable. This approach is expected to significantly influence both the design of the system as well as the information theoretic framework. Consequently, MINOAS provides the necessary new theoretical tools to assess the reconfigurable OWC system performance.

Table 12: WP4 DoW.

WP Number: 4	**Title: Physical layer and signal processing techniques**
The objectives of WP4 include: • the development of energy and spectrum transmission and reception techniques; • the development of signal processing techniques for the mitigation of hardware imperfections; • the development of novel light positioning approaches.	
Task 4.1 Novel energy and spectral efficient transmission and reception schemes development: Task 4.1 focuses on the design and development of novel energy and spectral efficient transmission and reception schemes through the exploitation for different propagation paths created by ORIS-assisted transmissions as well as rate splitting methodologies that allow low-complexity hardware imperfections mitigation. Moreover, this task will deliver novel channel estimation and channel prediction methodologies capable of de-coupling the phase of the source-ORIS and ORIS-destination channel coefficient. These methods will be built upon the reinforcement learning concept in order to provide high-level of adaptability in the continuously changing wireless environment. **Task 4.2 Intelligent receiver development for de-emphasizing the impact of hardware imperfections on the performance of ORIS-empowered OWC systems:** In addition, rate splitting and digital advanced signal processing techniques will be developed to mitigate the impact of hardware imperfections and the need of accurate channel estimation. In more detail, Task 4.2 will develop a low-complexity signal detection method that does not demand neither channel estimation nor hardware imperfection mitigation. On the contrary, it replaces both the channel estimator and the hardware imperfection mitigator of the receiver with a novel ML module that uses the Kronecker-type pilot structures for training and then applies the trained model in order to derive the transmitted message. This approach is expected to surpass by far conventional methods and even reach the expected performance of the ideal case, where both the channel state information is perfectly known and the impact of hardware imperfections is fully mitigated.	

Task 4.3 ML-enabled light positioning: The dynamic movement of users or access points needs to be taken into account in the beamforming algorithms, potentially including ORISs. The beamforming problem to be addressed in this task is much harder than usual since we need beamforming for two links (source to ORIS and ORIS to destination). For example, a network of fronthaul/backhaul links connected either via LOS paths or reflectors can be attenuated by different rain conditions or due to blockage. In this task the possibility will be investigated to route beams to alternative ways using, e.g., other ORIS reflectors. Which reflector to use for which beams at which time instants is a challenging optimization problem to be addressed. In order to solve such an optimization problem, we frist need to predict the position of each mobile node and interferer. Motivated by this, in T4.3, we develop a ML-based methodology that enables accurate positioning and mapping of the network's environments by exploiting different beam paths created by different ORISs and different ORIS functionalities, such as beam reflection, focusing, and splitting. The efficiency of all the aforementioned techniques will be quantified through simulations.

Table 13: WP5 DoW.

WP Number: 5	**Title: Novel joint spatial MAC and RA protocol**
The WP5 aims to create a novel joint spatial MAC and RA protocol that fully exploits the functionalities of the ORIS. The objectives of WP5 include: • the development of GF and SGF spatial non-orthogonal multiple access (NOMA) techniques; • the development of user grouping policies; • the utilization of MAC layer functionalities of device tracking methodologies; • the design of joint user association and resource allocation schemes by optimizing medium access and environmental variables; • the development of resource allocation policies; • the presentation of ORIS-empowered routing policies; and • the design of an adaptable and fast ML-based radio and spatial resource orchestrator.	
Task 5.1 ORIS-empowered cell-free GF and SGF NOMA policies: An increase in spectral efficiency will be achieved through novel spatial NOMA techniques that will take into consideration the existence of ORISs. Taking the aforementioned statement into account, Task 5.1 focuses on the design of ORIS-empowered cell-free GF and SGF NOMA policies. In more detail, it has two objectives. The first one includes the holistic definition of the protocol, i.e., its functionalities and policies, and the second one includes the extraction of its performance envelop. In this direction, three functionalities will be studied, namely: device-AP association and RA policy, device tracking, and routing in multi-RIS environments. Novel optimization problems will be formulated and solve that will return the optimal (or sub-optimal), device association and RA. The problems will take into account the location of the device, its blockage probability, as well as the application requirements and they will aim at minimizing the devices or overall system's energy footprint. To enable, device tracking, Task 4.2 and Task 4.3 feeds Task 5.1 with the requirements of the physical layer intelligent and light positioning algorithms. Taking into account these requirements, Task 5.1 optimizes the transmission frame structure. Finally, this task deals with optimizing routing in multi-ORIS wireless environments. In this direction, we will first formulate and solve a number of ORIS optimal placements and routing problems that will aim at maximizing the system's energy efficiency or minimizing the communication latency, without violating the application requirements. **Task 5.2 Reinforcement learning based adaptation in ORIS-empowered OWC systems:** To enable fast adaptation of both the network topology and RA, Task 5.2 will develop a novel ML-based orchestrator for ORIS-empowered OWC systems and networks. After the initial device association and RA (performed according to the policies of Task 5.1), the orchestrator will be responsible of performing all the necessary steps in order to guarantee high-level of reliability by means of almost instant adaptation to the wireless conditions. In this direction, it will take as input the current	

characteristics of the OWC networks, namely network topology, estimated blockage probability for each user, the blockage and interference profile, as well as the possible radiation patterns of each one of the ORISs, and it will return a set of recommendation with possible actions, such as the functionality that each ORIS need to perform, routing for each user, level of transmission power, device grouping strategy, and others, that can guarantee the system's optimal performance. The performance of the reinforcement learning strategy are assessed through extensive simulations.

The following table connects the workplan tasks with the research results.

Table 14: Tasks-research results relation.

Task	Result
Task 3.1-Optics-Signal modeling interface development	[R1] Creating the interface between the optical and wireless communication worlds through modeling optical wireless communications systems in direct and indirect LOS scenarios via ORIS and NLOS scenarios
	[R2] Stochastic channel modeling
Task 3.2 Performance analysis	[R3] Novel beyond Shannon communications theoretical framework
Task 3.3 Beyond Shannon Information Theoretic Framework	
Task 4.3 ML-enabled light positioning	[R4] Beam tracking and transmission techniques for environments with ORISs
Task 5.1 ORIS-empowered cell-free GF and SGF NOMA policies	[R5] MAC and resource allocation techniques
Task 5.2 Reinforcement learning based adaptation in ORIS-empowered OWC systems	[R6] ML techniques for the control and orchestration of ORIS aided optical wireless networks

The beam tracking and splitting functionalities of the ORIS will be verified by the MINOAS demonstrators described in WP6 (see Table 15).

Table 15: WP6 DoW.

WP Number: 6	**Title: Demonstration of ORIS-empowered OWC systems**
This work package deals with system integration, testing and experimentation. The objectives of this work package are: • to define the demonstration and testing activities; • to test and evaluate experimentally the developed models and systems; and • to perform the Proof-of-Concept demonstration.	
T6.1 Definition of demonstration scenarios and performance evaluation planning: The first goal of this task is the definition and design of the required system setup of the proof-of-concept demonstrators. The following 2 demonstrations will be implemented: i) ORIS beam steering and ii) ORIS beam splitting. The second goal is to evaluate the results achieved in the 2 demonstrators and to validate the concepts proposed in MINOAS. **T6.2 ORIS beam steering demonstrator:** In this task, a point-to-point ORIS beam steering demonstrator will be implemented based on the technologies and concepts developed in WP2 and WP4. Initially, interfacing between the components of the demonstrator will be specified, to guarantee a smooth integration. Integration of the baseband, and optical designs into complete ORIS prototypes will then follow. This demonstrator will be used to showcase an error free OWC scenario, which will validate the capability for reliable communication using ORIS. Measurements from this demonstrator will be fed to WP3 for validation of the theoretical framework. **T6.3 ORIS beam splitting demonstrator:** In this task, a point-to-multi-point ORIS beam splitting demonstrator will be implemented based on the technologies and concepts developed in WP2 and	

WP5. Initially, interfacing between the components of the demonstrator will be specified, to guarantee a smooth integration. Integration of the baseband, and optical designs into complete ORIS prototypes will then follow. This demonstrator will be used to showcase a multiple user OWC scenario, which will validate the capability for multi-user connectivity using ORIS. Measurements from this demonstrator will be fed to WP3 for validation of the theoretical framework.

4.3. Technical management

4.3.1. Technical management objectives and principles

In any research project, effective technical management is essential to ensure smooth progress, timely completion, and high-quality outcomes. The following objectives and principles guide the technical management of our research endeavor:

1. Clarity of Goals: Clearly define the research objectives, scope, and expected outcomes. Ensure that all the research team members have a shared understanding of these goals to align efforts effectively.
2. Resource Allocation: Allocate resources, including budget, personnel, and equipment, judiciously to support the research activities while maximizing efficiency and productivity.
3. Risk Management: Identify potential risks to the project's success, such as technical challenges, resource constraints, or external dependencies, and develop mitigation strategies to address them proactively.
4. Agile Methodology: Embrace an agile approach to project management, allowing for iterative development, frequent feedback loops, and adaptive planning to respond effectively to changing requirements or circumstances.
5. Collaboration and Communication: Foster open communication and collaboration among team members, stakeholders, and relevant parties to facilitate knowledge sharing, problem-solving, and decision-making throughout the project lifecycle.
6. Quality Assurance: Implement robust quality assurance processes to ensure that research activities adhere to established standards, methodologies, and best practices, thereby delivering reliable and valid results.
7. Documentation and Reporting: Maintain comprehensive documentation of all research activities, including methodologies, data collection procedures, analysis techniques, and results, to facilitate transparency, reproducibility, and dissemination of findings.
8. Ethical Considerations: Uphold ethical principles and guidelines relevant to the research domain, including confidentiality, integrity, and respect for human subjects, ensuring that research is conducted ethically and responsibly.
9. Continuous Improvement: Encourage a culture of continuous improvement, where lessons learned from past experiences are used to refine processes, optimize workflows, and enhance the overall effectiveness of technical management practices.
10. Stakeholder Engagement: Engage with relevant stakeholders, such as funding agencies, industry partners, and end-users, to solicit feedback, gather requirements, and ensure alignment between research objectives and stakeholder needs and priorities.

By adhering to these objectives and principles, we aim to foster an environment conducive to productive research endeavors, where innovation thrives, challenges are overcome, and meaningful contributions to the body of knowledge are made.

4.3.2. Technical management methodology

Effective technical management methodology is crucial for the successful execution of research projects. It encompasses the strategies, processes, and tools employed to plan, execute, monitor, and control the technical aspects of the project. The following methodology outlines the key steps and practices involved in managing the technical aspects of the research project MINOAS.

Step 1: Project Initiation:

- Define project objectives, scope, and deliverables in collaboration with stakeholders.
- Establish a project team with the necessary technical expertise and roles defined.
- Develop a project charter outlining the project's purpose, objectives, stakeholders, and high-level approach.

All the aforementioned steps were conducted during the proposal drafting phase.

Step 2: Technical Planning:

- In WP2, we conduct a thorough technical assessment to identify requirements, constraints, and risks.
- In WP1 and as a part of this deliverable, we develop a detailed technical plan outlining tasks, milestones, dependencies, and resource requirements.
- In D1.1., we define all technical specifications, methodologies, and standards to be followed throughout the project.

Step 3: Resource Management:

- In the grant agreement, we provided the resources allocations including personnel, equipment, and funding based on the technical plan.
- Internal reviews and GAs are conducted in order to allow resource utilization monitoring and allocations adjustment when needed in order to ensure optimal efficiency and productivity.
- The WPLs are responsible for the identification and mitigation of resource constraints or bottlenecks that may impact technical progress.

Step 4: Risk Management:

- Identify technical risks and uncertainties that may affect project objectives or timelines.
- Develop risk mitigation strategies to address identified risks, including contingency plans and alternative approaches.
- Regularly monitor and reassess technical risks throughout the project lifecycle.

Step 5: Technical Execution:

- All the research team members have agreed on implementing the technical plan according to defined specifications and methodologies.
- To Foster collaboration and communication among the MINOAS research team members to facilitate knowledge sharing and problem-solving, we created a number of tools and we prepared several GAs.
- Monitor technical progress against milestones and deliverables, addressing any deviations promptly.

Step 6: Quality Assurance:

- Implement quality assurance processes to ensure that technical deliverables meet established standards and requirements.
- Conduct regular internal reviews and evaluations of technical outputs to identify and address any deficiencies or discrepancies.

- Document and track technical issues, corrective actions, and lessons learned for future reference.

Step 7: Technical reporting and documentation:

- Maintain comprehensive documentation of technical activities, including methodologies, procedures, and results.
- Generate regular progress reports for stakeholders, highlighting technical achievements, challenges, and upcoming milestones.
- Ensure that technical documentation is accurate, accessible, and up-to-date throughout the project.

Step 8: Technical Closure:

- At the last month of the project, all the members of the research team will conduct a thorough review of technical deliverables against project objectives and requirements.
- A document with all the lessons learned, best practices, and recommendations for future projects will be released by MINOAS team.

By following this technical management methodology, MINOAS can effectively navigate its complex technical challenges, optimize resource utilization, and achieve their objectives with a high degree of success. Continuous monitoring, adaptation, and improvement are key to ensuring that technical management practices remain aligned with project goals and evolving needs.

4.3.2.1. Deliverables editors and reviewers

Table 16 summarizes the deliverables of project MINOAS and the possible internal reviewers for each deliverable. The table, especially the year#2 deliverables, will be updated in the course of the project.

Table 16: MINOAS deliverables.

Deliverable	Type	Dissemination Level	Due Date	Editor	Reviewer #1	Reviewer #2
D1.1-Project Administrative, Technical & Data Management Handbook	R	PU	M03	AAAB	EEK	NC
D1.2-Dissemination and Communication Plan	R	CO	M05	AAAB	EEK	NC
D6.1-Report on the demonstration scenarios and description of testbed implementation plan	R	PU	M13	EEK	AAAB	NC
D2.1-Architecture presentation paper submission	DEC	PU	M18	NC	AAAB	EEK
D4.1-Intelligent receiver for de-emphasizing the	DEC	PU	M19	AAAB	EEK	NC

impact of hardware imperfections on the performance of ORIS-empowered OWC systems paper submission						
D4.2-ML-enabled light positioning methodology journal	DEC	PU	M20	AAB	EEK	NC
D5.1-ORIS-empowered cell-free GF and SGF NOMA	DEC	PU	M21	NC	EEK	AAAB
D3.1-ORIS-empowered OWC performance analysis paper submission	DEC	PU	M22	NC	AAAB	AP
D1.3-Final Report	R	CO	M24	AAAB	EEK	NC
D5.2-Reinforcement learning based adaptation in ORIS-empowered OWC systems	DEC	PU	M24	NC	AAAB	AP
D6.2-ORIS beam steering/spliting demonstrator	DEM	PU	M24	EEK	NC	AAAB

The acronyms on the last three columns correspond to the MINOAS researchers, Table 2.

5. Innovation management

5.1. Overview of national, EU, and international initiatives for B5G/6G optical wireless systems

5.1.1. Related research and innovation projects

In the following table, we summarize the current national, EU, and international initiative for B5G/6G optical wireless systems.

Acronym	Framework	Description
SUPERIOT	Horizon Europe	SUPERIOT aims at developing a truly sustainable and highly flexible IoT system based on the use of optical and radio communications, and the exploitation of printed electronics technology for the implementation of sustainable IoT nodes. The dual-mode optical-radio approach provides unique characteristics to the IoT system. The system can be reconfigured to use optical, radio, or both connectivity approaches. The hybrid optical-radio system allows very efficient use of resources while combining the advantages of both wireless communication methods.
6G-EWOC	Horizon Europe	The 6G-EWOC project aims to contribute to the development of future 6G-AI based networks by ending with TRL-4-level developments on critical technologies and devices for expanding the reach of 6G, especially in high mobility scenarios. The three ambitions of 6G-EWOC focus on: AMB1, Optical Wireless Communications (OWC) for V2V and high-rate (Gb/s) V2I applications, chip-scale optical beamformers, and developing connected laser/radio detection, ranging, and communication (Lidar/Radar).

MINOAS aims at improving the optical wireless channel by adding an ORIS capable of creating a favorable electromagnetic environment. In contrast to the aforementioned projects, MINOAS does not intent to create any innovation in terms transmission or reception modules. On the contrast, MINOAS intends to increase the reliability of OWC systems by creating the technology innovation that allow us to manipulate the wireless medium in a favorable for the legitimate user manner.

5.2. Overview of the envisioned B5G/6G market

The envisioned market for B5G and 6G technologies represents a significant evolution in wireless systems, promising to revolutionize various industries and aspects of daily life. While specific predictions may vary, several key trends and opportunities can be identified:

Ultra-High-Speed Connectivity: B5G/6G networks aim to offer unprecedented data speeds, potentially reaching terabits per second (Tbps) or even higher. This level of speed could enable near-instantaneous downloads of large files, high-resolution streaming without buffering, and real-time communication with virtually no latency.

Massive Internet of Things (IoT) Integration: These advanced networks are expected to support a massive number of connected devices, far beyond what current 5G networks can accommodate. This will enable the proliferation of IoT devices in smart cities, industrial automation, healthcare, agriculture, and various other sectors, leading to improved efficiency, automation, and data-driven decision-making.

Low Latency and High Reliability: B5G/6G networks will significantly reduce latency, possibly reaching ultra-low levels measured in microseconds. This low latency is critical for applications such as autonomous vehicles, remote surgery, augmented reality (AR), and virtual reality (VR), where any delay can be detrimental. Additionally, these networks will offer high reliability, ensuring uninterrupted connectivity for mission-critical applications.

Non-Terrestrial Networks (NTN): Wireless systems that operate above the Earth's surface, including satellites (from low Earth to geostationary orbit), high-altitude platforms (HAPS), and unmanned aerial vehicles (UAVs, drones), stand to massively benefit from emerging B5G/6G technologies. Devices and components for such NTN will be essential to realizing seamless connectivity and bringing coverage even to remote areas that do not have access to traditional terrestrial networks. Broadband satellite internet providers, such as StarLink, are another example of such NTN.

AI Integration: Artificial intelligence (AI) will play a central role in B5G/6G networks, facilitating intelligent network management, predictive maintenance, security enhancement, and personalized services. AI-powered algorithms will optimize network resources, dynamically allocate bandwidth, and proactively identify and mitigate potential issues.

Edge Computing and Network Slicing: Edge computing will be seamlessly integrated into B5G/6G networks, allowing computation and data storage to be performed closer to the end-users. Network slicing will enable the creation of virtualized network segments tailored to specific applications or industries, ensuring optimal performance, security, and resource allocation for diverse use cases.

Expanded augmented reality (AR) and virtual reality (VR): With ultra-high-speed, low-latency connectivity, AR and VR experiences will become more immersive, interactive, and accessible. From gaming and entertainment to training, education, and remote collaboration, these technologies will redefine how people interact with digital content and each other.

Industry Transformation: B5G/6G networks will catalyze transformative changes across industries, enabling smart manufacturing, predictive maintenance, precision agriculture, remote healthcare services, immersive entertainment experiences, and much more. Businesses will leverage these technologies to drive innovation, improve operational efficiency, and deliver enhanced products and services to consumers.

Digital Twins: Virtual replicas of physical digital/wireless communication systems are especially intriguing for emerging applications in the context of IoT in our massively networked and digitalized environment. These mirror the behavior and performance of real-world networks, allowing engineers to simulate, analyze, and optimize wireless technologies before any costly and resource-demanding deployment or fabrication is undertaken. Digital twins will be empowered by B5G/6G networks, thus enhancing efficiency, helping troubleshoot issues, and facilitating advancements in the rapidly evolving field of wireless communication.

Privacy and Security Challenges: As connectivity becomes more pervasive and critical to daily life, addressing privacy and security concerns will be paramount. B5G/6G networks will need robust encryption, authentication mechanisms, and privacy-preserving technologies to safeguard sensitive data and mitigate cyber threats effectively.

Global Connectivity and Digital Inclusion: B5G/6G networks have the potential to bridge the digital divide by providing high-speed connectivity to underserved regions and populations worldwide. This expanded connectivity can empower individuals, stimulate economic growth, and foster innovation on a global scale.

Overall, the envisioned B5G/6G market represents a transformative shift in wireless communications, unlocking a myriad of opportunities for innovation, economic growth, and societal advancement. However, realizing this vision will require collaborative efforts from industry stakeholders, policymakers, and researchers to address technical challenges, regulatory issues, and societal implications effectively.

5.2.1. B5G/6G market landscape

As all the previous communication generations, 6G comes as a wave of revolution for the telecommunication world, which is expected to optimize performance and enhance the efficiency in industrial and consumer applications, while creating new domains of applications in diverse scenarios offering novel features. With the rise of IoT, Industry 4.0, and home automation, advanced network solutions have become essential. 6G aims to provide low latency and high data transfer rates, enabling smart technologies, automation, and AI across industries.

Despite the paramount interest of several industrial players, including manufacturers like Nokia, Ericsson, and Huawei, and operators, such as Telefonica, TIM, Vodafone, etc. as well as policy makers, such as the European Commission, the 6G market has not yet been clearly defined. This fact gives MINOAS project the opportunity to influence the next generation network by offering innovative solutions that can cover the 6G requirements. These requirements are end-user achievable data rate, latency, reliability, and availability. Next, we quantify the expected 6G requirements.

Typically, experts set 10 to 100 Gbps as the targets for 6G, and that means moving from the standards we follow in the license exempt frequency bands IEEE 802.11ad, which were released in 2018, to 802.11ay which has just been ratified and supports raw data rates of 34 Gbps or more. IEEE 802.11ay opens the door to both indoor and outdoor access networks with directional links.

According to the 5G infrastructure association, 6G will bring a near-instant and unrestricted complete wireless connectivity. A new landscape will also emerge for the enterprises, as a result of the convergence that 6G will allow in the fields of connectivity, robotics, cloud and secure and trustworthy commerce. This will radically reshape the way enterprises operate.

5.3. Innovation management

The innovation strategy is defined in D1.1 in terms of ensuring the project excellence that is described in Section 1.2. Innovation management methodology for MINOAS involves a systematic approach to foster creativity, manage the research and development process efficiently, and ensure the successful implementation and commercialization of new ideas. The methodology typically encompasses the following phases:

- <u>Phase 1-Ideation and Conceptualization:</u> The key goal of this section is to understand the challenges and limitations of current optical wireless networks (OWN). In this direction, we have regular brainstorming sessions, literature reviews, and expert consultations to generate innovative ideas for improving OWN using ML. For each identified innovation, we assess the technical feasibility, potential market, and resources required for the proposed ideas.
- <u>Phase 2-Research and Development (R&D)</u>: In this phase, we design and develop the prototype based on the chosen idea, including the ORIS, appropriate ML algorithms,

datasets, and OWN configurations. Finally, for each innovative idea, we conduct extensive experiments to test the prototype under various conditions. We collect and analyze data to evaluate the performance of the MINOAS system. Based on the test results, we refine the prototype through iterative development, enhancing its efficiency, scalability, and reliability.

- Phase 3-Integration and Validation: After the project end, we intend to integrate the MINOAS system into a larger network to test its interoperability and performance in a real-world scenario. This allows validation of the system against pre-defined criteria and objectives, including speed, reliability, and energy efficiency improvements. Finally, we will engage with potential users, industry partners, and other stakeholders to gather feedback and further refine the system.
- Phase 4-Commercialization and Scaling: In this phase, we conduct a comprehensive market analysis to understand the demand, competition, and potential barriers to entry. Next, we develop a business model that outlines how MINOAS solution will be commercialized, focusing on pricing strategies, distribution channels, and customer segments. Finally, we plan to scale the solution, considering manufacturing, distribution, and support for the MINOAS system.
- Phase 5-Knowledge Management and Continuous Innovation: In MINOAS, we document the development process, learnings, and technical details for future reference and knowledge sharing. The IP is protected through patents, or copyrights as applicable. To ensure continuous innovation within the two years of the project, we stay abreast of the latest developments in OWN technologies. This allow us to continuously improve and innovate the system. Finally, we actively involve stakeholders, including researchers, industries, and end-users, throughout the project to ensure alignment with market needs and user expectations.

6. Data management

6.1. Data summary

MINOAS is expected to deliver the following type of data:

- Deliverables,
- Technical and administrative reports,
- Preprints,
- Papers,
- Chapter in books,
- White papers,
- Presentations,
- Experimental datasets,
- Codes,
- Experimental datasets,
- Flyers,
- Newsletters, and
- Videos.

6.2. Open data management policy

MINOAS's general data management policy that is presented in the subsequent chapters has been developed in accordance with Horizon 2020 FAIR principles, open data requirements and implementation guidelines. It applies mainly to new results that are produced in MINOAS and that are to be made available by the project consortium as open source, open science and open data.

6.2.1. Making data findable

One of the key objectives of MINOAS data management plan is making data findable. In this direction, MINOAS follows ten (10) clearly defined steps:

1. Implementation of a data management system: In MINOAS, we use a table that categorize the outcomes of the project into:
    a. Deliverables
    b. Technical and administrative reports,
    c. Papers,
    d. Chapter in books,
    e. White papers,
    f. Presentations,
    g. Experimental datasets,
    h. Codes,
    i. Flyers,
    j. Newsletters, and
    k. Videos

The table has the following attributes:
    a. Identifier (ID): An increasing number that begins in 1.
    b. Title: The title of the document.

   c. Brief description: Free text of 500 characters.
   d. Type: A list that contains the following values: “Deliverable”, “Technical report”, “Administrative report”, “Journal paper”, “Conference paper”, “Chapter in book”, “White paper”, “Flyer”, “Newsletter”, and “Video”
   e. Dissemination level: A list that contains the following values: “Public” and “Confidential”.
   f. Version: Drafts are versioned as YYYYMMDD_x.y, while final files are versioned as YYYYMMDD_x.0, where YYYY is the year, MM is the month, DD is the day, x the submitted file version, and y the draft revision version.
   g. Repository link: MINOAS repository link that allows the research team to easily access the files.
2. Filenames: The file names that we use have the following format: [Type_ID]_[ID]_[Title]_[Version]. The possible [Type_ID] are documented in Table 17. The [ID] is taken by the MINOAS data table, while the [Title] is the title of the document. Finally, the version of the file is taken by the MINOAS data table.

Table 17: Possible [Type_ID].

[Type_ID]	**File type**
D	Deliverable
T	Technical report
A	Administrative report
J	Journal paper
C	Conference paper
B	Chapter in book
W	White paper
Pr	Presentation
E	Experimental datasets
CD	Code
F	Flyer
N	Newsletter
V	Video

3. Keywords: For each document we provide at least three search keywords. This is expected to maximize the possibilities for re-use.

6.2.2. Making data openly accessible

Only Deliverables that have been identified as confidential will not become available to the public. All the other documents will become accessible in the following open repositories.

Table 18: MINOAS open repositories.

Data type	MINOAS webpage	MINOAS YouTube channel	ArXiV	Zenodo	Publisher’ s website	ResearchGate	MINOAS github	IEEE Dataportal
Deliverable	✓			✓				
Technical report	✓			✓				
Administrative report	✓			✓				
Journal paper	✓		✓	✓	✓	✓		

Conference paper	✓		✓	✓	✓	✓		
Chapter in book					✓			
White paper	✓		✓	✓	✓	✓		
Presentations	✓			✓				
Experimental datasets	✓			✓				✓
Code	✓			✓			✓	
Flyer	✓			✓				
Newsletter	✓			✓				
Video	✓	✓						

6.2.3. Making data interoperable

To ensure data interoperability, all the MINOAS data are published using standard file formats (txt, pdf, csv etc.). All data are accessed using standard tools.

6.2.4. Increase data re-use

MINOAS intends to create a data library that will be presented and finds its place within the optical wireless and photonics communities. To achieve this, from MINOAS project day 1, we decided to use CC licenses and open repositories in order to allow third parties to use the produced data even after the end of the project. Moreover, as explained in Section 3, we follow a quality assurance control policy in order to ensure that the produced data are comprehensive and thus every scientist and researcher in the field can reuse them.

6.3. Confidential data management policy

Final versions of confidential deliverables, or of reports that contribute to a confidential deliverable, will be for the Consortium and the HFRI. Draft versions will be for the Consortium alone.

6.4. Data management responsibilities

MINOAS researcher team has specific responsibilities regarding data management to maintain the integrity and reproducibility of their work while adhering to legal and ethical standards. Next, we present the main data management responsibilities:

1. Data Collection: MINOAS researchers are responsible for collecting accurate and relevant data. All the data collection methods are well-documented and reproducible to maintain transparency and enable future replication or validation of the research findings.
2. Data Storage and Security: MINOAS is tasked with securely storing collected data to prevent loss, theft, or unauthorized access. The data are stored in reliable and secure locations, like encrypted databases or password-protected servers, to safeguard sensitive information. Regular backups and version control mechanisms are implemented to prevent data loss and maintain data integrity.
3. Data Documentation and Metadata: Proper documentation of data is essential for understanding its context, quality, and potential limitations. Motivated by this, MINOAS researchers create detailed metadata describing the characteristics, structure, and provenance of the data. Metadata include information, like data collection methods, variables, units of measurement, and any transformations or preprocessing steps applied to the data.

4. Data Sharing and Accessibility: MINOAS has a responsibility to share the data with the scientific community whenever possible, promoting transparency and collaboration. Data should be shared in accordance with the FAIR policy and CC licenses. In MINOAS, we use a number of data repositories, as presented in Table 18.
5. Data Analysis and Interpretation: MINOAS researchers employ rigorous and transparent methods to derive meaningful conclusions from the data. All the methods are well-documented. Interpretations of the data are based on sound scientific principles, avoiding bias or misrepresentation.

6.5. Data security

All the source files will be uploaded to the MINOAS repository. All the members of the research team will keep back-up source files.

6.6. Ethical issues

In general, the integration of AI into OWC systems introduces a number of ethical considerations. One prominent concern revolves around privacy infringement, as AI algorithms may inadvertently collect and analyze sensitive personal data transmitted through these systems without adequate consent or safeguards. Additionally, there's a risk of bias and discrimination embedded within AI models, potentially exacerbating disparities in access to optical wireless services or perpetuating harmful stereotypes. Moreover, the reliance on AI could lead to job displacement, raising questions about the societal impact on employment and the need for retraining programs.

In MINOAS, we recognize the aforementioned concerns, and we make the following statement:

- No personal data will be collected during MINOAS project.
- In MINOAS, AI is used to solve complex problems, such as beam-tracking and forth-dimensional (4D) resource block allocation. The operation and results of the produced ML models will be verified using exhaustive search approaches as well as the experts' experience.
- Finally, our results do not lead to network automation; thus, no job displacement issues or questions are raised.

7. IPR management and protection

An essential building block for the success of MINOAS project is the creation of an intellectual property (IP) management guideline that explicit rules concerning IP ownership, access rights to any background and foreground IP. To achieve this, we first present the European Regulatory Framework. Building upon it, we document the IPR management in MINOAS. In more detail, according to the Directive 2004/48/EC of the European Parliament and of the Council of 29 April 2004 on the enforcement of intellectual property rights:

"The achievement of the internal market entails eliminating restrictions on freedom of movement and distortions of competition, while creating an environment conducive to innovation and investment. In this context, the protection of intellectual property is an essential element for the success of the internal market. The protection of intellectual property is important not only for promoting innovation and creativity, but also for developing employment and improving competitiveness."

"The protection of intellectual property should allow the inventor or creator to derive a legitimate profit from his/ her invention or creation. It should also allow the widest possible dissemination of works, ideas and new know-how. At the same time, it should not hamper freedom of expression, the free movement of information, or the protection of personal data, including on the Internet."

"However, without effective means of enforcing intellectual property rights, innovation and creativity are discouraged and investment diminished. It is therefore necessary to ensure that the substantive law on intellectual property, which is nowadays largely part of the acquis communautaire, is applied effectively in the Community. In this respect, the means of enforcing intellectual property rights are of paramount importance for the success of the internal market."

To sum up, foreground IP shall be owned by the project partner carrying out the work leading to such IP. If any Foreground IP is created jointly by the two project partners and it is not possible to distinguish between the contributions of each of the project partners, such work will be jointly owned by the contributing project partners. The same shall apply if, in the course of carrying out work in the project, an invention is made having two or more parties contributing to it, and it is not possible to separate the individual contributions. Any such joint inventions and all related patent applications and patents shall be jointly owned by the contributing parties.

8. Risk management

In general, risks can be broadly classified into two categories, one related to the smooth execution of the project work-plan by the collaborating partners and a second regarding specific technical/research obstacles/limitations appearing during the project. For the former category specific project management actions will cope with those issues, while for the latter category technical resolutions will be provided. Table 19 summarizes the initial risks that have been identified by the MINOAS project partners.

Table 19: MINOAS initially identified risks.

Description of risk [impact]	WPs involved	Proposed risk –Mitigation measures
Administrative risks		
AR1: Lack of communication among the research team member [Low]	1	Regular meetings will be organized at project WP & Task level to safeguard smooth technical implementation & communications among team members. Insufficient communication amongst them will be escalated to the prime investigator (PI), who will try to encourage smoother collaboration. If the issue persists, solid goals will be set for all involved team members, which will be monitored closely.
AR2: Shortage of resources and/or change of personnel [Low]	1	UoWM and AUTH have already made binding agreements on resource availability. In the case of personnel substitution with another team member, the new member must demonstrate comparable competencies. The same applies for the shortage of (personnel) resources.
Scientific/technical risks		
STR1: Insufficient research team members competence/effectiveness [Low]	2-5	The research team is highly complementary & gathers together the requested skills for the main streams. All methodologies and technologies to be used in the implementation of the project are carefully selected so as to minimize potential risks. If an incompetence is identified, the PI will fill this gap either by himself, or through searching for a new collaborator.
STR2: Significant advances in SOTA outside MINOAS [Low]	2-5	Continue to monitor SOTA, and if necessary, consider alternative solutions going even beyond the advances in the SOTA and refocus/replan those parts of the project.
STR3: Intractable fundamentals derivation for some of MINOAS models [Medium]	3	Take alternative paths, consider simplified models and extract fundamental (insightful and tight) bounds.
STR4: Utilized ML training models are insufficient for a specific channel [Medium]	4-5	The training models will be carefully designed and refined from the early MINOAS stages and throughout all usage scenarios. Therefore, potential shortcomings will be identified and addressed early.
STR5: Measurements: non-repairable equipment failure [Low]	6	Simulations can be used instead for making the channel models based on the measurements that could be

		successfully performed. Also, it is possible to use partners' measurement equipment.
STR6: ORIS fundamental technological limitations (e.g., diffraction limit, fabrication costs/methods related to physical implementation), the bulk (aperture, thickness, weight) of the metasurface panels/boards along with the control electronics may constraint the performance expectations [Medium]	2, 6	The technology limitations that are related to the ORIS are recognized in an early stage of MINOAS project (WP2) and are taken into account when setting the targets of the selected application scenarios in WP2. Simulations will be conducted in order to ensure that the targeted KPIs can be met. Also, in case new technology limitations are revealed in WP6 (during the demonstration preparation phase), the WP6 leader will document the limitations and provide engineering insights and guidelines for further investigation. Finally, baseband signal processing solutions that may counterbalance the ORIS technological limitations will be tested.

Bearing in mind that risk may have an impact on the project schedule and project objectives and finally may lead to contractual issues, a Risks Manager will be appointed by the GA at the M04. He/she will be asked periodically to review the project progress and the risks items table to ensure that MINOAS remains online with its main technical objectives. The Risks Manager will be in charge of keeping up-to-date the Risk Management Table that will be produced by the WP1. He/she will interact with the GA and WPs in this task.

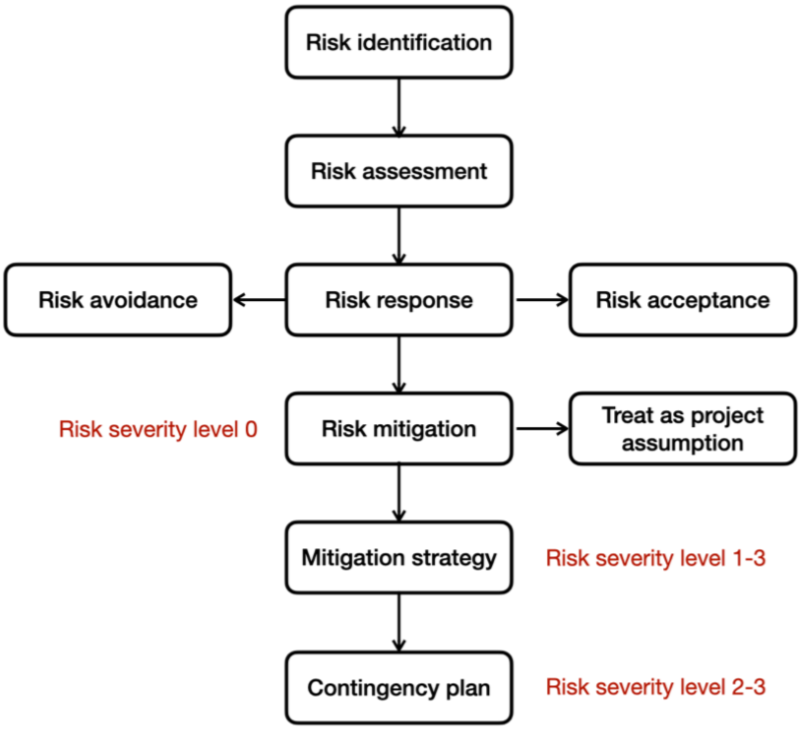

Figure 4: Risk management strategy.

The process of risk management is shown Figure 4. Once identified (qualitative analysis), risks will be weighted by degree of severity according to their probability of occurrence and impact on the project results. The impact on project results (quantitative analysis) will be classified according to different information provided by the risk originator, like delay of delivery, decrease of performance, impact on another deliverable, or commercial impact. Then, mitigation and contingency plans will be defined according to risk severity (risk response). Risks will then be monitored on a regular basis, with a combined top-down and bottom-up approach:

- At the project start, and during the GA meeting, high level risks will be defined and assessed;
- Risks at the task and WP level will be defined and followed-up weekly or bi-weekly at each WP meeting.

9. Conclusions

In this deliverable, we reported an overview of the project administration processes, described the technical management tools, and approaches that are followed, and provided data management guidelines. The innovation strategy was defined in terms of ensuring the project excellence. It documented the required processes and procedures for assessing the quality and the guidelines and risk assessment plans of the project. Finally, it addressed the lifecycle and public availability of research data generated by the project.

References

[**Alkyildiz2018**] I. F. Alkyildiz, C. Han, and S. Nie, “Combating the distance problem in millimeter wave and terahertz frequency bands,” IEEE Commun. Mag., vol. 56, no. 6, pp. 102-108, June 2018.

[**Andrews2016**] J. G. Andrews, X. Zhang, G. D. Durgin, and A. K. Gupta, “Are we approaching the fundamental limits of wireless network densification?” IEEE Communications Magazine, vol.54, no.10, pp.184–190, October 2016.

[**Arnon2012**] S. Arnon, J. Barry, G. Karagiannidis, R. Schober, and M. Uysal, Advanced Optical Wireless Communication Systems. Cambridge University Press, New York, NY, USA, 2012.

[**Boulogeorgos2018**] A.-A. A. Boulogeorgos, A. Alexiou, T. Merkle, C. Schubert, R. Elschner, A. Katsiotis, P. Stavrianos, D. Kritharidis, P. K. Chartsias, J. Kokkoniemi, M. Juntti, J. Lehtomäki, A. Teixeirá, and F. Rodrigues, “Terahertz technologies to deliver optical network quality of experience in wireless systems beyond 5G,” IEEE Commun. Mag., vol. 56, no. 6, pp. 144–151, Jun. 2018.

[**Cisco2017**] Cisco, “2020 cisco highlights,” 2017

[**Ghassemlooy2015**] Z. Ghassemlooy, S. Arnon, M. Uysal, Z. Xu and J. Cheng, "Emerging Optical Wireless Communications-Advances and Challenges," in IEEE J. Sel. Areas in Commun., vol. 33, no. 9, pp. 1738-1749, Sep. 2015.

[**Glybovski2016**] S. B. Glybovski, S. A. Tretyakov, P. A. Belov, Y. S. Kivshar, C. R. Simovski, “Metasurfaces: From microwaves to visible,” Physics Reports, vol. 634, May 2016.

[**Greyb**] https://www.greyb.com/li-fi-vlc-patent-landscape-study/

[**Liaskos2018**] C. Liaskos, S. Nie, A. Tsioliaridou, A. Pitsillides, S. Ioannidis, and I. F. Akyildiz, “A new wireless communication paradigm through software controlled metasurfaces,” IEEE Communications Magazine, vol. 56, no. 9, pp. 162–169, September 2018.

[**Pan2010**] S. J. Pan and Q. Yang, “A Survey on Transfer Learning,” IEEE Trans. on Knowl. and Data Eng., vol. 22, Oct. 2010.

[**Park2019**] J. Park, S. Samarakoon, M. Bennis, and M. Debbah, “Wireless Network Intelligence at the Edge,” submitted, 2019. [Online]. Available: https://arxiv.org/abs/1812.02858

[**Renzo2016**] M. D. Renzo, W. Lu, and P. Guan, “The intensity matching approach: A tractable stochastic geometry approximation to system-level analysis of cellular networks,” IEEE Trans. on Wireless Comm., vol. 15, no. 9, pp. 5963–5983, September 2016.

[**Shannon1948**] C. E. Shannon, “A mathematical theory of communication,” Bell System Technical Journal, vol. 27, no. 3, pp. 379–423, 1948.

[**Shao2015**] S. Shao, et al. “Design and analysis of a visible-light-communication enhanced WiFi system,” Journal of Optical Communications and Networking, vol. 7, no. 10, pp. 960-973, 2015.

[**Schenk2008**] T. Schenk, RF Imperfections in High-Rate Wireless Systems. The Netherlands: Springer, 2008.

[**Singh2013**] S. Singh, H. S. Dhillon, and J. G. Andrews, “Offloading in heterogeneous networks: Modeling, analysis, offloading in heterogeneous networks: Modeling, analysis, and design insights,” IEEE Transactions on Wireless Communications, vol. 12, no. 5, pp. 2484–2497, May 2013.

[**Tsilipakos2016**] O. Tsilipakos, A. C. Tasolamprou, A. Pitilakis, F. Liu, X. Wang, M. S. Mirmoosa, D. C. Tzarouchis, S. Abadal, Taghvaee, H., Liaskos, C., Tsioliaridou, A., Georgiou, J., Cabellos-Aparicio, E. Alarcón, S. Ioannidis, A. Pitsillides, I. F. Akyildiz, N. V. Kantartzis, E. N. Economou, C. M. Soukoulis, M. Kafesaki, S. Tretyakov, “Toward Intelligent Metasurfaces: The Progress

from Globally Tunable Metasurfaces to Software-Defined Metasurfaces with an Embedded Network of Controllers," Adv. Optical Mater., vol 8, 2020.
[**Wiener1948**] N. Wiener, Cybernetics, or Control and Communication in the Animal and the Machine. MIT Press, 1948.
[**Willebrand2002**] H. Willebrand, and G. S. Backsheesh, "Free space optics: Enabling optical connectivity in today's networks," SANS publishing, 2002.
[**Wu2014**] S, Wu, Y. Honggang, C.-H. Youn, "Visible light communications for 5G wireless networking systems: From fixed to mobile communications," IEEE Network, vol. 28, no. 6, pp. 41-45, 2014.
[**Zappone2018**] A. Zappone, M. Di Renzo, and M. Debbah, "Wireless Networks Design in the Era of Deep Learning: Model-Based, AI-Based, or Both?", IEEE Trans. on Comm., 2019.