Connected Robotics: Evolution and Significance for Europe

Next-G Network as the Architectural Foundation for Future Autonomous Robotic Systems

eu ROBOTICS

eu ROBOTICS TOPIC GROUPS

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1. Executive Summary

This position paper presents a comprehensive vision for **connected robotics**, emphasising the impact of next generation communication networks, particularly the forthcoming 6G capabilities on future robotics applications. The analysis underscores how robust connectivity is not merely an enhancement but a foundational imperative **for intelligent, interconnected robotic systems**. The report analyses lessons learned from current 5G and Wi-Fi deployments, providing a practical gap analysis. It also identifies critical technical, ethical, and societal challenges that must be proactively addressed, potentially results in actionable recommendations for fostering a sustainable, trustworthy, and **globally competitive connected robotics European ecosystem**.
The topic of connected robotics is of paramount importance at this time due to the accelerating adoption of robotics across diverse sectors, including logistics, manufacturing, healthcare, and smart cities. The integration of advanced wireless sensing, communication, and AI-driven computational capabilities is becoming increasingly critical for future robotics applications. At the same time, the ongoing transition from 5G (IMT-2020) to 6G (IMT-2030) presents a timely opportunity to shape the future of robotic capabilities and their underlying communication infrastructure [1].
Beside the research and technology development, a business and market perspective, connected robotics, empowered by NextG network, offers significant added value. It will enable intelligent, interconnected robotic systems to operate with unprecedented levels of reliability, efficiency, and autonomy, whilst simultaneously minimising operational complexity and costs. This transformation will lay the foundation for innovation across a multitude of sectors, ranging from precision agriculture and advanced healthcare solutions to industrial automation and environmental monitoring.

2. The euRobotics Connected Robotics Topic Group: Vision and Activities

2.1. Defining Connected Robotics

Connected robotics represents a paradigm shift in the design and operation of robotic systems, moving beyond isolated, standalone machines to highly integrated networked entities. This definition includes robotic systems that leverage advanced communication networks to significantly enhance their capabilities, enable complex collaboration, and integrate seamlessly into broader digital ecosystems. These systems are characterised by their ability to share data, coordinate actions, and collectively perceive and interact with their environment, often across distributed geographical areas [4].
Connected robotics refers to the integration of various technologies and systems to create a cohesive and intelligent network. It encompasses the use of robotics and autonomous systems to implement complex, cognitive-capable systems that can communicate and interact with each other and their environment. This definition aligns with the multidisciplinary nature of robotics and the need for standards to ensure effective implementation and interoperability across different robotic systems. [5]
Historically, industrial robots operated largely in isolation within controlled environments, performing

repetitive tasks with limited external communication. The evolution of robotics has progressively led to systems that increasingly rely on robust communication for enhanced autonomy, shared perception, and collaborative functionality. This progression is driven by the growing complexity of tasks and the desire to deploy robots in dynamic, unstructured environments that inherently necessitate a shift towards networked, intelligent, and often distributed operations. This transition from isolated to connected robotics represents a fundamental architectural and operational transformation. It is compelled by the imperative for greater efficiency, enhanced reliability, and the ability to execute complex tasks that are inherently beyond the capabilities of a single, unnetworked robot. This transformation implies a move towards collective intelligence and distributed task execution, where the network itself becomes an integral part of the robotic system's intelligence. The significance of pervasive connectivity in robotics enabling capabilities previously unattainable across a diverse range of sectors. These include, but are not limited to, advanced industrial automation, precision agriculture, sophisticated healthcare solutions, and the development of intelligent smart cities [1]. The ability for robots to communicate seamlessly with each other, with human operators, and with cloud-based intelligence fundamentally redefines their potential impact on industry and society.

2.2. Topic Group Objectives

The euRobotics Connected Robotics Topic Group (CRTG) is positioned within the broader euRobotics framework [16] to strengthen Europe's competitiveness and industrial leadership in the global robotics landscape [2], [3]. The core activity of the CRTG is to convene a diverse assembly of stakeholders, including researchers, engineers, entrepreneurs, and visionaries, with the explicit goal of breaking new ground in robotics. This collaborative effort is designed to yield tangible benefits for organisations, the European economy, and wider society [16].
The CRTG actively engages in identifying critical gaps and challenges within the field of connected robotics. It is responsible for defining clear solution paths, establishing measurable milestones, mobilising its members (and non-members) to achieve real innovations, and effectively translating theoretical advances into practical, deployable realities [10]. This goes significantly beyond mere academic discourse; it highlights a strong, pragmatic emphasis on applied research, technology transfer, and commercialisation. This practical focus is a crucial underpinning for a position paper advocating for actionable future directions in connected robotics, as it ensures that proposed strategies are grounded in a commitment to tangible results and market relevance.

2.3. Key Activities and Technology Focus Areas

The euRobotics Topic Groups, including the CRTG, comprehensively "span the full spectrum of activity from basic research, technological development, to concrete innovation and knowledge transfer" [16]. This broad scope ensures a holistic approach to advancing the field of connected robotics. Their collaborative methodology includes the utilisation of a dedicated Topic Groups Portal for technical and community interactions, collaborative content creation and discussions, and polls for effective prioritisation of key topics and research areas [10 following to the topic groups, such as the Telerobotics TG, Standards TG, Aerial Robotics TG, and Inspection & Maintenance TG have collaborated in 6G empowering future Robotics workshops at ERF 2025, conversations aimed to clarify the focus of the new TG and ensure addressing the topics of interest raised during these discussions generated valuable suggestions, and identified synergies between the proposed TG and the aforementioned groups to enhance collaboration and innovation across related areas. The CRTG primary goal is to foster collaboration between robotics and communications experts, enabling them to jointly tackle potential challenges while discussing robotic requirements and the capabilities of communication systems, and vice versa, with support from euRobotics members. Measures will be implemented to ensure ongoing communication and coordination. **Connected Robotics topic group** aims to advance the integration of robotics and next generation mobile technologies, including cutting-edge connectivity, radio-based sensing, and AI-native solutions, specifically for future robotics such as autonomous mobile robots (AMRs) Automated Guided Vehicles (AGVs), manipulators and humanoids.

With the emergence of next-generation International Mobile Telecommunications (IMT) technologies, there is a significant opportunity to enhance autonomous systems across various sectors, such as construction, autonomous maintenance & inspection, mining, and operations in challenging environments like nuclear energy or recycling facilities. The Connected Robotics TG will focus on communication-based enhancements for mobile robots operating in in public, private, rural, and urban areas. The initial scopes commonly identified by the CRTG coordinators with industrial and academic supporters including the following scope:

- **AI-Native Solutions:** Integrating AI-native solutions into next-generation communication networks is essential for enabling robots to operate effectively in diverse, dynamic scenarios because it uses AI techniques from the ground up as a core component, rather than adding AI features and agents later. This integration enhances high-level reasoning and facilitates computational offloading. Utilising distributed learning methodologies allows robots to process real-time data, make autonomous decisions, and adapt to changing environments. The concept of agentic AI further enhances resilience and scalability in deployments. Agentic AI is a very efficient possibility to build flexible AI-native solutions.
- **Advanced Communication and Sensing Technologies:** The Connected Robotics Topic Group is investigating advanced mobile wireless technologies, including high-reliability communication, radio sensing, and agentic AI. The aim is to develop new protocols and standards for robust, real-time communication between mobile robots and their infrastructure. This involves integrating protocols across various technology domains to ensure seamless operation in dynamic environments. We also leverage advanced radio-based sensing systems, such as Integrated Sensing and Communications (ISAC) and data fusion techniques, to enhance perception capabilities, improving real-time cognition, decision-making, navigation, obstacle detection, and environmental perception. Saying this highly efficient integration of mobile radio-based sensing mechanism provided by the radio access points and the radio device (3GPP based) with the onboard sensors (non-3GPP) sensors will play a crucial role to complement the perception where agentic AI might enable flexible processing among domains and networks.
- **Real-Time Monitoring and Simulation:** Digital twins utilise advanced simulation techniques to create real-time models of physical systems, enhanced by IMT-2030 capabilities. This integration facilitates continuous monitoring applications such as in production lines and improve robots task execution by allowing immediate feedback and rapid adjustments through ultra-reliable,

low-latency communication. Consequently, operational visibility improves, enabling proactive maintenance and reducing downtime. The collaboration between digital twins and NextG network optimises the robotic functions and task execution efficiency and accelerates AI training using synthetic data. Digital twins are also promising to generate virtual training data sets such as those demonstrated by NVIDIA.

- **Co-Design for Enhanced Fleet Robotics Communications:** Fleet Robotics Communications is crucial in applications like logistics and search and rescue, where multiple robots collaborate to achieve shared objectives. Decentralised control systems and local communication in Multi-Robot Systems (MRS) enhance coordination and task execution. Integrating robotic and communication systems requires seamless architecture and dynamic network configuration, focusing on low-latency communication and adaptive resource optimization.
- **Cyber-Physical Systems (CPS):** CPS represents an evolution of cybernetic systems, integrating computing, communication networks, and physical processes. Robots uniquely interact with the environment, actively modifying it. Combined with Augmented Reality (AR), CPS enhances human-machine interaction by providing immersive visualisations and real-time data overlays. The advent of NextG network will accelerate AR adoption, enabling applications across sectors such as automotive, healthcare, smart manufacturing, and urban infrastructure.
- **Use Case Development:** We promote collaboration among stakeholders to ensure compatibility and integration of diverse robotic systems, identifying real-world applications and conducting pilot projects. This is particularly important in scenarios where ISAC can significantly enhance performance, helping to understand the future requirements of general-purpose robots, including AMRs.

The CRTG plays an integral role in providing substantive content and strategic input to the overarching *A Unified Vision for European Robotics* of euRobotics AISBL [3]. This demonstrates their direct influence on European robotics policy and future research directions. Furthermore, euRobotics has explicitly endorsed the one6G "6G Empowering Future Robotics" white paper [1]. The CRTG functions as a critical intermediary, bridging the gap between fundamental research and industrial application by translating strategic visions into actionable roadmaps. This formal endorsement of the one6G white paper signifies a crucial, high-level alignment between leading European robotics and telecommunications organizations. This convergence of vision is vital for securing coordinated funding, setting cohesive standards, and fostering a coherent innovation ecosystem across Europe, thereby directly supporting the 'Whole Europe' strategy for global leadership. By translating strategic visions into actionable roadmaps, the CRTG and its partners provide the tangible pathways necessary to attract the long-term, high-risk private investment that the euRobotics strategy deems critical for future growth.

Furthermore, euRobotics Connected Robotics TG plan its activities based on the defined scope of activities and collaborate with other relevant TGs such as Telerobotics/Artificial Intelligence and Cognition in Robotics (AICoR), inspection and maintenance (I&M) and Standards and related TGs, as well as with one6G 6G empowering robotics Work Items under the euRobotics and one6G MoU.

2.4. Role in Fostering European Robotics Collaboration

euRobotics' central mission is to secure Europe's industrial leadership in the global robotics landscape by

fostering a cohesive ecosystem. This is pursued through a unified approach to research, innovation, and deployment, which emphasizes a holistic, cross-sectoral strategy rather than fragmented development. This effort, which initially involved a key collaboration with the Big Data Value Association (BDVA) on the Artificial Intelligence Public Private Partnership (AI PPP), has now transitioned [2]. Following the conclusion of the SPARC partnership, euRobotics now represents the private sector within the new AI, Data and Robotics Association (ADRA) under the Horizon Europe program (2021-2027). The ultimate goal of this strategic partnership is to ensure European sovereignty by 2030 in the development and deployment of trustworthy, safe, and robust AI, Data, and Robotics, creating significant technical, economic, and societal value while adhering to core European values.
The organisation emphasises a unified approach to research, innovation, deployment, and uptake, advocating for a cohesive strategy that aligns the efforts of research institutions, industrial players, and policymakers within a common framework [3]. The CRTG, as an integral component of euRobotics, is not solely focused on technological advancement but actively contributes to building a cohesive and competitive European ecosystem. The strategic collaboration with BDVA through the AI PPP signifies a profound recognition that connected robotics is inherently and inextricably intertwined with advancements in Artificial Intelligence and data management. This necessitates a holistic, cross-sectoral strategy rather than fragmented, siloed development efforts. The focus on a unified approach and the pursuit of "industrial leadership" elevates this beyond research coordination, indicating that the future of connected robotics is viewed as a strategic economic for Europe, requiring integrated policy, funding, and talent development and social awareness to compete globally.

3. NextG Network as an Enabler for Future Robotics

3.1. Bridging the Gaps from 5G and Wi-Fi

The emergence of 5G and advanced Wi-Fi has significantly enhanced connected robotics by enabling improved communication, coordination, and autonomy across diverse applications. However, operational experience with these technologies reveals limitations that constrain their ability to reliably support next-generation robotics. These lessons highlight persistent technical and architectural gaps to be addressed for the transformative capabilities envisioned with 6G.

- **Latency and Determinism Challenges in 5G/Wi-Fi:** Despite performance improvements over previous generations, Wi-Fi's best-effort delivery model introduces unpredictable latency and jitter, unsuitable for closed-loop robotic control scenarios that demand consistent sub-millisecond responsiveness. Similarly, while 5G networks can approach ultra-low latency, standard deployments challenge to guarantee deterministic end-to-end latency and minimal jitter necessary to support real-time synchronisation, multimodal (including haptic) feedback, and advanced coordinated manipulation of multiple robots. Packet loss and transmission variability further degrade control fidelity in dynamic environments.
- **Reliability and Resilience for Mission-Critical Operations:** Applications requiring ultra-high reliability—such as surgical robotics or autonomous vehicles—expose gaps in handover mechanisms and network resilience of current 5G and Wi-Fi systems. Connectivity interruptions caused by interference, mobility, or coverage holes undermine the stringent uptime

requirements (e.g., “six nines” availability) needed for safety-critical robotic functions. Redundant paths, seamless mobility management, and interference mitigation on WiFi unlicensed bands remain largely insufficient for the demands of dynamic, safety-oriented robotic deployments.

- **Sensing and Localisation Limitations of Current Radio Technologies:** Current radio technologies provide data communication, relying on sensors—lidar, cameras, GPS—for accurate localisation and environmental awareness. This division elevates system complexity and cost, while limiting the scalability and precision of robot navigation and perception. Achieving centimeter-level accuracy and pervasive situational awareness solely through radio-based sensing remains an open challenge, restricting operational efficiency in unstructured and cluttered environments.
- **Scalability and Management of Large Robot Fleets:** Handling thousands of heterogeneous robots over 5G and Wi-Fi networks highlights critical issues in resource management, interference control, and secure data exchange. Conventional centralised control generates overhead and latency that compromise fleet responsiveness and robustness. Current network designs lack flexible, decentralised orchestration mechanisms essential for scaling coordinated robot operations across diverse environments and applications.
- **Energy Efficiency and Computational Constraints:** Constrained energy budgets of mobile robots are challenged by the computational load imposed by autonomous operation and network communication. Present architectures often rely on offloading to distant cloud resources with consequent increased latency, connectivity dependencies, and increased power consumption due to local processing leading to reducing operational duration. Efficient energy management through adaptive computation partitioning between robots, edge, cloud, and communication networks remains a critical unmet need

3.2 Transformative Potential of NextG for Robotic Applications

The expected capabilities of 6G including Hyper-reliable low-latency communication (HRLLC), which is vital for safety-critical applications and real-time control loops; ubiquitous connectivity, essential for connecting vast numbers of sensors and robotic agents; and ISAC, a revolutionary feature that merges communication and environmental perception, and the AI-native [1], [9]. The pivotal role of 6G in advancing robotic functionalities suggests that its capabilities are not merely an incremental upgrade but a foundational requirement for enabling the next generation of robotic functionalities. Many advanced robotic applications, particularly those involving real-time human-robot interaction, distributed control, or shared perception in dynamic environments, are simply not feasible or scalable without the extreme performance metrics promised by 6G. This positions 6G as a catalyst for entirely new robotic paradigms, making demand for highly intelligent, seamlessly interconnected robotic systems possible to operate with unprecedented levels of reliability, efficiency, and autonomy, all whilst simultaneously minimising operational complexity and costs.

Fig 1- **Core requirements of future robotic applications**

The one6G paper systematically maps the stringent requirements of future robotic systems to the expected, advanced capabilities of the International Mobile Telecommunications-2030 (IMT-2030) framework, providing a clear roadmap for technological integration [1]. The consistent use of the term "transformative" in this context implies a qualitative leap in robotic capabilities, rather than just incremental quantitative improvements. This suggests that 6G can empower new classes of robotic applications and operational models that are currently impossible, thereby contributing to increased productivity, enhanced human well-being, and European technical sovereignty. For example, remote surgery with haptic feedback or large-scale autonomous construction using swarms of robots require a level of real-time control, sensing, and coordination that is fundamentally different from current capabilities, thereby redefining the scope of what robots can achieve.

3.3. Key NextG Network Features and Enabling Technologies for Connected Robotics

The one6G white paper details crucial features introduced by NextG network that are specifically designed to enable smart robotic applications [1]. These enabling technologies include:

- **Advanced Communication and Sensing Technologies:** ISAC is a revolutionary IMT-2030 feature that allows communication networks to simultaneously perform sensing functions. This capability significantly enhances robot perception and situational awareness by providing a richer, network-wide understanding of the environment. ISAC fundamentally blurs the distinction between communication and perception, effectively transforming the network itself into a distributed, pervasive sensor. This allows 6G network to generate a vast amount of sensing data based on environmental scanning and reconstruction as well as dynamic object detection and imaging, that can be used for efficient training for AI. In addition, robots can also gain a more comprehensive and collective understanding of their environment from network than could be achieved through isolated onboard sensors, provided that 6G network is multi-modal sensing based, i.e., diffusion of data from multiple sources (e.g., RF signal, radar, LiDAR, camera, etc.) for redundancy across multi-modalities for improved robustness, reliability and accuracy, directly enhancing critical functionalities like Simultaneous Localisation and Mapping (SLAM) and advanced object recognition in complex, dynamic scenes [9],[11],[12]. The IEEE P1955 standard for 6G-Empowering Robotics further highlights ISAC as central to 6G architectures [16].
- **AI native and communication:** This is one of the defining features of 6G, enabling efficient collaborative intelligence among robots, massive computation offloading to the edge or cloud, and autonomous network capable of self-optimisation and adaptive management that cater to their operational contexts. Technologies such as distributed computing, federated learning and

collaborative robot-network AI, semantic communication, and AI Agentic solutions for both radio access and core network, etc., could be enablers to elevate robotic applications, empowering them to handle complex tasks in various conditions with minimal cost and intervention.

- **Guaranteed immersive experience:** These technologies are critical for achieving the guaranteed composite requirement (a joint requirement of high data rates, low latency and high reliability) [8] and expansive coverage necessary for sharing vast amounts of multimodal sensor data from robots/networks, supporting high-fidelity perception and decision-making [9]. In addition, Hyper-Reliable Low-Latency Communication (HRLLC) is another IMT-2030 capability for closed-loop, real-time control of robotic systems and safety-critical applications where hyper-reliable connectivity is paramount, such as collaborative industrial robots or autonomous vehicles over distance.
- **Ubiquitous connectivity:** this includes Non-Terrestrial Network (NTN) and mesh/multi-hop network, and multi-layer NTN [6] and is crucial for providing extended and ubiquitous coverage, particularly for remote or highly mobile robotic deployments in areas where terrestrial infrastructure is limited or non-existent, such as precision agriculture or disaster response [9], [12].

Beyond merely consuming network services, robotic technologies can also contribute significant benefits to 6G network performance. Robots can potentially act as mobile relays, distributed sensors, or even edge computing nodes within the network infrastructure itself, creating a symbiotic relationship between robotics and communication.

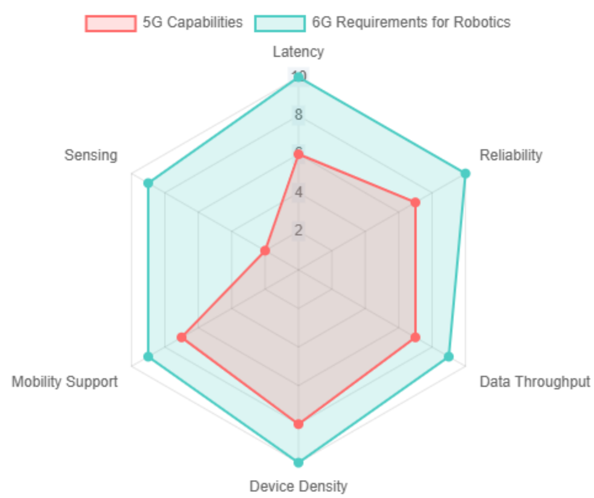

Fig 2- **Advanced and new capabilities**

The synergy between **digital twins** and advanced communication systems, particularly with the capabilities of ISAC multimodal information, creates a powerful loop of real-time monitoring and control. Digital twins act as receivers and interpreters of data, while communication technologies.

The robotics industry is increasingly focused on **energy efficiency**, and a major strategy for achieving this is by shifting more processing capabilities to the edge or cloud. Edge/cloud computing involves processing multimodal data closer to the source rather than on the robot itself. This has significant implications for both energy consumption and overall performance, by enabling robots to offload data and make decisions in real time. The evolving 6G network architecture is designed to support **the**

seamless integration of sensing, computation, and control functionalities directly within the mobile communication network infrastructure itself.

The push towards an "**AI-native" and "lean" NextG network architecture** [18] signifies a profound shift in network design philosophy. This architecture is conceived to inherently optimise performance, adapt to dynamic conditions, and enable advanced functionalities through pervasive artificial intelligence. This implies a highly optimised, self-configuring, and adaptive network specifically engineered to handle the dynamic, diverse, and stringent demands of robotic systems. Such an architecture would move beyond static resource allocation to predictive, AI-driven management, ensuring optimal performance for real-time robotic operations.

Furthermore, the integration of terrestrial networks operating in cohesive tandem with non-terrestrial mechanisms (e.g., satellites, Uncrewed Aerial Vehicles (UAVs)) is emphasised as an essential component for advancing the comprehensive NextG network landscape and ensuring ubiquitous connectivity for robotics, especially in challenging or remote environments.

3.4. Emerging Use Cases and Applications

The pervasive potential of connected robotics is evident in the extensive breadth of applications poised for transformation by NextG network. These include traditional industrial settings, logistics, manufacturing, healthcare, and smart cities, extending to precision agriculture and environmental monitoring which showcases a mobile radio-connected humanoid robot AVATAR, autonomous mobile robots for industrial safety, and collaborative robots (cobots) integrated into smart construction environments.

Beyond existing applications, NextG network will significantly empower advanced and often biologically inspired robotic concepts. This includes the development of soft robotics, complex multi-robot systems, large-scale swarm robotics, and sophisticated shared control systems. The extensive breadth of applications, spanning from traditional industrial settings to environmental monitoring and advanced humanoid robots, vividly demonstrates the pervasive potential of connected robotics. The explicit inclusion of "soft robotics" [17] and "swarm robotics" points towards a future where advanced, often biologically inspired, robotic designs will heavily rely on sophisticated connectivity for their coordination, emergent intelligence, and adaptive behaviours. This broadens the societal, ethical, and regulatory implications significantly.

4. Challenges and Considerations in Connected Robotics

4.1. Technical Challenges

Despite the transformative promises of NextG network, the practical implementation of connected robotics will still confront significant technical hurdles. Ensuring consistent ultra-low latency and ultra-high reliability wireless connection remains a considerable challenge, particularly in dynamic, unpredictable, and communication-degraded environments such as disaster zones or remote industrial sites. The challenge of managing and coordinating massive numbers of connected devices, including diverse robots, numerous sensors, and IoT endpoints, whilst ensuring network capacity and avoiding

congestion, is also paramount [1].
Interoperability presents another critical need: ensuring seamless communication and data exchange between heterogeneous robotic systems and network components originating from different manufacturers and operating under various standards. Furthermore, addressing the substantial energy footprint of always-on connected robots and the underlying high-performance NextG network infrastructure is crucial for sustainable deployment. Finally, the efficient handling and processing of the immense volume of multimodal data generated by connected robots necessitates robust edge and cloud computing architectures to enable real-time decision-making [1]. Whilst NextG network can offer unprecedented solutions to many communication challenges, such as system resilience, network optimisation, and efficient data management will remain crucial, even with the advent of advanced 6G infrastructure, to ensure real-world deployability. To this end, the upcoming demand of computing and AI resources enforce the discussion about the strategy to deploy certain functionalities to the robot, the edge nodes, the cloud or to the NextG network. To this end, the upcoming demand for computing and AI resources enforces the discussion about the strategy to deploy certain functionalities to the robot, the edge nodes, the cloud, or the NextG network. For the generalized robots acting in unstructured environments, a deep understanding of the environment and the context of objects is crucial for the flow of necessary actions to fulfill the task. Besides the communication capabilities, the NextG network will also improve environmental perception by radio sensing and agentic-based processing. These persistent practical hurdles require specific research into robust control, predictive algorithms, and efficient data handling, rather than simply relying on network upgrades. These persistent practical hurdles require specific research into robust control, predictive algorithms, and efficient data handling, rather than simply relying on network upgrades.

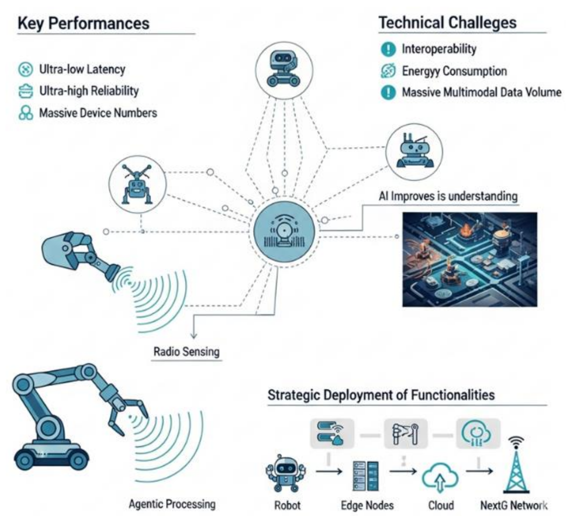

Fig 3- **AI Capabilities, KPIs, and Challenges**

4.2. Ethical, Privacy, and Security Implications

The widespread deployment of connected robotics introduces profound ethical, privacy, and security considerations that must be addressed proactively. Protecting sensitive multimodal information collected by robotic sensors, especially when operating in public spaces or interacting with individuals, is important. This is governed by the **General Data Protection Regulation (GDPR**), which highlights the

importance of data privacy for the EU government. The critical need to secure highly interconnected robotic systems from malicious attacks that could compromise control, data integrity, or lead to catastrophic safety hazards cannot be overstated.
Ensuring that AI models guiding robotic behaviours are transparent, explainable, and inherently trustworthy is vital to foster public acceptance and accountability. Guaranteeing the safe and predictable operation of autonomous and collaborative robots, particularly in dynamic human-robot interaction scenarios, requires rigorous validation and robust control mechanisms [16]. Beyond technical safeguards, addressing broader societal concerns such as potential job displacement, ensuring responsible and equitable deployment of robotic technologies, and fostering public acceptance are crucial. euRobotics actively advocates for promoting a "realistic image of robotics" to mitigate unfounded fears and foster a balanced understanding of their capabilities and limitations [3]. The recurring emphasis on ethical, privacy, and sustainability considerations within the one6G white paper and euRobotics' proactive stance signifies a crucial shift towards responsible innovation. This indicates that the long-term success, public acceptance, and beneficial integration of connected robotics are as fundamentally dependent on addressing these non-technical, societal aspects as they are on achieving technological breakthroughs. Ethical design and public trust are now core principles, not afterthoughts, and are critical success factors for the entire field.

4.3. Sustainability and Societal Impact

The imperative to minimise the environmental footprint associated with the deployment and operation of NextG networks and the vast number of connected robotic systems is a significant consideration, aligning with broader European sustainability goals. Notably, euRobotics has a dedicated "Robotics for Sustainability" Topic Group, underscoring this commitment.
From an economic perspective, connected robotics presents a dual potential: increased productivity and the creation of new economic opportunities, alongside the need to address concerns regarding potential job displacement due to increased automation.[3] Finally, cultivating public trust, understanding, and acceptance of robotic systems is crucial. This involves actively working to dispel "fears about robots" and promoting a balanced, realistic view of their capabilities and societal benefits. The explicit and strategic linking of sustainability to 6G-empowered robotics within the one6G white papers and through euRobotics' dedicated Topic Group indicates a clear recognition that technological advancement in connected robotics must intrinsically align with broader environmental and societal goals. This moves beyond purely economic or performance-based metrics to encompass a holistic view of impact, integrating sustainability as a fundamental design constraint and strategic objective.

4.4. Standardisation and Regulatory Landscape

Strengthening global standards is critical, particularly through organisations like 3GPP, EN ISO (safety), ETSI ISG ISAC [15], ETSI ISG ENI [14], and IEEE (ethics) to drive economies of scale, ensure interoperability, and provide a stable foundation for the development and widespread adoption of next-generation robotics [22], [23]. The one6G white paper specifically recommends actively involving robotics experts in the early stages of standard development. This ensures that communication

standards are tailored to the unique and demanding requirements of robotic applications, reflecting the complex interplay between communication, robotics, AI, and ethical considerations. The IEEE P1955 standard for 6G-Empowering Robotics is a key initiative in this area [16].
The imperative for developing adaptive and proactive regulatory frameworks that can keep pace with rapid technological advancements is also significant. These frameworks must effectively address emerging issues such as data privacy, cybersecurity, and safety without inadvertently stifling innovation [1], [3]. Standardisation is explicitly highlighted as critical not only for technical interoperability but also for achieving commercial viability and widespread market adoption. The specific call for "multidisciplinary collaboration" in standards development, particularly involving robotics experts in telecom standards bodies like 3GPP, signifies a crucial recognition: technical standards must now reflect the complex interplay between communication, robotics, AI, and ethical considerations, necessitating input from a diverse array of fields to ensure holistic and effective regulation. This ensures that future networks are inherently "robot-ready" and that regulatory frameworks consider the full spectrum of implications from the outset.

5. Relevant Activities and Future Outlook

5.1. Current Activities in the Domain

The euRobotics Connected Robotics Topic Group (CRTG) serves as a "crucible where ideas become innovation," bringing together researchers, engineers, entrepreneurs, visionaries and creators to advance the field [10]. Their activities span the full spectrum from basic research to technological development, concrete innovation, and knowledge transfer, identifying gaps, defining solution paths, and mobilising members to achieve real innovations [10], [12]. The CRTG actively contributes content to the euRobotics' Unified Vision for European Robotics. euRobotics also collaborates with the Big Data Value Association (BDVA) on the Artificial Intelligence Public Private Partnership (AI PPP), aiming to boost industrial AI uptake and connect AI, Data, and Robotics innovation and research communities across Europe [2]. This partnership seeks to align user value and industrial needs with research excellence in AI, fostering a connected European AI ecosystem [2].
The one6G Association actively publishes white papers, such as "6G Empowering Future Robotics," which explore the transformative role of 6G in advancing robotic applications [1]. They also host summits and panels, showcasing prototyping activities and live demonstrations. Recent demonstrations have included 5G-connected humanoid robots, autonomous mobile robots for industrial safety, and collaborative robots in smart construction environments, highlighting key 6G enablers like ISAC and AI-driven systems. These activities emphasise turning 6G concepts into reality through hands-on validation and cross-sector collaboration. Furthermore, 3GPP is actively engaged in defining requirements for 6G, including those for collaborative robots and ISAC, through initiatives like the FS_SOBOT (Study on Network of Service Robots with Ambient Intelligence) [23], [24]. The IEEE P1955 standard for 6G-Empowering Robotics is also under development, focusing on use case scenarios, requirements, and architectural impact [16].

5.2. Strategic Research and Development Priorities

Continued and sustained research and investment in intelligent robotic systems are critically needed, particularly as the technological landscape transitions from 5G (IMT-2020) to 6G (IMT-2030). Specific strategic research and development priorities include:

- **Advanced Communication for Robotics and Autonomous Systems (RAS):** Prioritising research into novel communication paradigms for large-scale centralised and ad-hoc networks, the application of Reconfigurable Intelligent Surfaces (IRS), and the integration of non-terrestrial networks. This will enable robots to not only utilise networks but also contribute to their resilience and expansion [12].
- **Resilient Distributed Control and fleet management:** Emphasising the need for further development of safe distributed control mechanisms for multi-robot systems, specifically addressing challenges posed by communication delays. This includes leveraging advanced techniques like Graph Neural Networks (GNNs) and designing lightweight communication protocols on practical resilience in communication-degraded environments [34], [35].
- **Bio-inspired and Soft Robotics:** Advocating for continued exploration and investment in new design paradigms for future robot companions, focusing on embodied intelligence, morphological computation, and the unique challenges of soft robotics. This involves developing communication and control systems capable of managing complex, deformable structures.
- **Integrated Sensing, Communication, and AI:** Prioritising interdisciplinary research into the seamless integration of sensing, communication, and artificial intelligence as foundational pillars for next-generation connected robotics. This will enable the network to function as a pervasive sensor, enhancing collective perception and decision-making [1], [9].
- **Safety standard for humanoid robots:** currently there is no safety standard reflecting the new type of robots and their usage as companion of humans. Safety regulations will also impact the design and architecture of the control and communication network as well as the flexibility to apply dedicated mechanism in specific situation e.g. hospital, home-care, shopping scenarios. NextG sensing could be a promising extension to increase the safety by complementing state of the art sensors.

These strategic recommendations synthesise the core research areas of leading experts with the broader visions articulated by one6G and euRobotics. This demonstrates a cohesive and multi-faceted strategic direction for future R&D, providing concrete areas for targeted investment and collaborative efforts that align with the most pressing technical and societal needs of connected robotics. It shows that the future requires deep dives into specific technical areas whilst simultaneously integrating these into a larger, coherent framework.

5.3. Multidisciplinary Collaboration and Innovation Ecosystems

The inherent complexity and pervasive impact of connected robotics necessitate a fundamental departure from siloed research and development. Therefore, fostering multidisciplinary collaboration and robust innovation ecosystems is paramount:

- **Cross-Sectoral Collaboration:** Emphasising the imperative for continuous and enhanced collaboration among diverse stakeholders, including industry leaders, academic researchers, and policymakers, to accelerate innovation and deployment [1].

- **Academic-Industry Linkages:** Advocating for strengthening existing mechanisms and developing new pathways for effective knowledge transfer and the translation of research into practical innovations, aligning with the core mandate of euRobotics Topic Groups [3], [19].
- **"Whole Europe" Approach:** Reinforcing the strategic necessity of a unified European approach that integrates research, innovation, deployment, and uptake across member states to maximise collective impact and competitiveness [3]. This is not just a nicety; it is a direct consequence of the multidisciplinary nature of connected robotics, where no single field can solve the challenges alone.
- **AI, Data, and Robotics Integration:** Recommending further investment in and expansion of the AI PPP initiative to ensure seamless connection and coordination among these critical technology communities, recognising that connected robotics is inextricably linked to advancements in AI and data management [2].

Companies such as ABB have already developed and deployed solutions like Fleet Assessment to benchmark the connected robots, provide preventive care and condition monitoring/diagnostics. Connected Robotics applications integrate different types of devices such as collaborative robotic things mobile robotic things (e.g., automated guided vehicles—AGVs), lightweight mobile platforms, used as fleets in warehouses and distribution centers, manufacturing intralogistics, agriculture, and specific environments in logistics in hospitals or retail. The fleets of robotic things (service and humanoid robots) are used for logistics and delivery as well as for moving objects, such as boxes, pallets, or tools, in industrial settings between machinery, transfer points, or storage areas [20].

The repeated call for multidisciplinary and cross-sectoral collaboration underscores that the inherent complexity and pervasive impact of connected robotics necessitate a fundamental departure from siloed research and development. The "Whole Europe" approach further reinforces the strategic importance of a unified, coordinated effort to achieve global leadership in this domain.

5.4. Policy and Investment Recommendations

Driven by a projected market growth to over $150 billion by 2030, the business opportunities for robotics in next-generation cellular systems are substantial, extending far beyond traditional manufacturing and logistics [29]. We must collaborate with robotics experts to explore NextG sensing and communication features for robotic technology and develop advancements like SLAM to enhance 5G/6G systems in line with the European Commission's Work Programme [30]. A key market lies in Robotics for NextG network, where mobile robots equipped with advanced positioning capabilities—such as SLAM [36]—can operate in complex urban or remote environments. Furthermore, UAVs present a critical opportunity to act as mobile cellular base stations, extending network coverage or serving as a vital substitute when ground infrastructure is affected by natural disasters [31]. Drone-as-a-Service Market Revenue was valued at USD 6.3 Billion in 2024 and is estimated to reach USD 27.3 Billion by 2033, growing at a CAGR of 18.1% from 2026 to 2033 [32]. This application is part of the growing "Drones for Emergency Responder" market, which is expected to grow from 6.8 (USD Billion) in 2024 to 12.5 (USD Billion) by 2032 [33], highlighting a significant business case for resilient, robot-enabled communication networks.

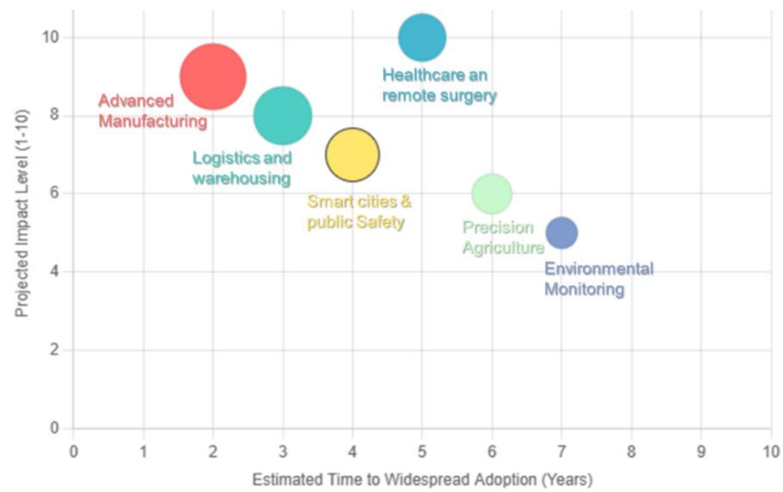

Fig 4- **Future-Forward Applications of Connected Robotics**

To fully realise the potential of connected robotics, supportive policy and investment frameworks are essential:

- **Standardisation:** Providing specific recommendations for strengthening global standards, particularly within 3GPP, to foster economies of scale, ensure interoperability, and accelerate market penetration for connected robotics [1][23][37]. The call for multidisciplinary collaboration in standards development means that technical standards must now reflect the complex interplay between communication, robotics, AI, and ethical considerations.
- **Commercial Feasibility:** Recommending dedicated efforts to investigate the commercial feasibility of implementing extreme IMT-2030 requirements, ensuring that technological advancements align with realistic market needs and business models [1].
- **Ethical Guidelines and Regulation:** Proposing the development of adaptive and proactive regulatory frameworks that effectively address evolving issues of privacy, cybersecurity, and ethical considerations, crucially without stifling innovation [1][3][16].
- **Funding Mechanisms:** Advocating for robust public and private funding mechanisms specifically designed to support European AI and robotics initiatives, fostering a competitive and innovative ecosystem [2].

These policy recommendations are directly derived from the identified technical and societal challenges, as well as the strategic visions of euRobotics and one6G. This section provides actionable advice for a broad range of stakeholders, extending beyond the immediate research community to include policymakers, regulators, and investors, ensuring a comprehensive approach to the future of connected robotics.

5.5. SWOT Analysis of Connected Robotics

NextG network has the potential to bring together fields such as connectivity, robotics, cloud and secure and trustworthy commerce [30]. Understanding the strengths, weaknesses, opportunities, and threats from the perspectives of key stakeholders such as Network Operators, Network and Component Vendors, Robotics Manufacturers, and industrial or consumer end users is crucial for strategic planning and successful deployment.

1. Mobile Network Operators

- **Strengths (S):**
  - **Ubiquitous Connectivity:** Ability to provide pervasive NextG network coverage, including Non-Terrestrial Networks as well as multi-hop and multi-layer NTN, essential for mobile and remote robotics [13].
  - **New Revenue Streams:** Opportunities for high-value services beyond basic connectivity, such as network slicing for mission-critical robotics, edge AI computing, and ISAC-as-a-service [1].
  - **Network Orchestration Expertise:** Existing capabilities in managing complex network infrastructures can be exploited for robotic fleet management.
- **Weaknesses (W):**
  - **Infrastructure Investment:** Significant capital expenditure required for NextG network rollout, including higher frequency bands and denser deployments.
  - **Lack of Robotics Expertise:** May lack in-depth knowledge of Robotics applications and solutions, leading to integration challenges.
  - **Complexity of Integration:** Integrating diverse robotic systems and applications into a unified network architecture demands new skills and operational models.
- **Opportunities (O):**
  - **Partnerships:** Collaborate with robotics companies to co-develop tailored NextG network solutions and vertical-specific applications.
  - **Market Growth:** Tap into the rapidly growing robotics market by offering differentiated connectivity and intelligence services.
  - **Standardisation Leadership:** Influence 3GPP and other standards bodies to ensure NextG network specifications align with operator capabilities and robotic application performance requirements [16].
- **Threats (T):**
  - **Competition:** New entrants (e.g., hyperscalers, private network providers) offering specialised robotic connectivity solutions.
  - **Technological Obsolescence:** Rapid evolution of robotics and AI may outpace traditional network upgrade cycles.
  - **Regulatory Hurdles:** Complex and evolving regulatory landscape for spectrum, data privacy, and cross-border operations.

2. Network and Component Vendors

- **Strengths (S):**
  - **Technological Expertise:** Deep knowledge in developing advanced communication technologies (e.g., ISAC, HRLLC, AI-native network elements) [13].
  - **Standardisation Influence:** Active participation in 3GPP and other bodies allows shaping future NextG network standards to include robotics requirements [16].
  - **Scalability:** Ability to produce hardware and software solutions for large-scale network deployments.
- **Weaknesses (W):**
  - **R&D Costs:** High investment required for cutting-edge NextG network and AI research

and development.
    - **Interoperability Challenges:** Ensuring seamless integration of components from various vendors within complex robotic ecosystems.
    - **Market Fragmentation:** Diverse requirements from different robotic verticals necessitate customisation, need for market education, increasing overheads.
- **Opportunities (O):**
    - **Early Mover Advantage:** Capture significant market share by developing innovative NextG network-enabled robotic components and solutions.
    - **New Product Categories:** Create specialised hardware (e.g., ISAC-enabled transceivers) and software (e.g., AI orchestration platforms) for connected robotics.
    - **Global Market Reach:** Leverage 3GPP standards for widespread adoption of their products.
- **Threats (T):**
    - **Intellectual Property Disputes:** Complex patent landscape in NextG network and AI technologies.
    - **Innovation Cycles:** Challenge for Longer development cycles in Manufacturing to adapt to new and continuously innovative technological paradigms.

3. Robotics Manufacturers

- **Strengths (S):**
    - **Application Expertise:** Deep understanding of specific robotic use cases and operational environments.
    - **Hardware and Software Integration:** Experience in designing and manufacturing complex robotic systems.
    - **Innovation Agility:** Often smaller, more agile companies capable of rapid prototyping and specialisation.
- **Weaknesses (W):**
    - **Connectivity Dependency:** Reliance on external NextG network infrastructure for advanced functionalities, which may not be universally available.
    - **Lack of Communication Expertise:** May lack in-depth knowledge of wireless communication solutions, leading to integration challenges.
    - **Cost of Advanced Components:** Unknown cost of integrating NextG network-specific hardware (e.g., ISAC modules) into robotic platforms to run cost benefit analysis for investment.
- **Opportunities (O):**
    - **Enhanced Capabilities:** Enhanced levels of autonomy, collaboration, and safety (e.g., dynamic safety zones, precise SLAM) [1].
    - **New Business Models:** Develop Robot-as-a-Service (RaaS) offerings leveraging pervasive sensing, positioning, connectivity and cloud intelligence.
    - **Market Diversification:** Expand into new verticals and applications that can utilize robotics solutions such a AMRs, UAVs or SLAMs for extended coverage and positioning.
- **Threats (T):**
    - **Standardisation Gaps:** Lack of clear, harmonised standards for robot-network

interaction hindering widespread adoption.
    - **Public Acceptance:** Societal concerns regarding job displacement, privacy, ethics, and safety potentially impacting market growth [8].

4. End-Users (Industries and Consumers)

- **Strengths (S):**
    - **Operational Efficiency:** Significant improvements in productivity, cost reduction, and quality through automation and intelligent systems.
    - **Enhanced Safety:** Collaborative robots and dynamic safety zones improve workplace safety, particularly in hazardous environments.
    - **New Services:** Access to entirely new capabilities and services (e.g., remote healthcare, autonomous logistics).
- **Weaknesses (W):**
    - **Initial Investment:** Significant capital required for acquiring or integrating connected robotic systems.
    - **Skill Gap:** Need for new skill sets to operate, maintain, and manage advanced robotic systems.
    - **Integration Complexity:** Challenges in integrating new robotic solutions with existing legacy systems and workflows.
- **Opportunities (O):**
    - **Competitive Advantage:** Early adoption of connected robotics can provide a significant edge in efficiency and innovation.
    - **Resource Optimisation:** Better utilisation of resources (e.g., energy, materials, labour) through intelligent automation.
    - **Resilience:** Enhanced operational resilience, particularly in disaster recovery scenarios where UAVs can restore communications [31].
- **Threats (T):**
    - **Job Displacement Concerns:** Potential for automation to displace human labour, leading to societal resistance [27].
    - **Data Privacy and Security Risks:** Potential risks for collection and use of sensitive data by connected robots and potential cyber threats.
    - **Trust and Reliability:** Public and industrial apprehension regarding the trustworthiness and reliability of highly autonomous systems.

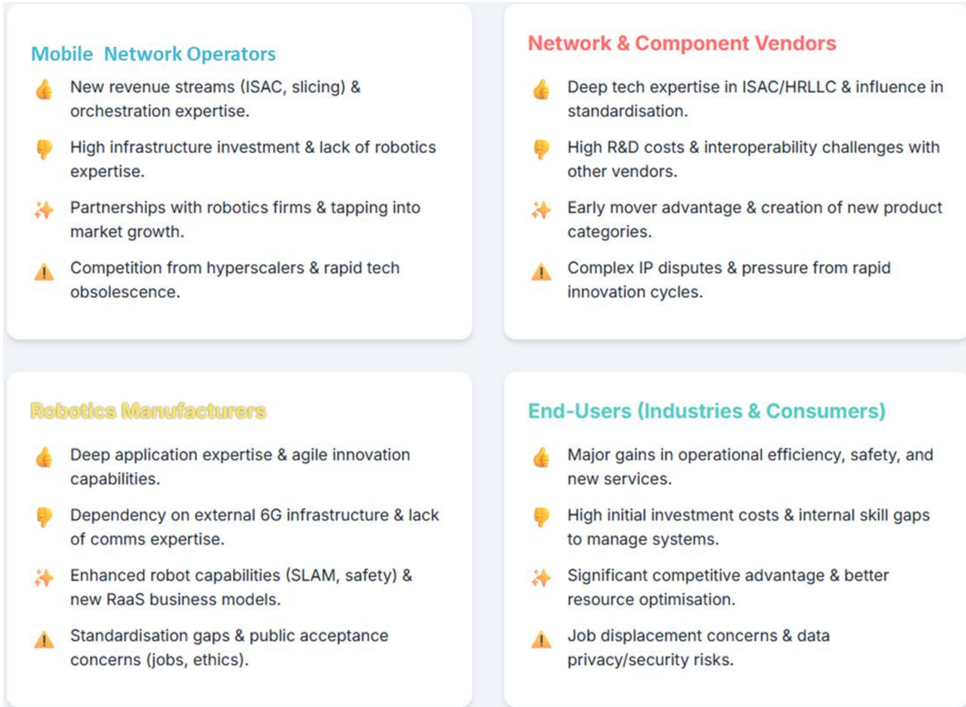

Fig 5- **Connected Robotics SWOT Analysis**

6. Remarks

Connected robotics, profoundly underpinned by the capabilities of NextG networks, represents a transformative frontier with the potential to redefine industries and societal interactions. This paper underscores the critical role of advanced connectivity in enabling a new generation of intelligent, interconnected robotic systems, moving beyond isolated machines to collaborative entities that leverage collective intelligence. The strategic alignment between euRobotics and one6G, complemented by the specialized expertise from leading research institutions, provides a robust foundation for Europe's leadership in this domain and directly supports the "Whole Europe" strategy for global leadership.

Realising this vision, however, necessitates a holistic approach that seamlessly integrates cutting-edge technological advancements with critical ethical, societal, and standardization considerations. A deep understanding of the performance limitations in current 5G and Wi-Fi deployments for robotics is crucial for defining future requirements and guiding architectural innovation. Addressing technical challenges such as latency, scalability, and data processing is paramount, but this must be done in parallel with ensuring data privacy, cybersecurity, trustworthiness, and societal acceptance. The commitment to sustainability, both in the development and deployment of connected robotics, must also remain a core principle. As a critical intermediary, the CRTG bridges the gap between fundamental research and industrial application by stimulating a continuum of understanding among end-users, innovators, and researchers, translating strategic visions into actionable roadmaps. This systematic mapping of requirements provides a clear framework for regulators, ensuring that standards and policies can be developed in alignment with market and innovation needs, and also serves as a foundational document for developing a European skills framework.

By prioritizing sustained multidisciplinary research and development, fostering collaboration across academia, industry, and policy-making bodies, and establishing adaptive regulatory frameworks, Europe can forge a future that is not only sustainable and trustworthy but also profoundly beneficial to society, enabled by the pervasive deployment of intelligent, interconnected robotic systems.

Acknowledgements

euRobotics and one6G association has initiated the joint forward-looking **Connected Robotics Topic Group (CRTG**) following one6G white papers on **6G empowering robotics**, and a number of workshops and events jointly organised by roboticists and communication experts from leading industries and research institutions.

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Expert Perspectives on Connected Robotics

Research on Communication and Network Foundations - Dr Syed Ali Raza Zaidi

[School of Electronic and Electrical Engineering | University of Leeds, accessed July 28, 2025, https://eps.leeds.ac.uk/electronic-engineering/staff/624/dr-syed-ali-raza-zaidi, Cheddar Hub, accessed July 28, 2025, https://cheddarhub.org/person/dr-syed-ali-raza-zaidi/]

Research from the **University of Leeds** focuses on wireless communication networks, robotics and autonomous systems (RAS), Internet of Things (IoT), embedded systems design, and the AI-native design of future wireless networks. This work applies system-level approaches to telecommunication networks, providing a holistic view of connected systems. Key research interests lie at the intersection of "Communication and Networking for IoT, Robotics and Autonomous Systems," explicitly exploring both "RAS for communication and communication for RAS themes", indicating a bidirectional relationship where robots both consume and contribute to network capabilities.

Contributions directly address foundational aspects of 6G, including research on Reconfigurable Intelligent Surfaces (IRS) for enhancing spectral efficiency and the development of Non-Terrestrial UAV Clients for Beyond 5G Networks, which are crucial for extending 6G coverage and supporting mobile robotic platforms. This research also encompasses the design, analysis, and implementation of large-scale ad hoc wireless networks, employing tools from stochastic geometry and random graph theory. This is vital for managing dense robotic deployments and ensuring robust connectivity in dynamic environments. Further research extends to "Tiny machine learning on the edge" and "Unlocking Edge Intelligence through TinyML", which are crucial for enabling autonomous decision-making and data processing directly on robotic platforms with limited resources, reducing reliance on centralised cloud infrastructure. The specific focus on "RAS for communication" suggests a revolutionary shift where robots are not merely passive users of the 6G network but active, intelligent components of the communication infrastructure itself. This could involve robots dynamically extending network coverage in remote or hazardous areas, acting as mobile base stations or relays, or serving as distributed sensing nodes that contribute to real-time network optimisation and resource allocation.

Research on Distributed Perception and Human-Robot Collaboration - Prof Stefano Ghidoni

[Università di Padova (UNIPD) | Department of Information Engineering | Available: https://www.dei.unipd.it/~ghidoni/ Research profile - ResearchGate, accessed July 28, 2025, https://www.researchgate.net/profile/Stefano-Ghidoni-2, accessed July 28, 2025.]

Work from the **University of Padova** focuses on computer vision for robotics, human-robot collaboration (HRC), deep learning applications, and industrial vision systems. This research is crucial for the advancement of Industry 4.0, particularly in enabling safe and effective human-robot collaboration. This includes robust human monitoring using multi-camera systems, precise human localisation in robotic workcells, advanced human motion prediction (leveraging physical and physiological signals), and facilitating collaborative assembly tasks through intuitive interfaces like hand gestures.

This research emphasises the significant advantages of employing robots in conjunction with human labor for executing complex tasks to achieve improved performance, enhanced efficiency, cost-effectiveness, increased flexibility, and superior fault-tolerance compared to single-robot systems.

Research on Autonomous Navigation, Interaction in Future Robotics- Prof Alberto Jardón Huete

[accessed July 28, 2025, https://researchportal.uc3m.es/display/inv21183]

Research from UC3M focuses on the intersection of Robotics, Computer Vision, and Human-Robot Interaction, with a strong emphasis on designing service robots for rehabilitation and assistive technology that improve quality of life. This work champions a highly user-centric approach, leveraging technologies like Serious Games, Virtual Reality (VR), and Extended Reality (XR) to create intuitive and engaging interactions. The core objective is to enhance the **user experience (userX)** and overall usability, developing **friendly interfaces** for **collaborative robotics** in personalized rehabilitation, where robots and humans work together safely and effectively.

This vision of creating robotic "companions" rather than mere tools is shared by contributions to visionary EU projects like **++**, exploring future robot companions, and **ALMA**, which delves into advanced Algebraic Machine Learning. This paradigm shift demands advanced physical and cognitive capabilities. For instance, concepts like **"soft robotics"** and **"morphological computation"** are explored to enable robots that can gently perform therapeutic manipulations or adapt to human environments. Achieving this level of sophisticated, safe, and adaptive interaction pushes the boundaries of network design requiring novel communication and control architectures to handle vast amounts of sensory data and precise, distributed control. The seamless integration of these assistive companions into our lives is fundamentally dependent on the capabilities of 6G. **Next-generation networks are the key enabler**, providing the required ultra-low latency and high bandwidth for: a) **Real-time data streaming** from wearable sensors for continuous monitoring; b) **Precise, haptic feedback** essential for tele-rehabilitation and safe physical interaction; c) **Immersive VR/XR environments** for therapy and training. Ultimately, 6G will provide the foundation for truly responsive and effective assistive robots that can operate seamlessly in human-centric environments, ensuring a safe, personalized, and enriching user experience.

Acronyms

3GPP	3rd Generation Partnership Project
5GS	5G System
6GS	6G System
AGV	Automated Guided Vehicle
AI	Artificial Intelligence
CAV	Connected and Automated Vehicle
CRM	Customer Relationship Management
ERP	Enterprise Resource Planning
GDPR	**General Data Protection Regulation**
HRLLC	Hyper Reliable Low Latency Communication
IEEE	Institute of Electrical and Electronics Engineers
IMT	International Mobile Union
ITU	International Telecommunications Union
ISAC	Integrated Sensing and Communications
KPI	Key Performance Indicators
LIDAR	Light Detection and Ranging
ML	Machine Learning
NextG	Next Generation
NLP	Natural Language Processing
SDO	Standardisation Organization
SLAM	Simultaneous Localization and Mapping
SOBOT	Service Robot
UC	Use Case
WG	Working Group
WI	Working Item