6G-MIRAI-HARMONY: Machine Intelligence based Radio Access Infrastructure

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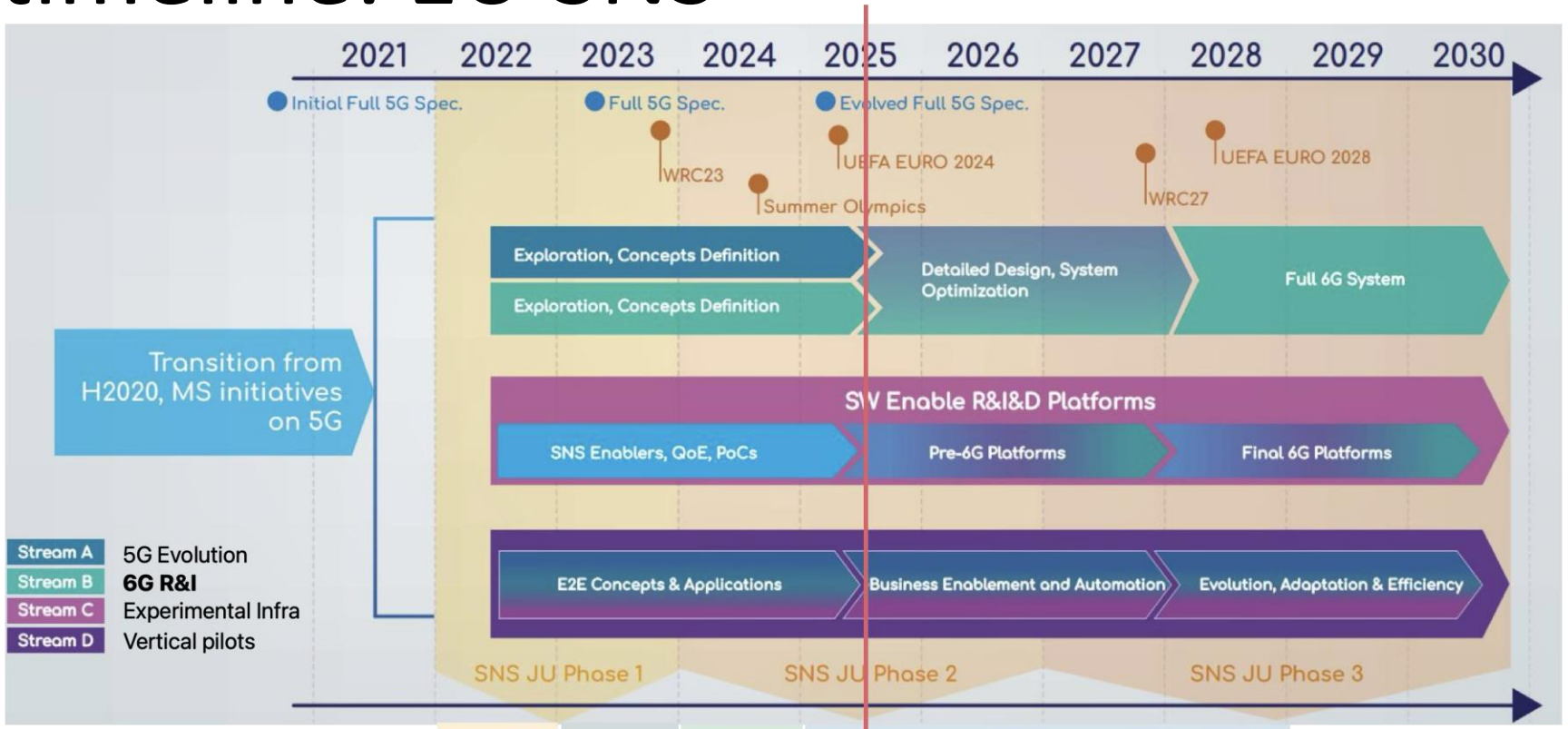
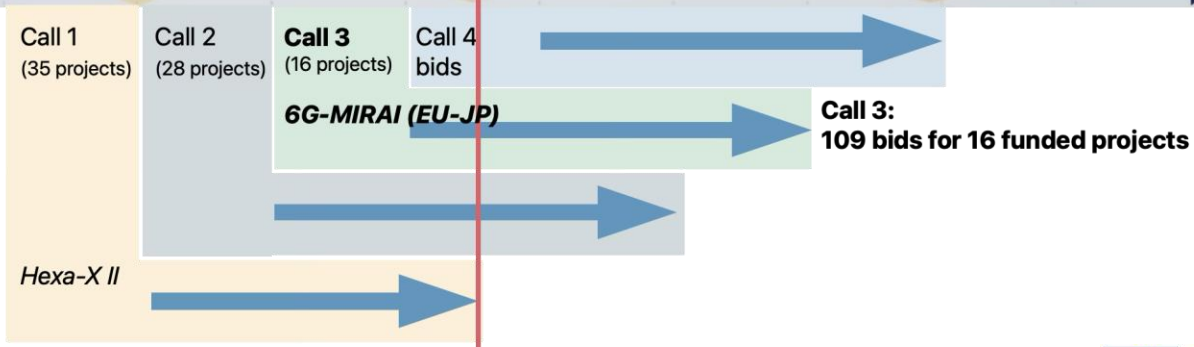
Co-funded by the European Union

6GSNS

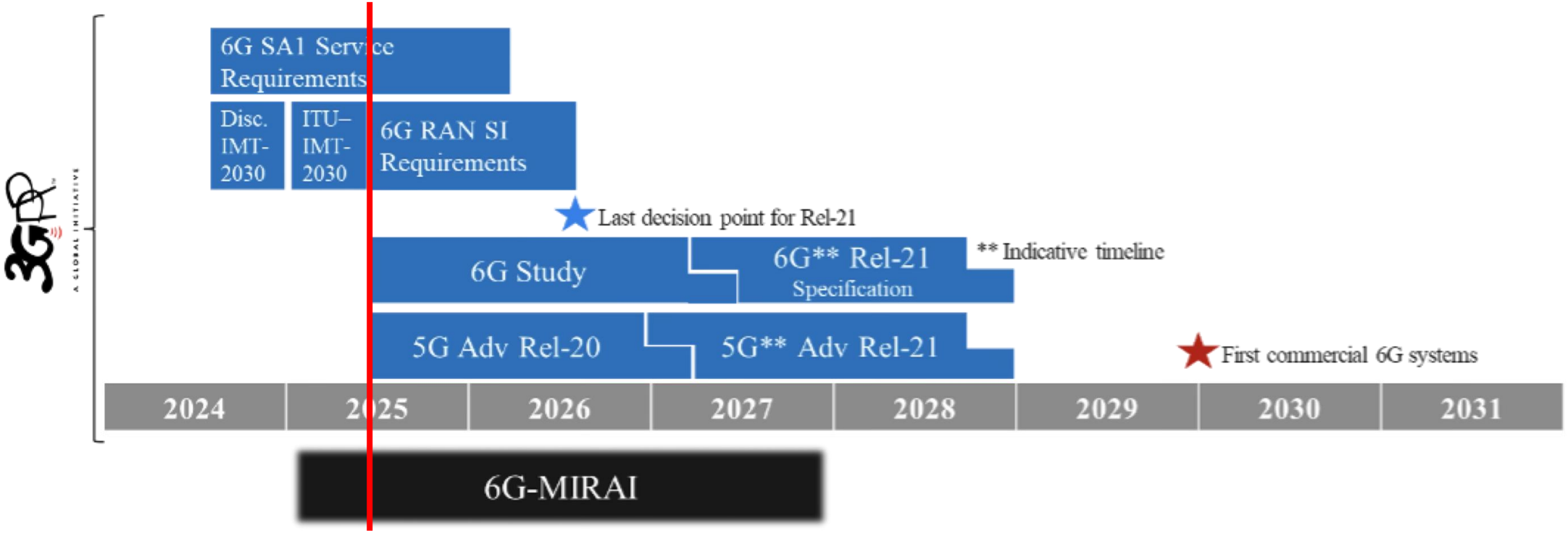
6G timeline: EU SNS



Original source: SNS R&I Work Programme 2024

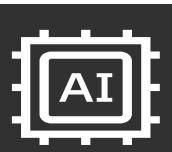


6G timeline: 3GPP

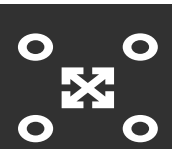


- Contribute to the anticipated (AI/ML-related) 6G study items in Rel-20 that will identify the core 6G functionalities, and can provide inputs for the corresponding Rel-21 work item delivering the first 6G specification
- Could provide baseline research for Rel-21 study items in AI/ML, which will potentially expand on the baseline 6G functionality and potentially consider more intricate use cases and architectures such cell-free schemes

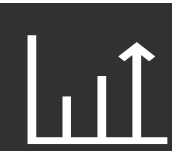
6G-MIRAI-HARMONY: overview



AI-native 6G air interface and RAN architecture



Concept validation and pre-alignment for standardization



Start April 2025, duration 36 months

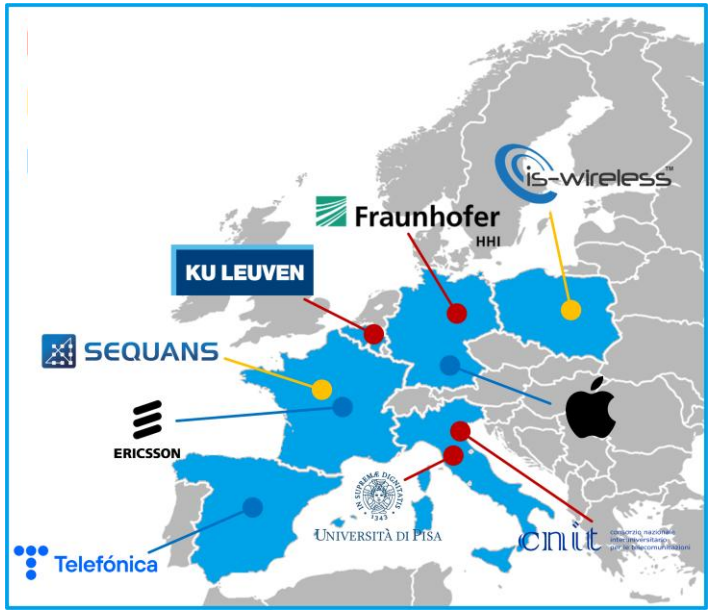
9 partners in EU, 7 partners in Japan

Collaboration between EU (6G-MIRAI) and Japan (HARMONY)

Collaboration EU - Japan

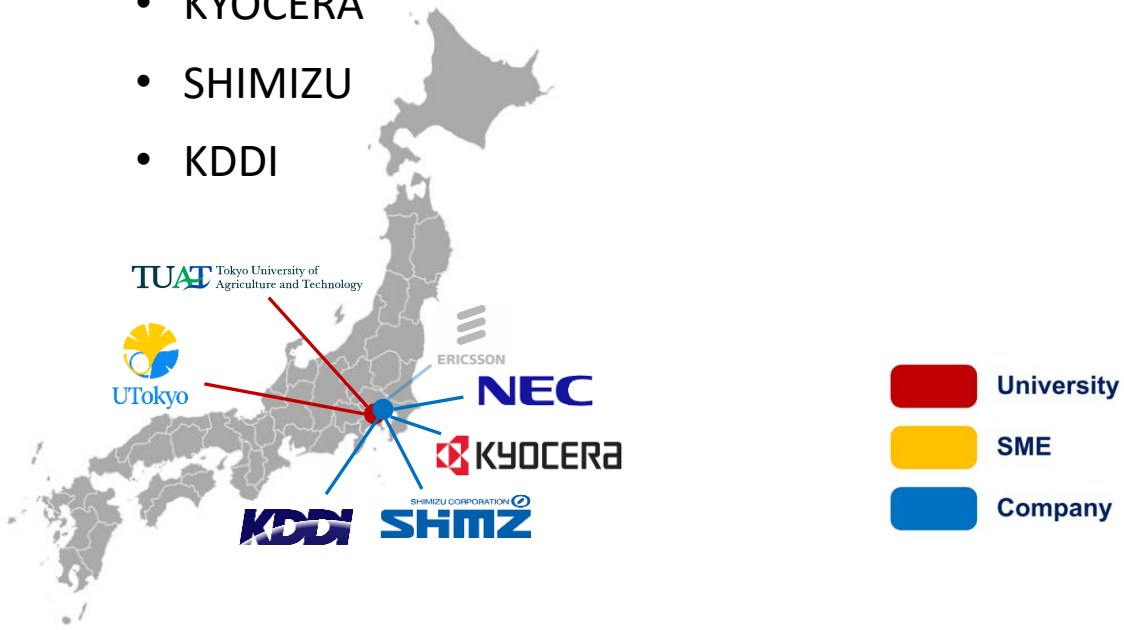
EU (6G-MIRAI project)

- Ericsson (Project Lead)
- Fraunhofer (Technical Lead)
- Apple (Communication Mgr)
- CNIT
- University Pisa
- KU Leuven
- IS-Wireless
- Sequans
- Telefonica



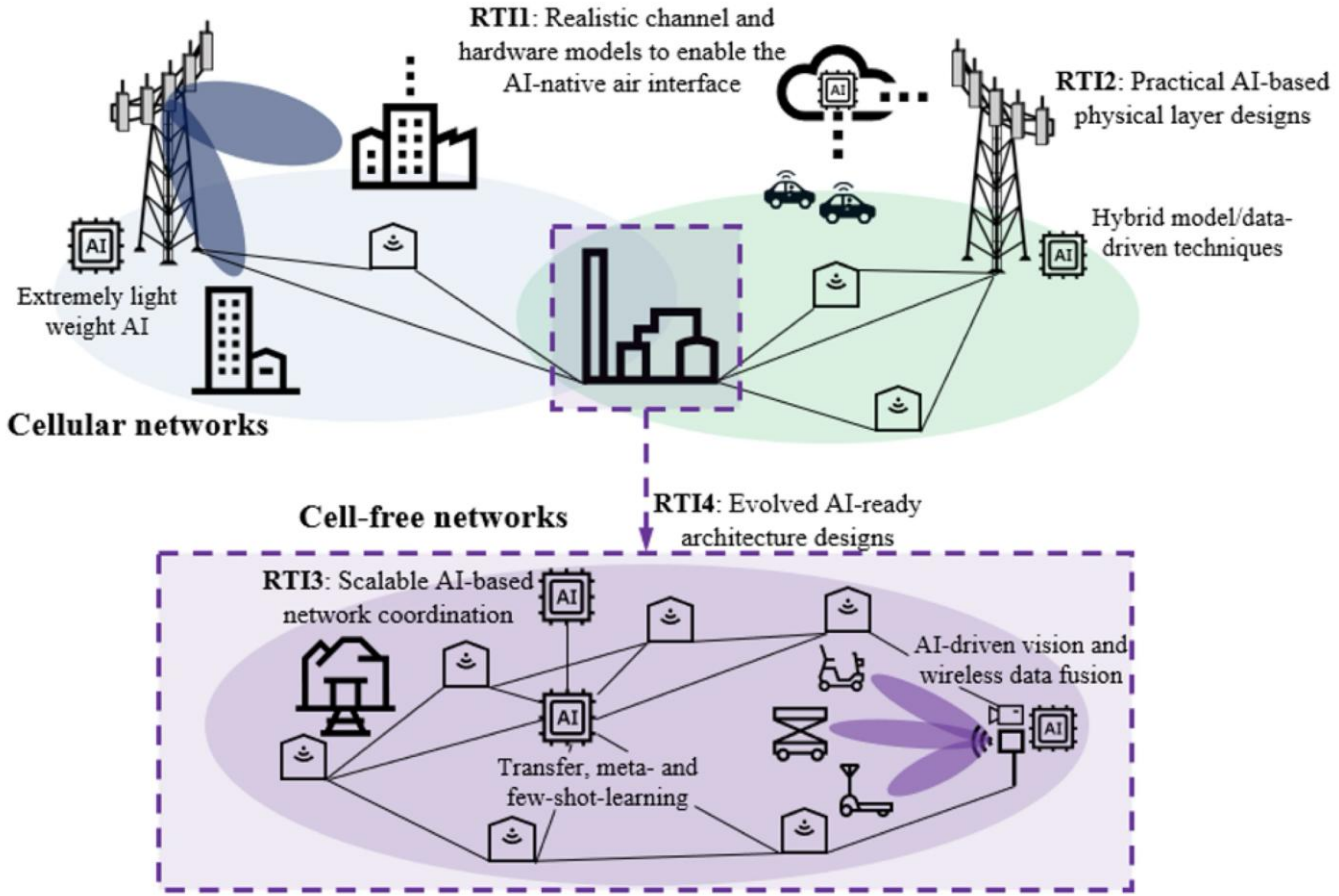
Japan (HARMONY project)

- The University of Tokyo (Project Lead)
- Tokyo University of Agriculture and Technology
- NEC
- KYOCERA
- SHIMIZU
- KDDI

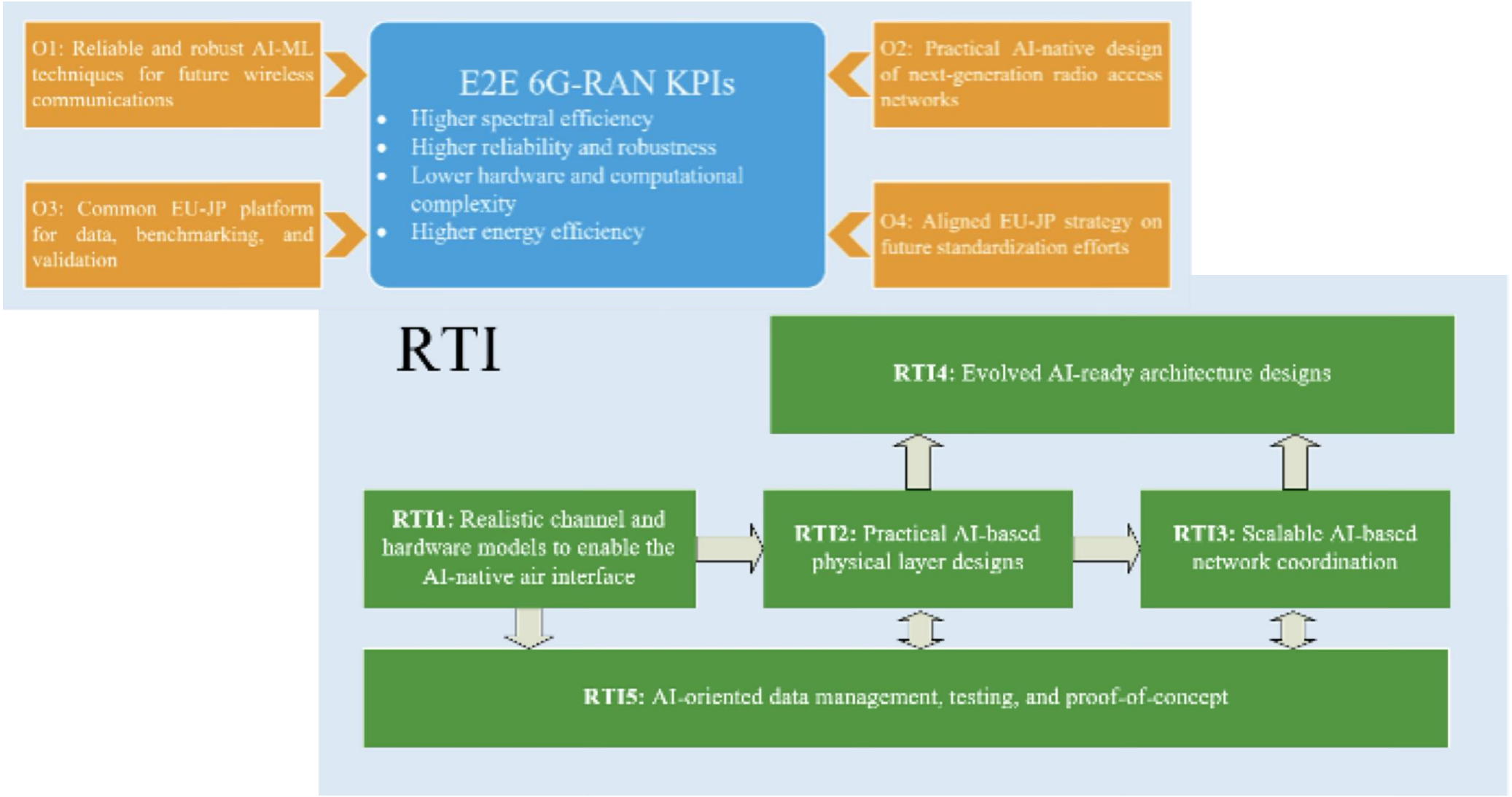


6G-MIRAI-HARMONY (EU): Overview

Overall goal: developing reliable and robust AI-native wireless communication systems that enable the practical exploitation of the full potential of the latest physical layer technological advances, especially cell-free massive MIMO, and of next-generation virtualized and potentially disaggregated RANs.



6G-MIRAI-HARMONY: Objectives



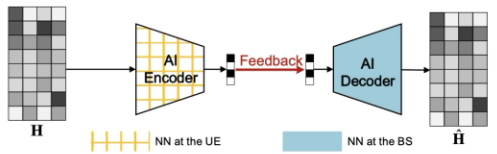
6G-MIRAI-HARMONY: Baseline

	Native AI
AI-native distributed **6G** RAN architecture Research: Cell-free architecture 5G-A: (O)RAN disaggregation, radio protocol stack (multi-connectivity), NR energy saving (38.864)	Research: AI-enhanced protocol stack and RAN optimization (QoS, mobility, energy saving) 5G-A: AI for NG-RAN study (37.817,38.743), AI for Mobility study (38.744)
AI-native **6G** air interface Research: Cell-free PHY 5G-A: dMIMO	Research: Native AI air interface (e.g., waveform learning) with synthetic channels and high complexity 5G-A: AI/ML for NR air interface study (38.843)
	Methodology: *Data collection* *AI performance evaluation ("AI QoS", Trustworthiness / Robustness)* *AI Testing*

6G-MIRAI-HARMONY: Baseline ML for air interface in 5G-A (SI started R18)

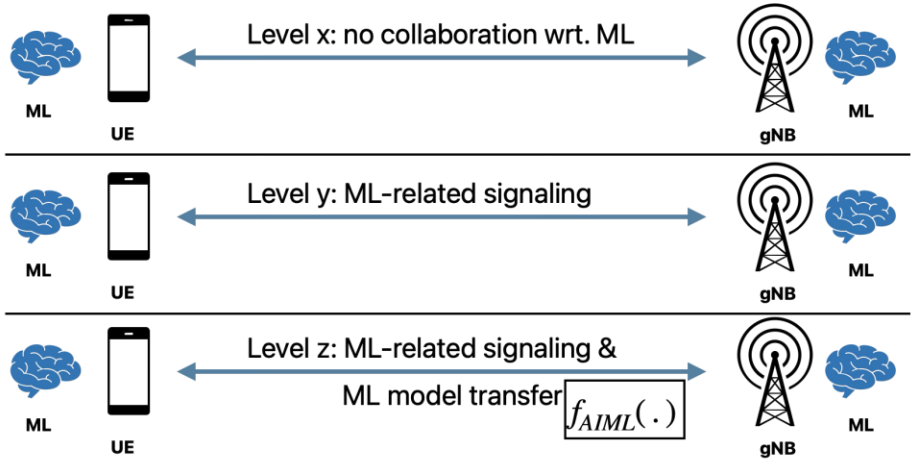
3 use cases (UE / gNB):

- CSI feedback: CSI compression (autoencoder across UE and gNB) & CSI prediction (UE/gNB)
- Beam management: beam prediction (UE/gNB) in spatial / temporal domain to
  - reduce measurement latency / overhead
  - reduce scheduling latency / selection accuracy / improve throughput
- Positioning: improve accuracy (LoS, nLoS classification) / reduce overhead, enhance measurement reporting

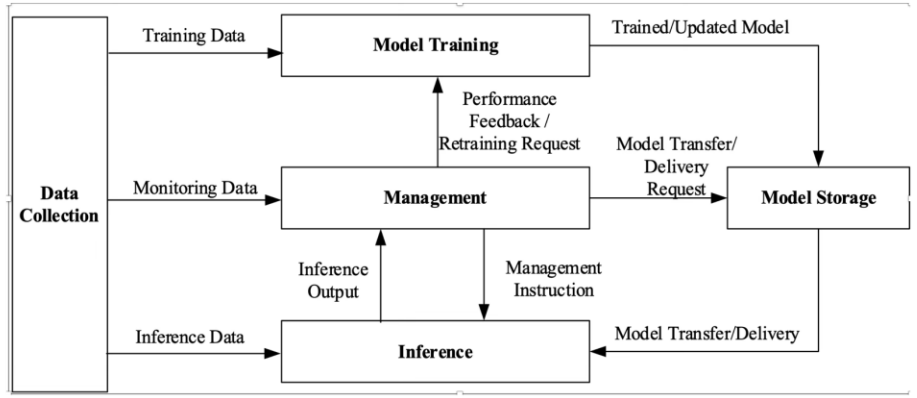


Guo, Jiajia, et al. "AI for CSI feedback enhancement in 5G-advanced." *IEEE Wireless Communications* (2022).

UE / gNB signaling (collaboration models)



Life-Cycle Management / workflow (source: 3GPP TR 38.843)

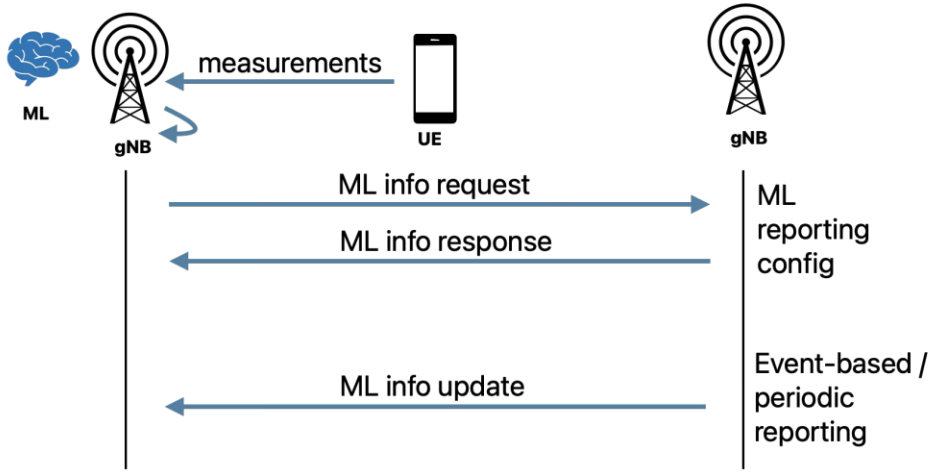


6G-MIRAI-HARMONY: Baseline ML for RAN in 5G-A (SI started in R17)

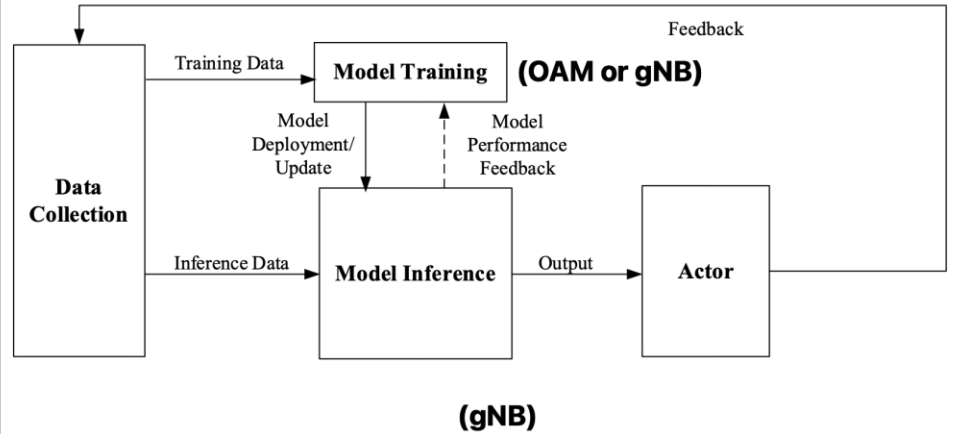
3 use cases (gNB / OAM): network performance optimization

- Network Energy Saving (input info: UE trajectory & measurements (RSRP, RSRQ, SINR), energy efficiency/resource states; prediction info: energy / HO strategy, energy efficiency/resource state, feedback info: energy efficiency/resource state, UE/network KPIs)
- Load Balancing (input info: UE trajectory & measurements (RSRP, RSRQ, SINR), traffic, resource states, UE KPIs; prediction info: target cell / affected UEs, resource states; feedback info: target resource state, UE/network KPIs
- Mobility Optimization (input info: UE trajectory / HO history & measurements (RSRP, RSRQ, SINR), traffic, resource states, HO-UE KPIs; prediction info: UE trajectory, HO target node, traffic; feedback info: resource states, HO-UE / network KPIs

ML-related signaling (use case agnostic)



Functional framework / workflow (original source: 3GPP TR 37.817)



6G-MIRAI-HARMONY: Innovations

	Native AI
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	Methodology: *Data collection* *AI performance evaluation ("AI QoS", Trustworthiness / Robustness)* *AI Testing*

6G-MIRAI-HARMONY: Innovations in AI

		Native AI	
AI-native distributed **6G** RAN architecture Research: Cell-free architecture 5G-A: (O)RAN disaggregation, radio protocol stack (multi-connectivity), NR energy saving (38.864)	Cell-free protocol stack (cluster config)	Research: AI-enhanced protocol stack and RAN optimization (QoS, mobility, energy saving) 5G-A: AI for NG-RAN study (37.817,38.743), AI for Mobility study (38.744)	• Native AI 6G Arch / AI cluster config (scalability: coordination latency, compute; UE QoS vs. network energy saving) • Distributed learning • Routing / duplication; Predictive, low latency mobility in cell free • AI LCM/workflow/robustness in RAN
AI-native **6G** air interface Research: Cell-free PHY 5G-A: dMIMO	Practical designs accounting for synchronization, reciprocity, and hardware impairments	Research: Native AI air interface (e.g., waveform learning) with synthetic channels and high complexity 5G-A: AI/ML for NR air interface study (38.843)	• Generative AI for realistic channel modelling • Hybrid model/data-driven techniques • AI/ML designs robust against realistic channels and hardware • AI-based (joint) traffic prediction and beamforming design
		Methodology: *Data collection* *AI performance evaluation ("AI QoS", Trustworthiness / Robustness)* *AI Testing*	

6G-MIRAI-HARMONY: *PoC & Standards*

		Native AI	
AI-native distributed **6G** RAN architecture Research: Cell-free architecture 5G-A: (O)RAN disaggregation, radio protocol stack (multi-connectivity), NR energy saving (38.864) Cell-free protocol stack (cluster config)		Research: AI-enhanced protocol stack and RAN optimization (QoS, mobility, energy saving) 5G-A: AI for NG-RAN study (37.817,38.743), AI for Mobility study (38.744)	• Native AI 6G Arch / AI cluster config (scalability: coordination latency, compute; UE QoS vs. network energy saving) • Distributed learning • Routing / duplication; Predictive, low latency mobility in cell free • AI LCM/workflow/robustness in RAN
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		Methodology: *Data collection* *AI performance evaluation ("AI QoS", Trustworthiness / Robustness)* *AI Testing*	*Common PoC platform / framework:* *Data generation (sim), sharing, common benchmarking, validation (energy consumption of AI !)* *Model compression; learning from small data sets*

Common standards strategy:
AI for 6G study Rel. 20 (joint CSI /joint beam prediction; energy saving)
AI LCM / workflow in ORAN

6G-MIRAI-HARMONY: Baseline & Landing Zone ML for air interface & RAN in 6G [RP-251881_6G_WG_SID]

"AI/ML for 6GR and Radio Access Network, leveraging 5G AI/ML framework, as appropriate [See TR38.843] [RAN1, RAN2, RAN3, RAN4]
Note: NW for AI is assumed to be covered by new services

6GR and RAN design shall ensure that the 6G System can also operate without AI/ML"

Use cases:

"Identify Use Case(s) of interest (either existing or new) with compelling trade-off between e.g., performance, complexity, etc...
Coordinated discussion needs to be ensured with related design areas, where needed (e.g., MIMO, Mobility, etc...)

NOTE: lead WG depends on the use case."

Signaling / collaboration models: *(5G-A as baseline)*

"Extensible AI/ML enablers based on the identified Use Case(s), including

i. LCM procedures [RAN2, RAN1, RAN3, RAN4]

ii. Data collection and data management, in coordination with SA WGs [RAN2, RAN3, RAN1]"

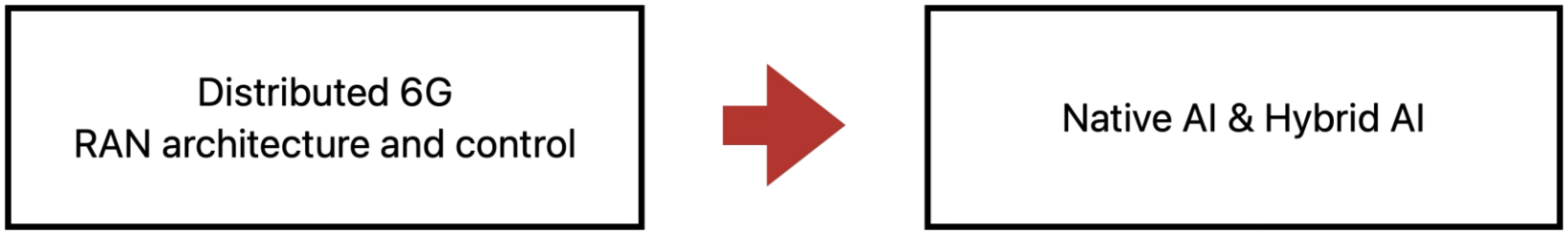
AI/ML framework:

"Extensible AI/ML enablers based on the identified Use Case(s), including

i. LCM procedures [RAN2, RAN1, RAN3, RAN4]

Ii. Data collection and data management, in coordination with SA WGs [RAN2, RAN3, RAN1]"

6G-MIRAI-HARMONY: distributed 6G RAN architecture & control



Native AI & Hybrid AI

- AI based solutions to ensure flexible and adaptable (user-centric) RAN systems
- In addition to L1, some of the L2/L3 procedures are expected to be significantly enhanced by data-driven techniques, such as resource optimization, mobility management etc.
- Lifecycle management as an important aspect to ensure future-proof design of these systems.

Research directions for 6G-MIRAI-HARMONY:

1. AI based radio resource allocation / optimization for deterministic low latency (UE perspective)
2. Predictive mobility procedures for improved QoS (as perceived by the UE) in (user-centric) RAN
3. AI lifecycle management (MLOps) procedures (for UE, in coordination with the network), considering aspects of hybrid (combined domain knowledge- and data-driven) subsystems

6G-MIRAI-HARMONY: Workpackages

6G-MIRAI (EU)		HARMONY (Japan)
WP1: AI-native practical 6G air interface WP2: AI distributed 6G RAN architecture & control	⟺	WP1: AI-Native and User-Centric RAN Architecture WP2: Harmonization of Multi-AI Networks WP3: AI-Native RAN
WP3: Scenarios & data, validation & benchmarking	⟺	WP4: Architecture and Component Technology Evaluation via Testbed Demonstrations
WP4: Cooperation, dissemination and impact WP5: Project management	⟺	Dissemination Project management

6G-MIRAI-HARMONY: Expected Results

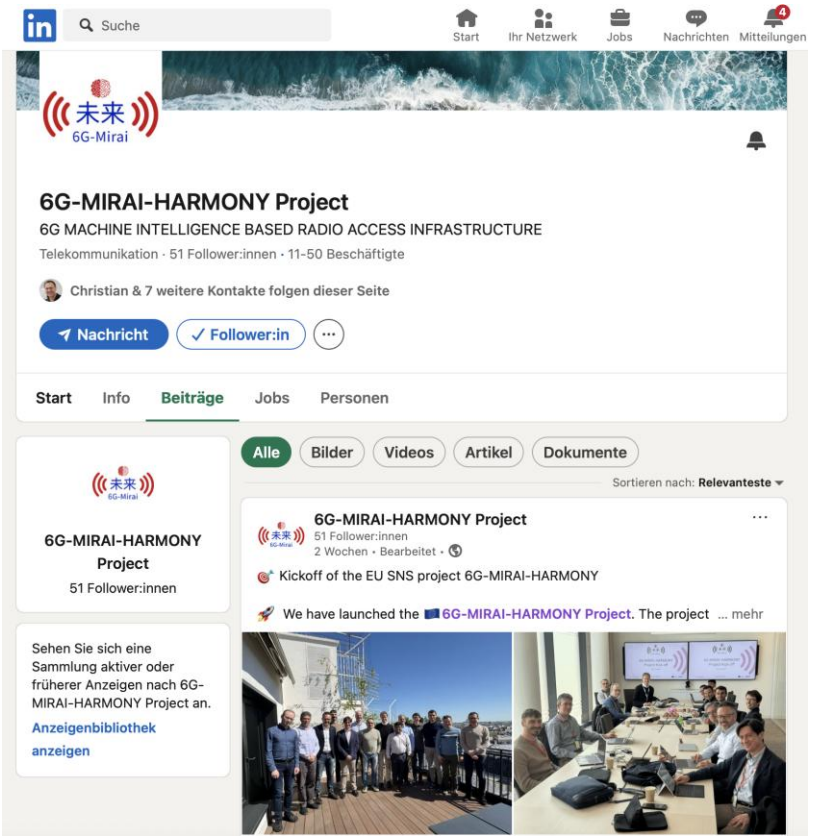
- AI-native 6G air interface (baseband) design considering realistic channels and hardware capabilities
- AI-native 6G RAN architecture design allowing for intelligent network control and efficient multi-connectivity

- Data handling methodology for validation and benchmarking suitable for AI-native wireless research
- Deliver open, curated datasets which enable 6G-MIRAI and other projects to create robust ML algorithms
- Deliver PoC framework to validate results and a common baseline for further collaborative work

- EU standards pre-alignment, incl. Japan where applicable
- Create roadmap for industrialization across EU and Japan

Collaborate with us

EU Project Lead: Tobias Ley, tobias.ley@ericsson.com, EU Technical Lead: Renato Cavalcante, renato.cavalcante@hhi.fraunhofer.de,
EU Communication Manager: Henning Sanneck, h_sanneck@apple.com, JP Project Lead: Akihiro Nakao nakao@nakao-lab.org



Visit us at 6g-mirai-harmony.eu

6G-MIRAI-HARMONY

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