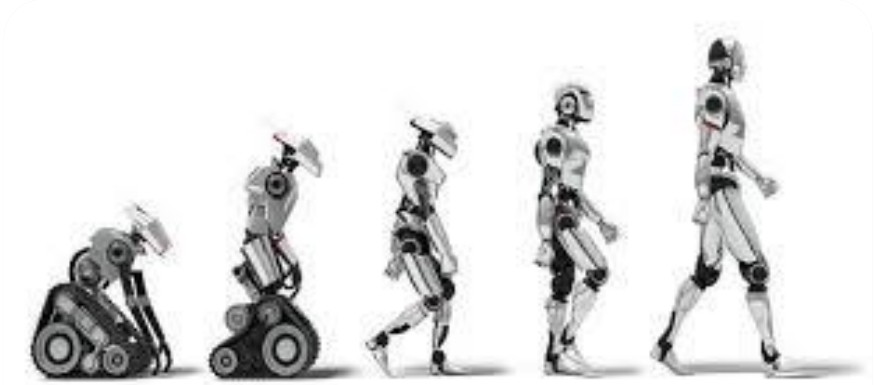
Exploring the Role of 6G Technology in Robotics Applications

IEEE RTSI 2024 — RESEARCH AND TECHNOLOGIES FOR SOCIETY AND INDUSTRY — 8th International Forum

Mona Ghassemian

19th September 2024



WORKSHOP ON HUMANOID ROBOTICS GO UBIQUITOUS!
INDUSTRIES AND RESEARCHERS AS THE KEY ENABLERS

KEY TERMS

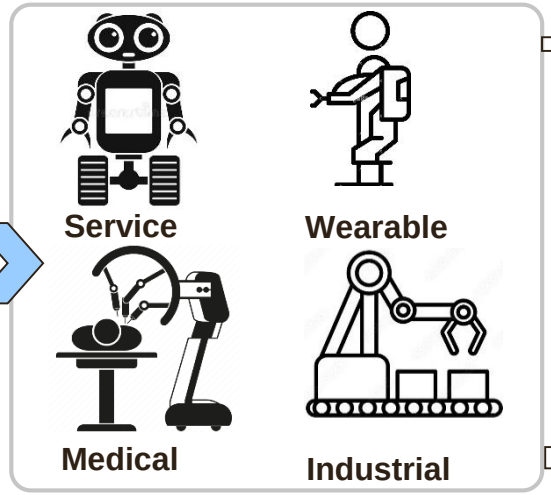
Service oriented robot (SOBOT): *Robot in personal use or professional use that performs useful tasks for humans or equipment.*

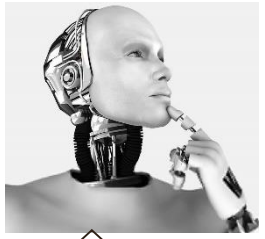
Industrial robot: *automatically controlled, reprogrammable multipurpose manipulator, programmable in 3 or more axes, which can be either fixed in place or fixed to a mobile platform for use in automation applications in an industrial environment.*

Medical robot: *robot intended to be used as medical electrical equipment or medical electrical systems.*

Wearable robot: *robot attached to and carried by the human during use & provides an assistive force for supplementation or augmentation of personal capabilities*

Humanoid robot: *robot with body, head and limbs, looking and moving like a human.*

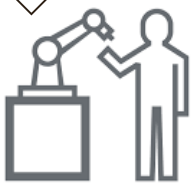




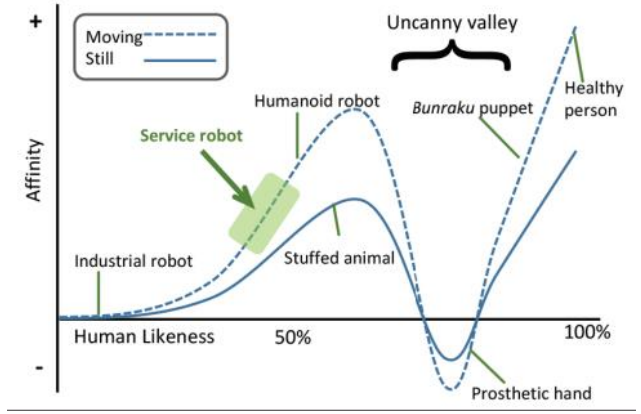
Humanoid robot

Cobots: robots tightly collaborating with humans; must be aware of human movements & autonomously adapt their behavior to prevent accidents with humans or other robots in a hybrid cell.
Cobotic cells: collaborative industrial workspaces.
Hybrid cell: workspace without a safety cage.

Human in loop



Cobots



Source: M. Mori, IEEE spectrum-2012

Humanoid technology to mature in 2040 to 2050

Collaboration: *operation by purposely designed robots and person working within the same space*
Cooperation: *information & action exchanges between multiple robots to ensure that their motions work effectively together to accomplish the task.*

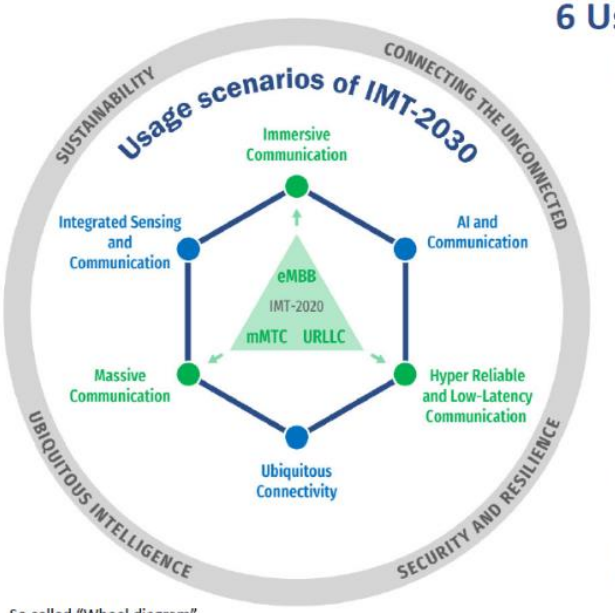
ISO 8373:2021 Robotics Vocabulary
ISO 10218:1:2016 Robots and robotic devices – Collaborative robots

OVERVIEW

- ***New features from 6G*:** what are the new/enhanced features introduced by 6G which are relevant for robotic industries?
- ***Exploring Robotic Usecases & Requirements:*** What are the Robotics applications' sensing & communication performance requirements and how to identify them?
- ***Enabling technologies***: What are the main elements that may help to achieve the stringent requirements?
- ***Architecture impacts****:* What will be the potential the impacts on the architecture to support robotics functionalities, particularly perception, cognition, and actuation?
- ***Multidisciplinary research and standardisation:*** How can 6G and Robotics research outputs shape into interoperable standards.

FROM IMT-2020 TO IMT-2030

Usage scenarios



So called "Wheel diagram"

6 Usage scenarios

Extension from IMT-2020 (5G)

- eMBB ➡ Immersive Communication
- mMTC ➡ Massive Communication
- URLLC ➡ HRLLC (Hyper Reliable & Low-Latency Communication)

New

- Ubiquitous Connectivity
- AI and Communication
- Integrated Sensing and Communication

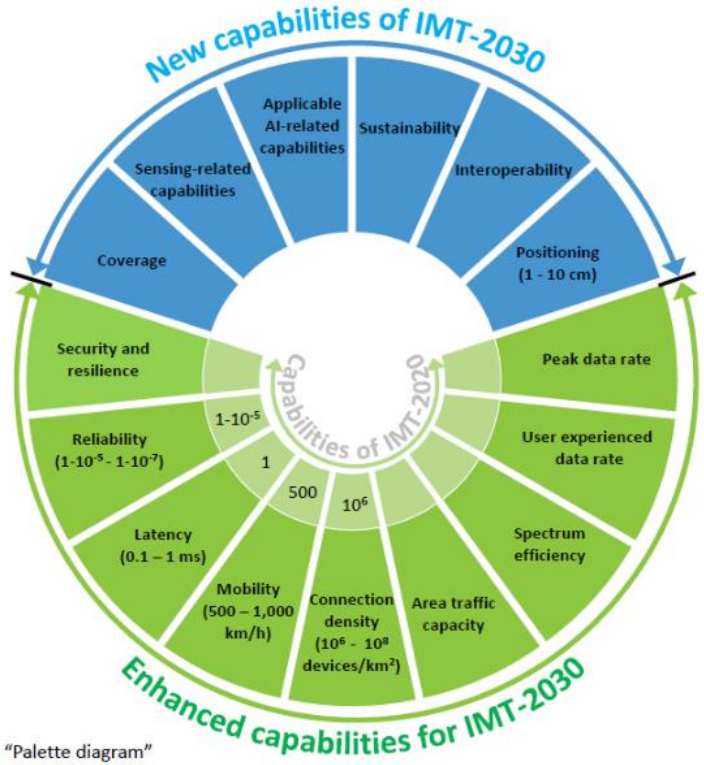
4 Overarching aspects:

act as design principles commonly applicable to all usage scenarios

Sustainability, Connecting the unconnected, Ubiquitous intelligence, Security/resilience

Source: Recommendation ITU-R M.2160-0 (11/2023), "Framework and overall objectives of the future development of IMT for 2030 and beyond"

Capabilities of IMT-2030



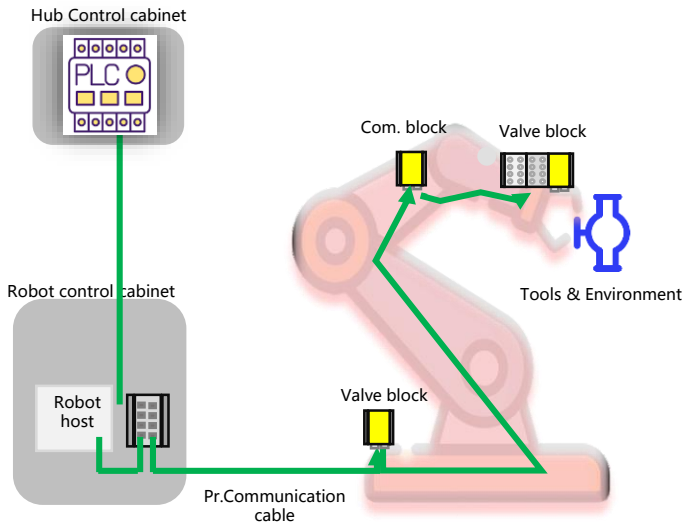
So called "Palette diagram"

5G and 5G-Advanced (IMT-2020) already include features to support a number of robotic use cases
Complex scenarios may require 6G (IMT-2030): **multi-user**, **multi-device**, and **multi-modal** applications

Robotics and automation systems objectives can introduce new and stringent requirements for 6GS.

EVOLUTION FROM 5G/5GA TO 6G

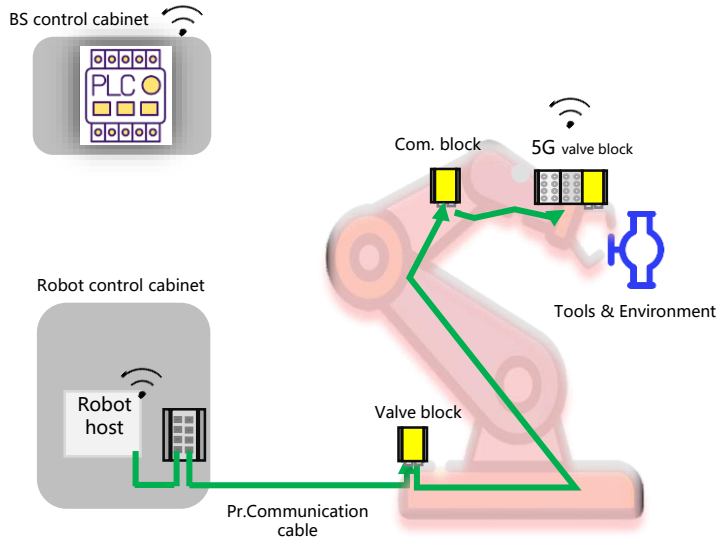
Wired Communication



Perception

Action

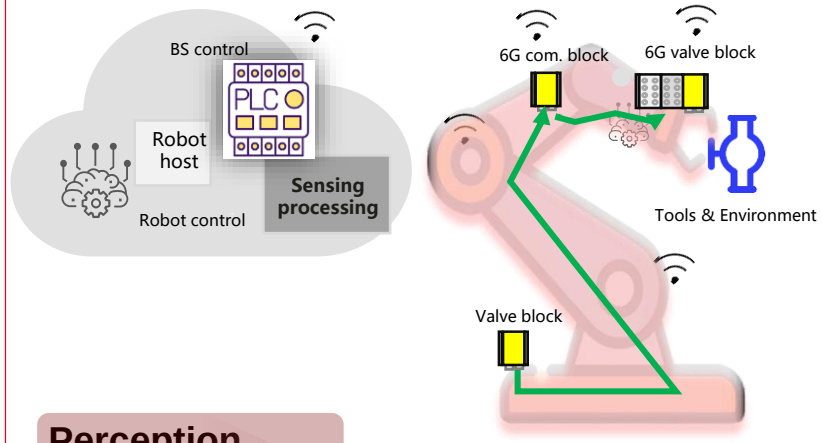
5G Advanced



Wireless connected Robot
Partly support perception based on connected cameras

Action

6G



Perception

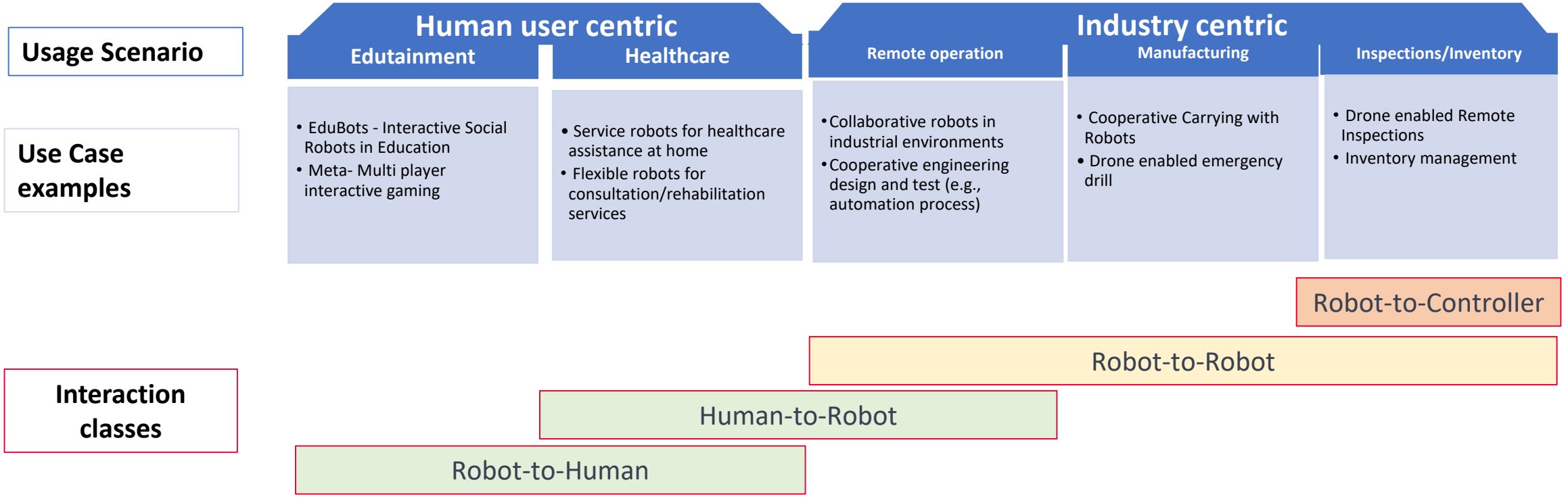
Cognition

Action

Revolutionised Robot by 6G

6G technologies enhance robotic capabilities for automation ⇔ Robotic technologies improve the performance of 6GS.

USE CASES INTERACTION CLASSIFICATION

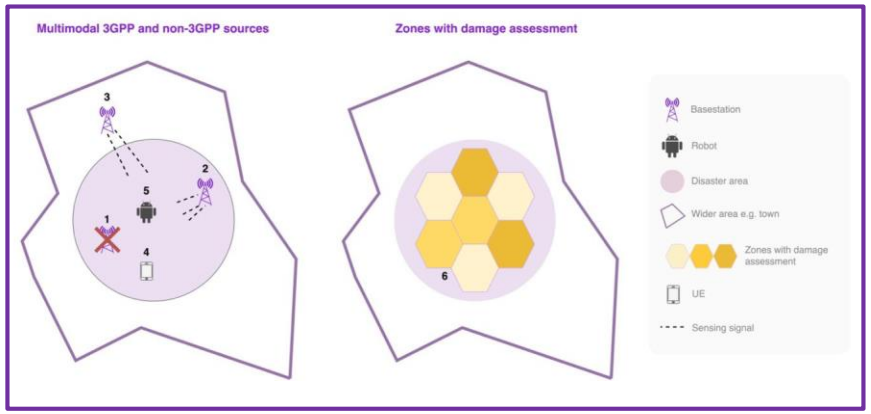


What features do humanoid interactions contribute to the use case classifications?

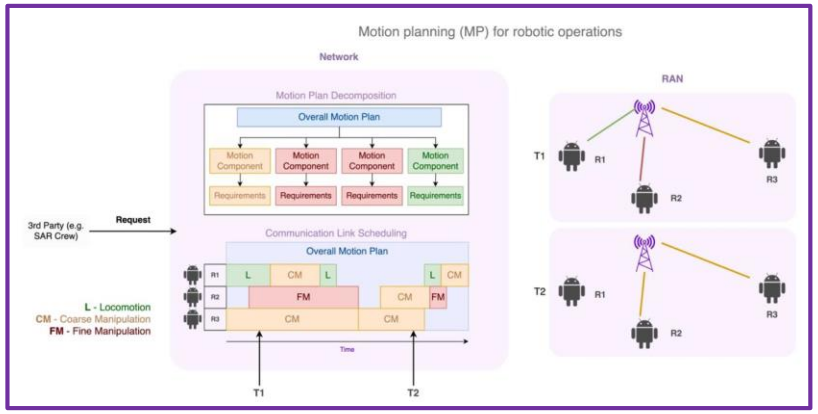
Revised from: [one6G White Paper, "6G & Robotics: Use Cases and Potential Service Requirements," June 2023.]

USE CASES IN ROBOT COOPERATION

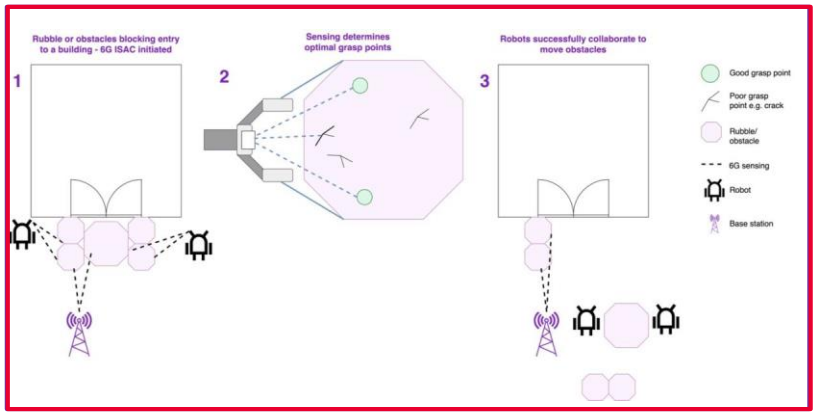
Assessing infrastructure damage



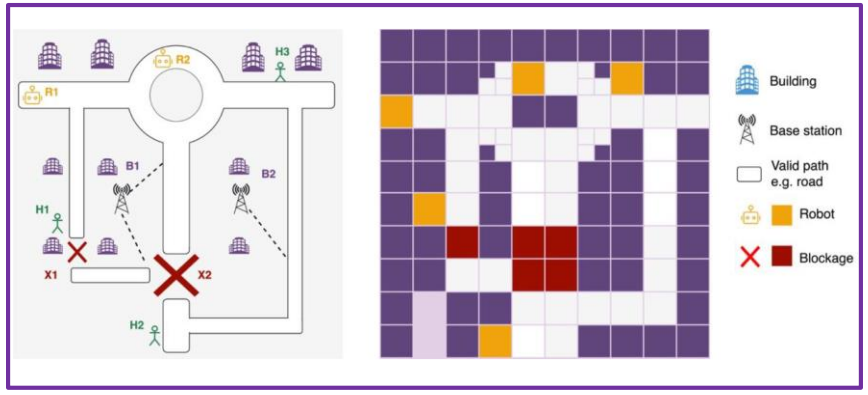
Link scheduling for motion planning



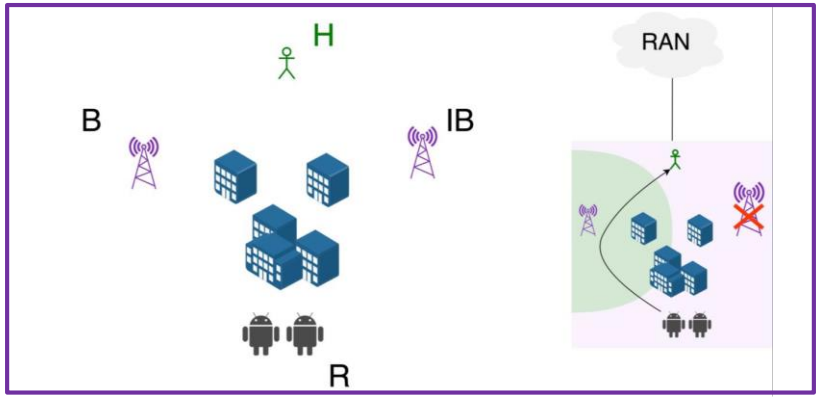
Cooperative Robots



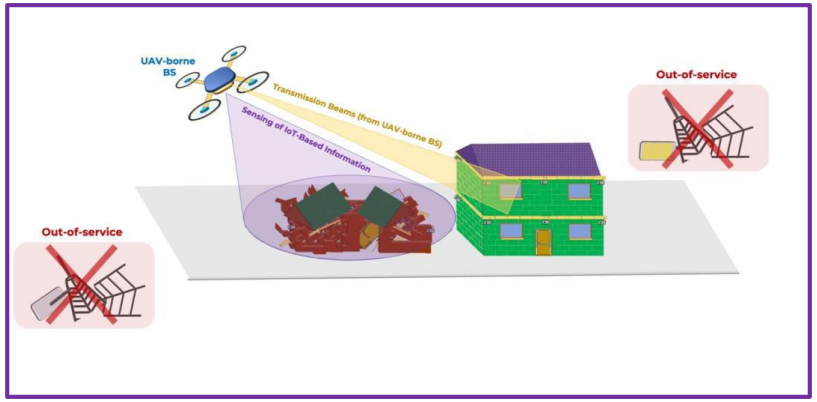
Sensing for environment mapping



Communication-aware motion plans

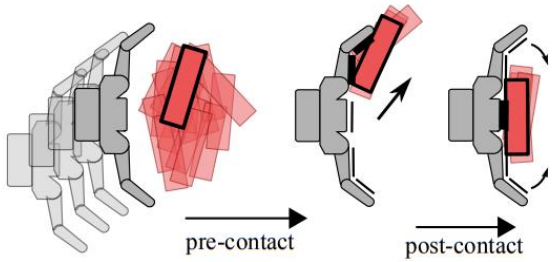


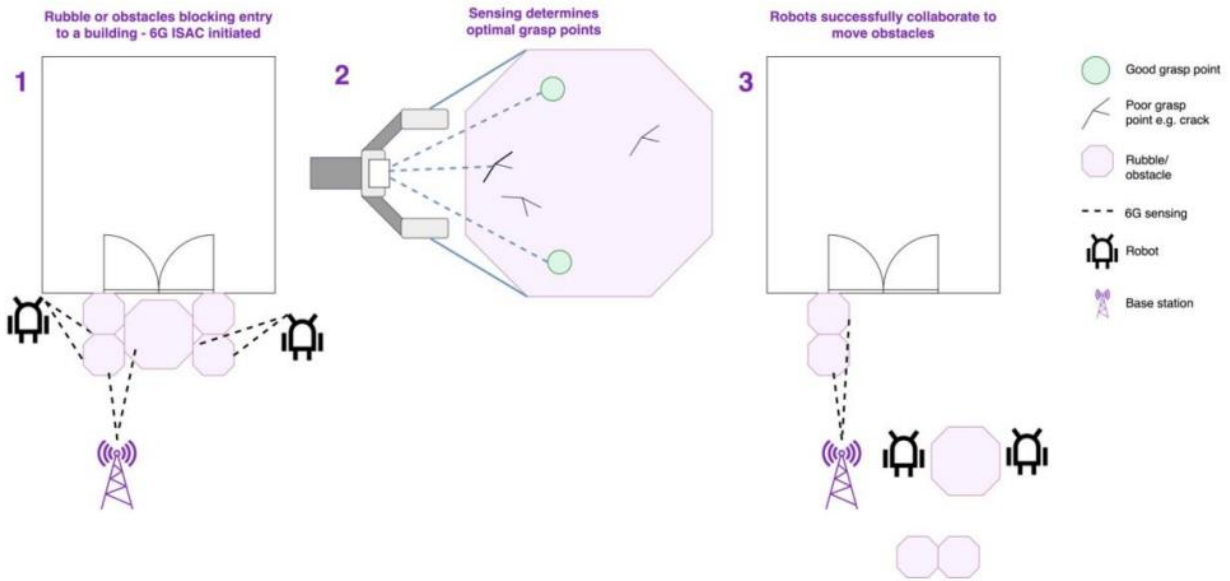
Sensing for survival detection



[one6G White Paper, "6G & Robotics: Identifying Use Cases and Potential Service Requirements – Methodology and Examples," June 2024.]

USE-CASE EXAMPLE: COOPERATIVE ROBOTS





Pre-conditions:

• The robot behaviour is orchestrated by a **task planner (TP),** which can be provided by a 3rd party e.g. one of the robots or an external device.

• Each robot has an on-board **motion planner (MP)** and local controller (LC). The LC's operate with a refreshing rate of 1ms.

• Each robot has an embedded UE with **ISAC capability.**

• Each entity (robot, base station, TP) is connected to the 6GS, which manages the **sensing task**.

Existing features:

High reliability transfer of haptic data (99.9999999%) supported for extended reality applications with humans as the end user.

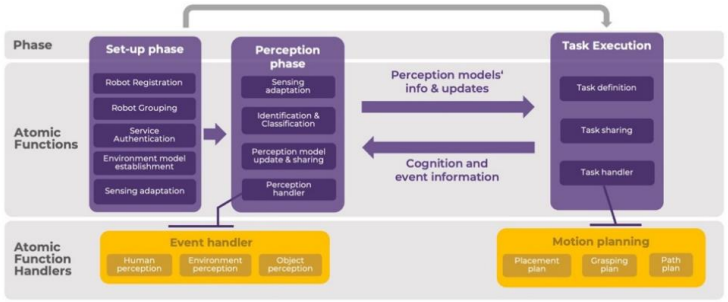
Potential new requirements:

• **Confidence level of fine-positioning** estimates should be 99% (0.01m horizontal/vertical) if only robots are present in the environment. High confidence is required as the consequences for a failed grasp hold can be significant in terms of damage to robots.

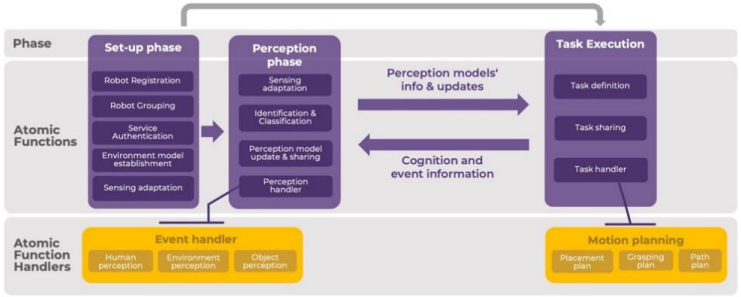
• Transfer of dynamic interaction data between robots requires low latency, e.g. 0.001 – 0.01s, and **high reliability**. This is an enhancement compared to existing 3GPP requirements on factory and public safety.

[one6G White Paper, "6G & Robotics: Identifying Use Cases and Potential Service Requirements – Methodology and Examples," June 2024. (Section 3.6)]

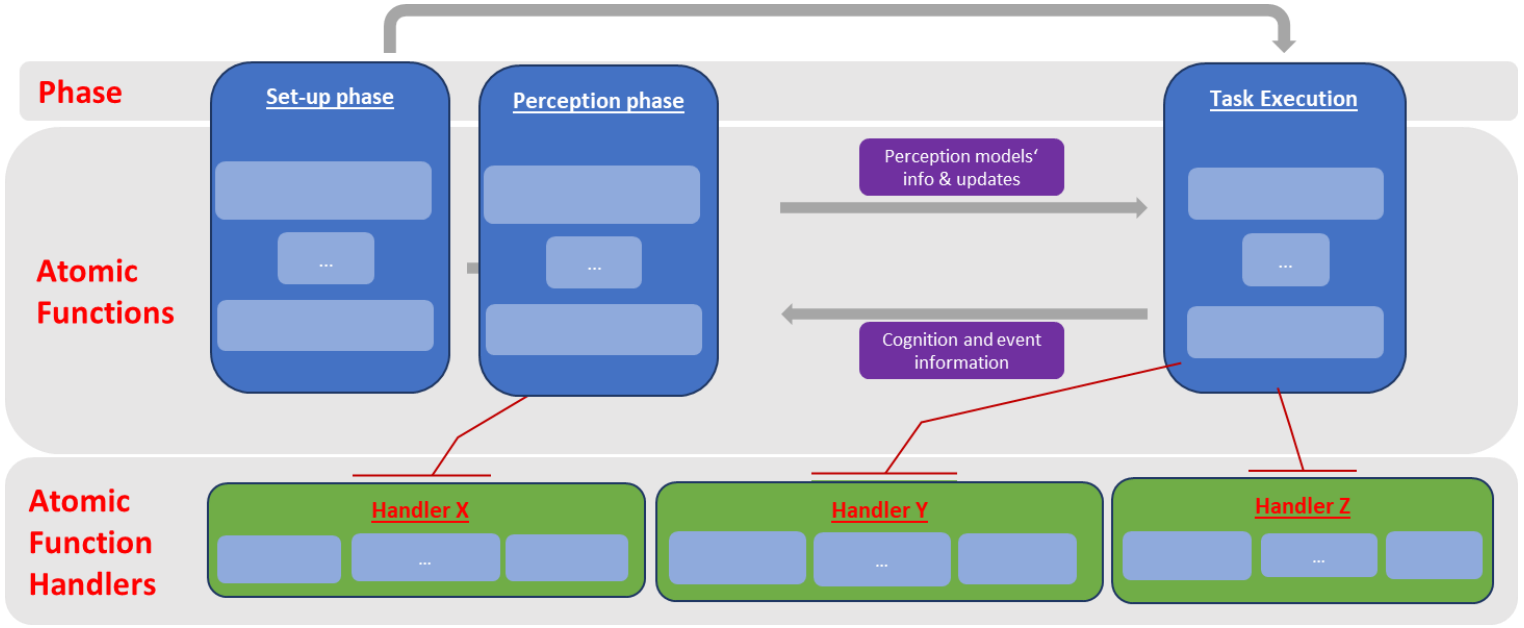
METHODOLOGY -GENERIC INTERACTION CLASS

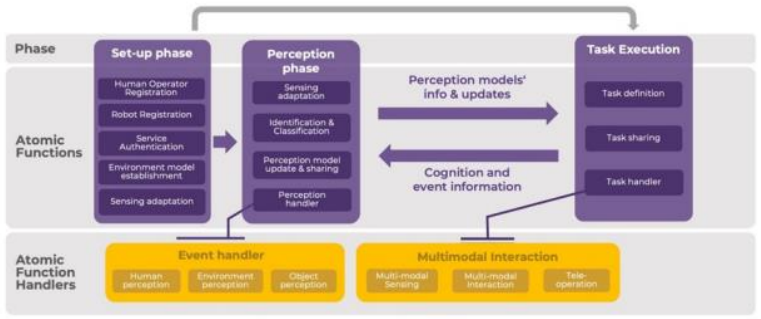


Robot-to-Robot (R2R) Interaction

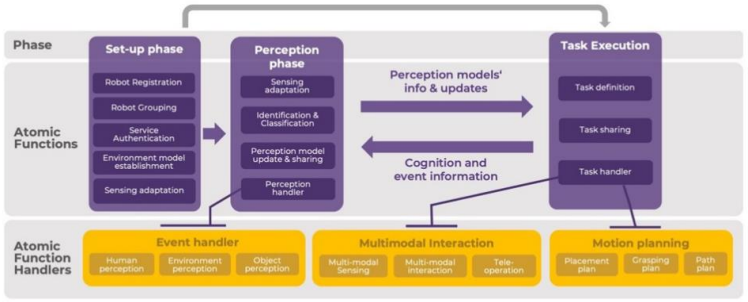


Robot-to-Controller (R2C) Interaction





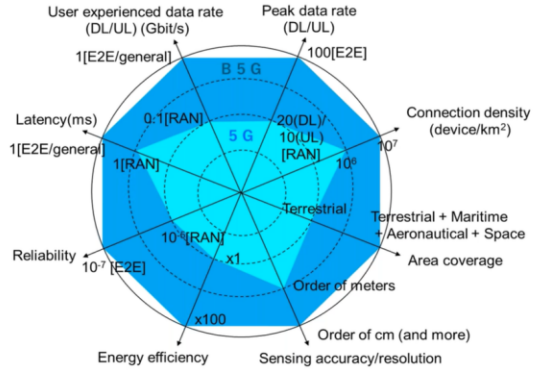
Human-to-Robot (H2R) Interaction



Robot-to-Human (R2H) Interaction

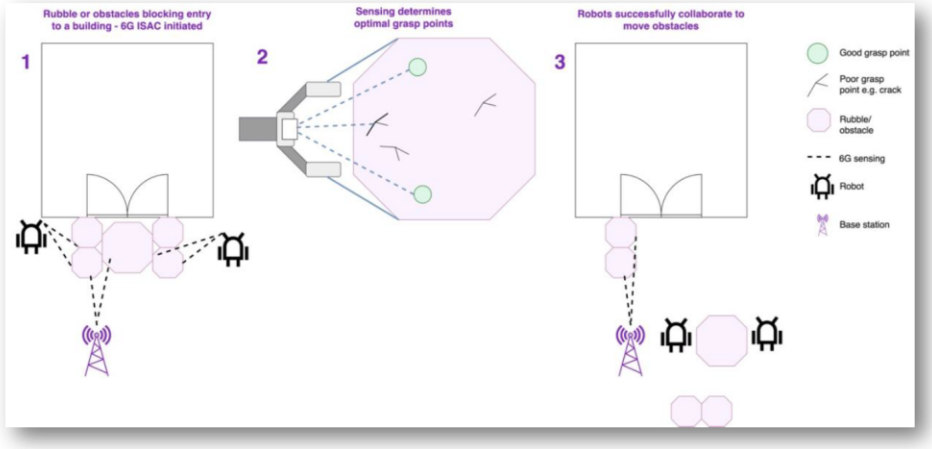
[one6G White Paper, "6G & Robotics: A Methodology to Identify Potential Service Requirements for 6G-empowered Robotic Use Cases," Nov. 2023.]

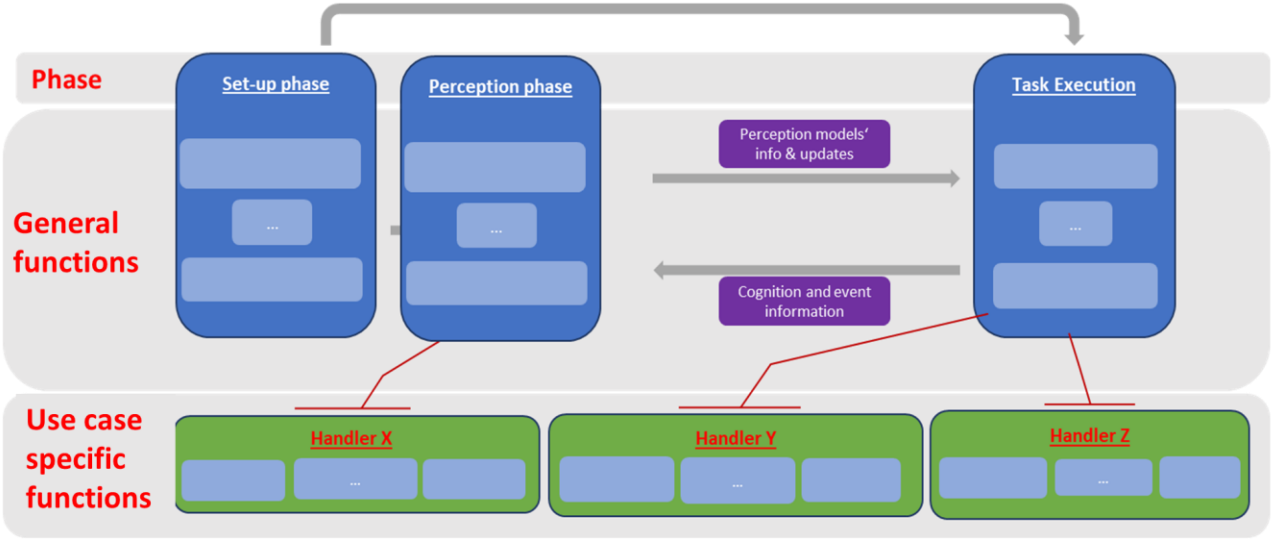
USAGE SCENARIOS AND POTENTIAL SERVICE REQUIREMENTS



Radar chart on target KPIs (compared to 5G)

Cooperative Robots

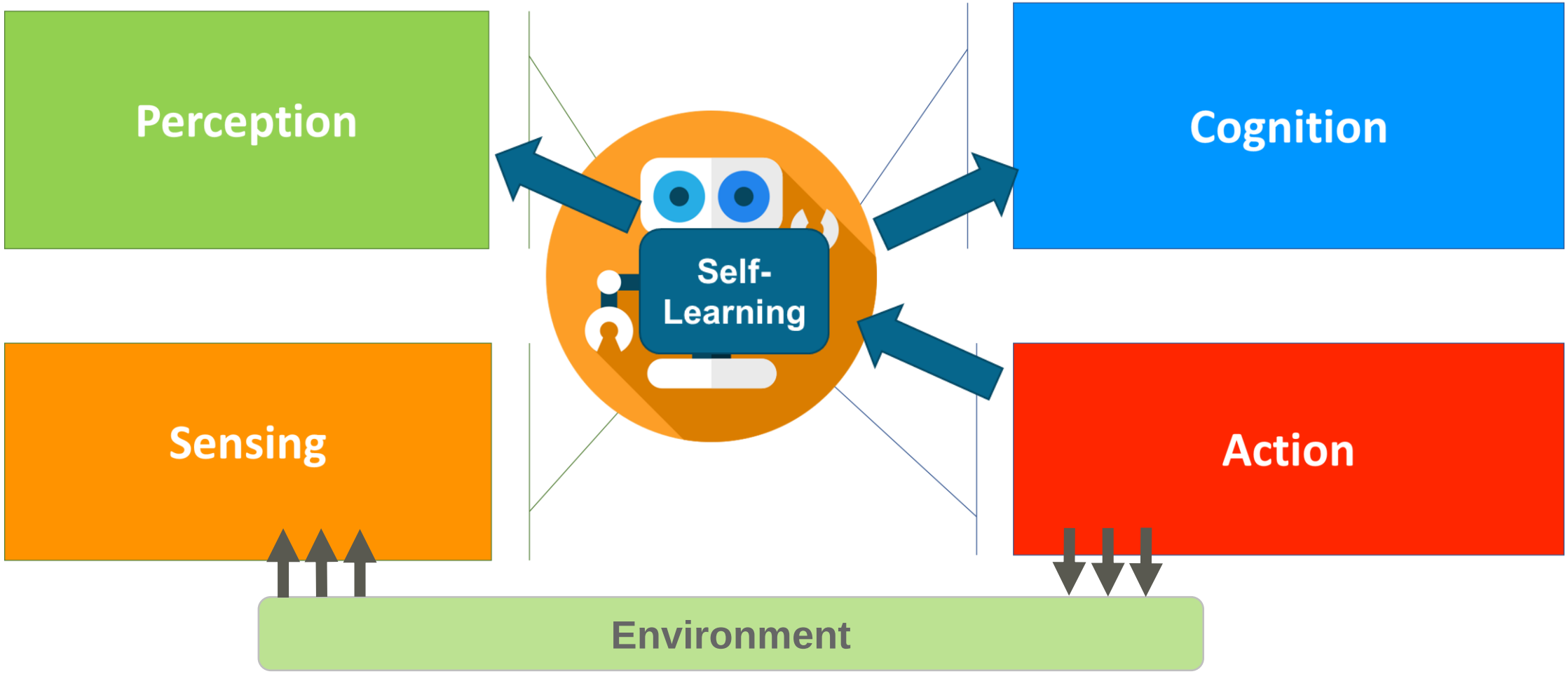




[one6G White Paper, "6G & Robotics: Identifying Use Cases and Potential Service Requirements – Methodology and Examples," June 2024]

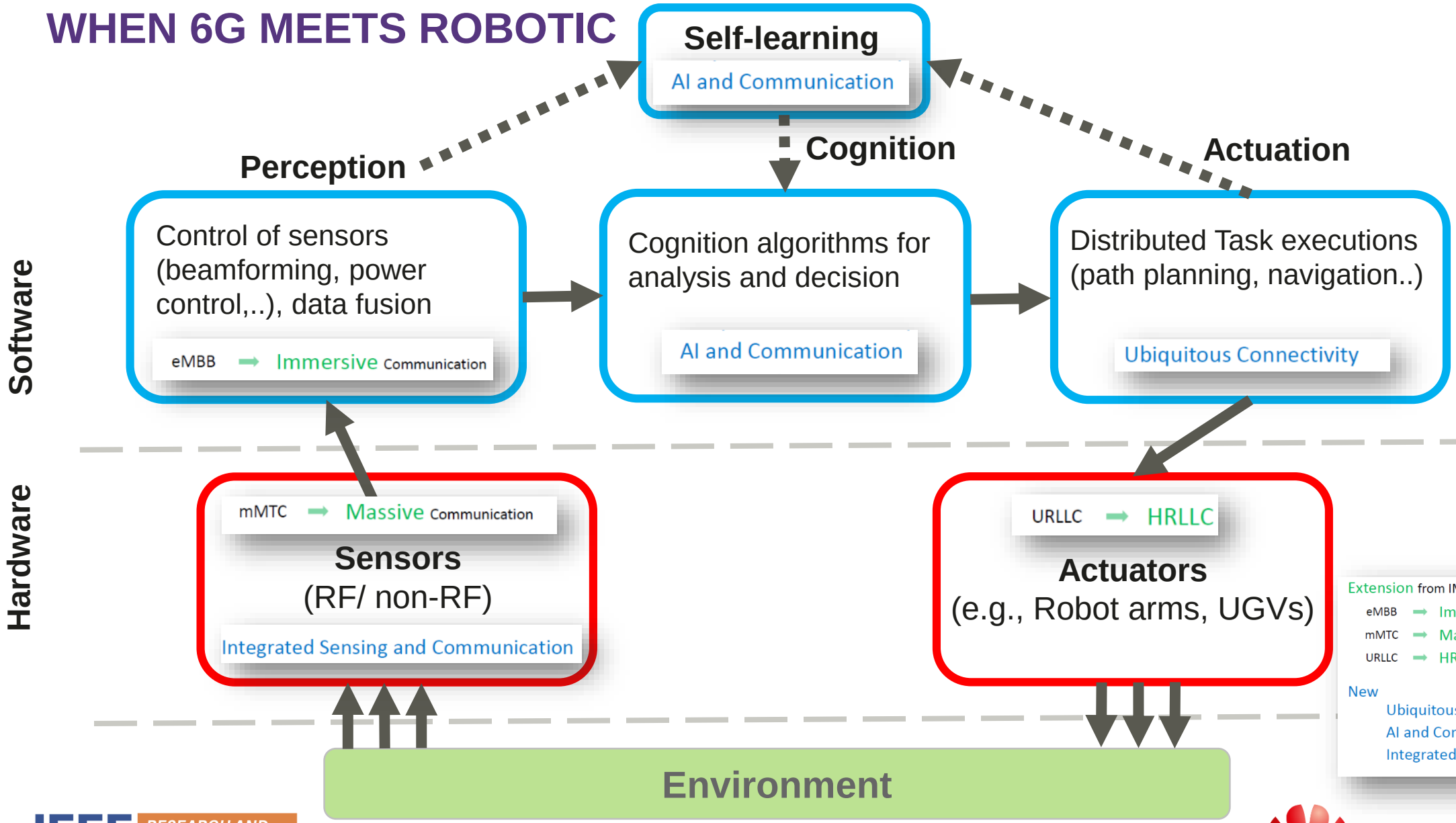
[one6G White Paper, "6G & Robotics: A Methodology **to Identify Potential Service Requirements for 6G-empowered** Robotic Use Cases," Nov. 2023]

ROBOTICS HIGH LEVEL FUNCTIONALITY BLOCK

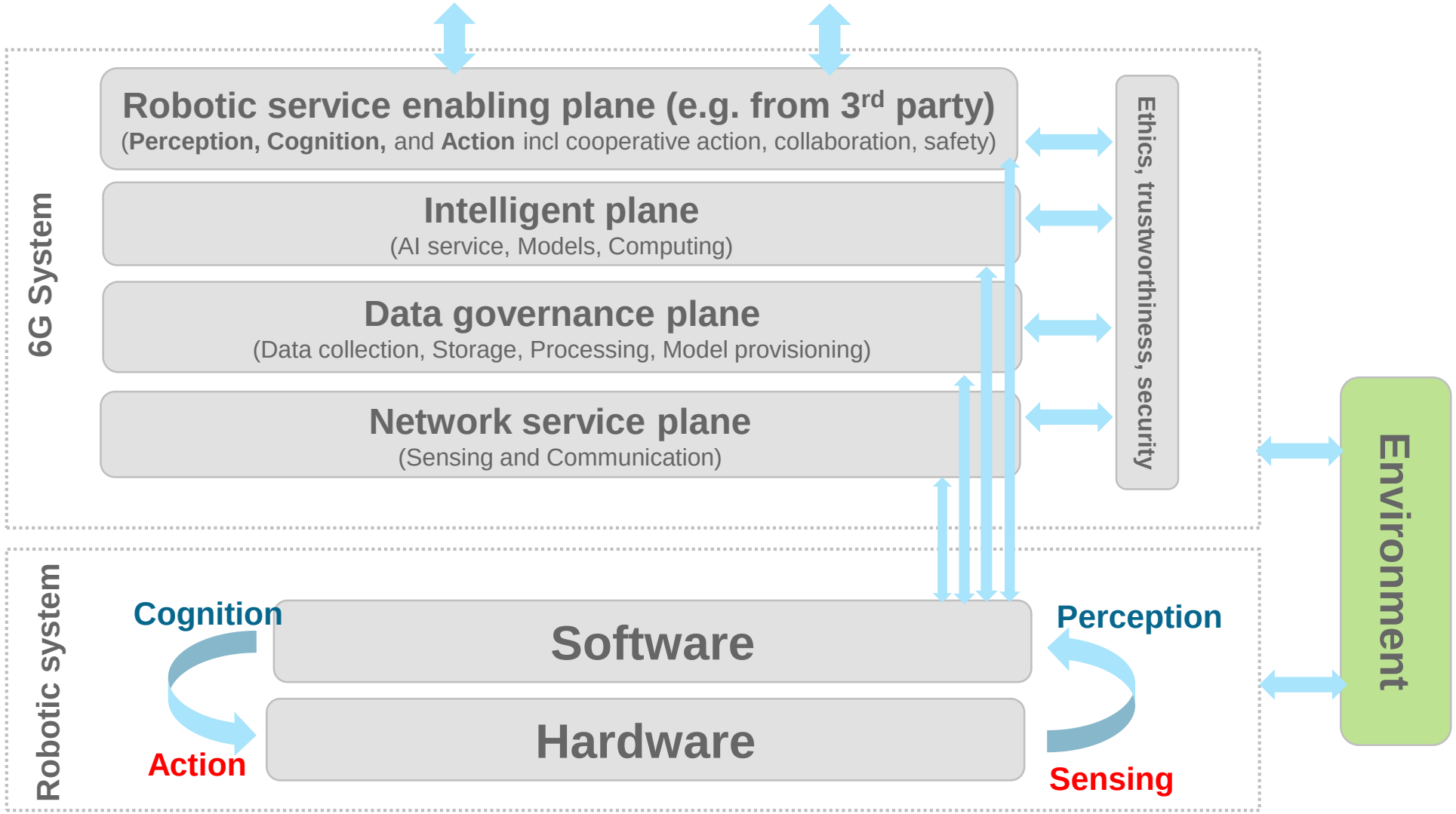


Robotic use cases require services beyond communication to support perception, cognition, and action.

WHEN 6G MEETS ROBOTIC



HIGH LEVEL ARCHITECTURE



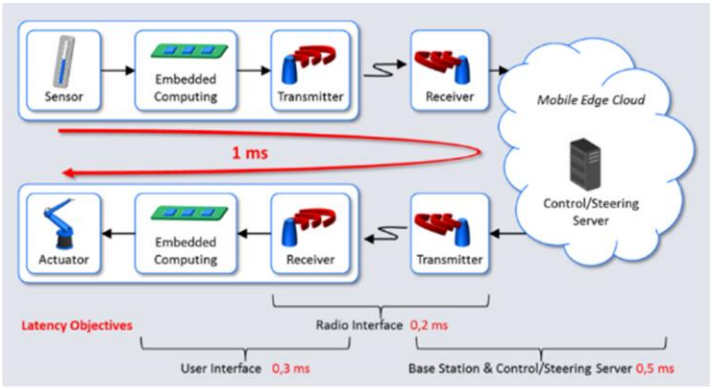
IEEE & 3GPP SDOS' ACTIVITIES FOR ROBOTIC USE CASES

IEEE SA Working Groups

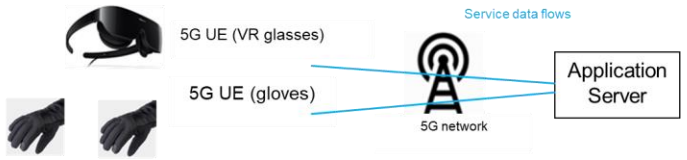
IEEE P1918.1 Tactile Internet: TI*
IEEE P1955 6G empowering Robotics
IEEE P7008™ Ethically Driven Nudging For Robotic, Intelligent And Autonomous Systems
IEEE 802.1 TSN

3GPP SA1/SA2

TR 22.847 Supporting tactile & multi-modality comm services (**TACMM**)- Stage 1 (Release 18)
TS 22.104 Service requirements for cyber-physical control applications in vertical domains (**Cyber-CAV**)- Stage 1 (Release 18)
TR 22.804 Study on Communication for Automation in Vertical domains (**CAV**)- Stage 1 (Release 18)
TR 23.700 Study on architecture enhancement for XR and media services (**XRM**)- Stage 2 (Release 18)
TR 22.916 Study on Network of Service Robots with Ambient Intelligence (**SOBOT**)- Stage 1 (Release 19)
TR 22.856 Study on Localized Mobile Metaverse Services. (**MetaVerse**) - Stage 1 (Release 19)



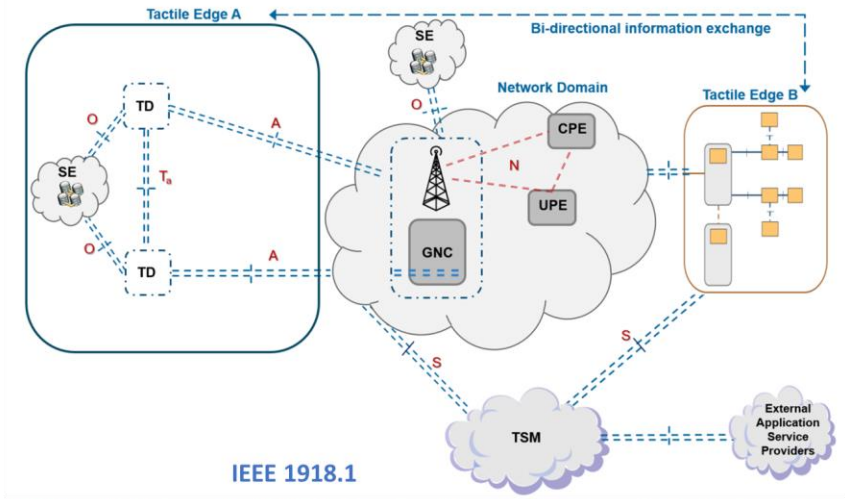
ITU-T Technology Watch Report (August 2014)



3GPP TR 22.847 V18.2.0 (2022-03) TACMM

Table 5.7.3-1 Typical QoS requirements for multi-modal streams [14] [15] [16] [17] [18]

	Haptics	Video	Audio
Jitter (ms)	≤ 2	≤ 30	≤ 30
Delay (ms)	≤ 50	≤ 400	≤ 150
Packet loss (%)	≤ 10	≤ 1	≤ 1
Update rate (Hz)	≥ 1000	≥ 30	≥ 50
Packet size (bytes)	64-128	≤ MTU	160-320
Throughput (kbit/s)	512-1024	2500 - 40000	64-128



IEEE 1918.1

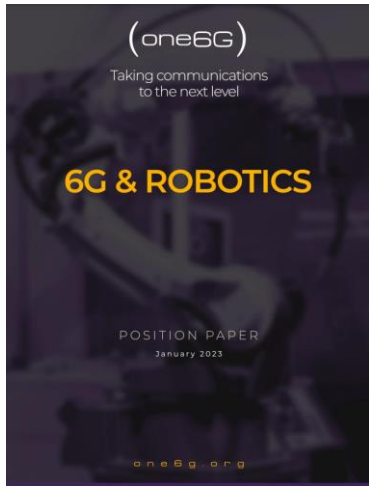
[*] – IEEE Tactile Internet (p1918.1): Standard for Tactile Internet: Application Scenarios, Definitions and Terminology, Architecture, Functions, and Technical Assumptions

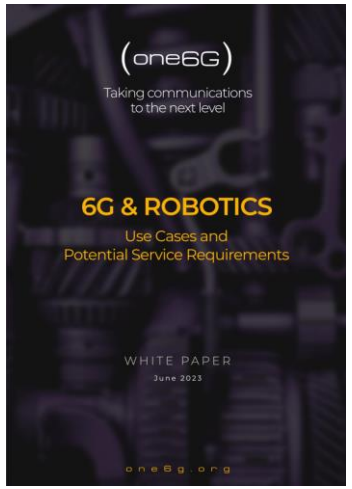
SDOS' LANDSCAPE FOR ROBOTIC USE CASES

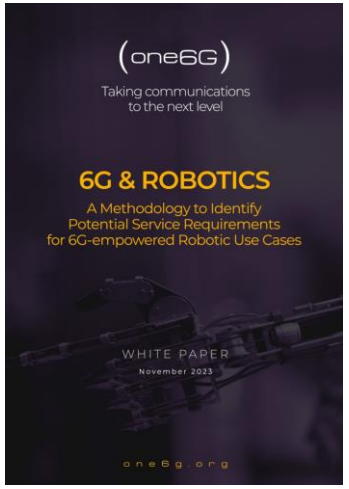
[Ghassemian et. al, "Standardisation landscape for 6G robotic services", 7 Nov 2023, IEEE CSCN 2023]

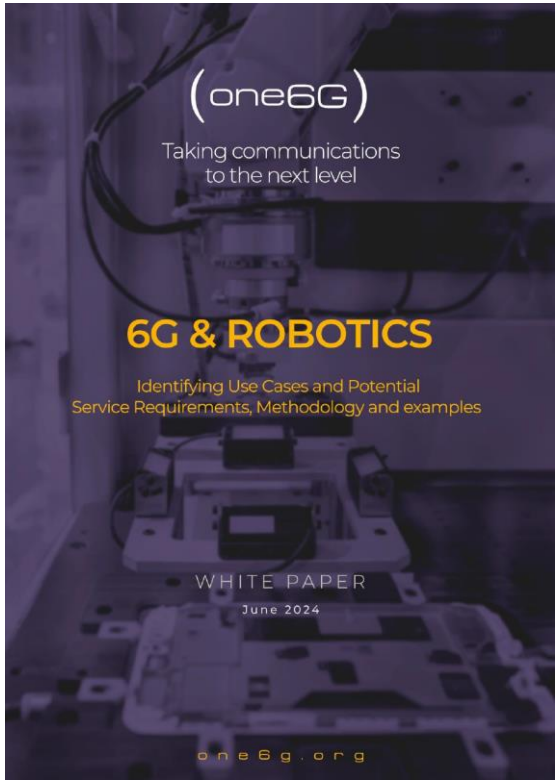
How 6G research outputs be standardised cross relevant SDOs to achieve harmonised and interoperable standards?

6G and Robotics – whitepapers









White Paper Volume 3:

- Published June 2024
- Analysis of 6G communication & sensing requirements for robotics applications
- A total of 7 use cases are presented across a range of robotics verticals including disaster response and collaborative robots are presented
- Additional use-case suggestions in logistics for further consideration

Scan this QR code to download the white paper!

Contributors:

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WIRELESS WORLD RESEARCH FORUM

HUAWEI

Invitation to participate in 6G Robotics activities

(one6G)

WORK ITEM 216 (WG2)

WI216 – 6G empowered robotics

Queen Mary University of London, Huawei Technologies, King's College London, UC3M, International Hellenic Univ, Toshiba, NKUA, ITI, UCD, TUD, CTTC, RWTH, RDIC, KCCTech, UNS, SmartAvatar, Univ of Sussex, Univ of Alberta, UPV, Extended robotics, VegaGlobalSystems (VGS), UPV, Utwente, Turkcell, Scuola Superiore Sant'Anna, Prensilia, PAL robotics, Connected Places Catapult, UMA, TECNUN, ZettaScale, NineTiles, CNIT, Shadow Robot, Univ of Northumbria, KIT

Prof Kaspar Althoefer – Queen Mary University of London
Dr Mona Ghassemian – Huawei Technologies

Biweekly meetings (Online)

IEEE SA STANDARDS ASSOCIATION

IEEE

Active PAR

P1955

Standard for 6G Empowering Robotics: Use Case Scenarios, Requirements, Architectural Impact, and Technical Assumptions

SUBSCRIBE

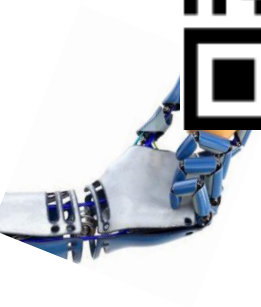
Working groups: 6G and robotics (WG1), 6G empowered robotics (WG2)
More information: https://one6g.org/resources/publications/
Call for participation: https://one6g.org

Sponsor Committee: COM/MobiNet-SC - Mobile Communication Networks
Co-Sponsor Committee: Robotics and Automation (RAS)
Call for participation: https://standards.ieee.org/ieee/1955/11660/

Thank you.

Interested to participate in
one6G **6G empowering robotics** activities?

Mona.Ghassemian@Huawei.com



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