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The 6G workshop series by Hexa-X

Special-purpose Functionalities: Intermediate Solutions

Björn Richerzhagen
(WP7 Lead, Siemens)

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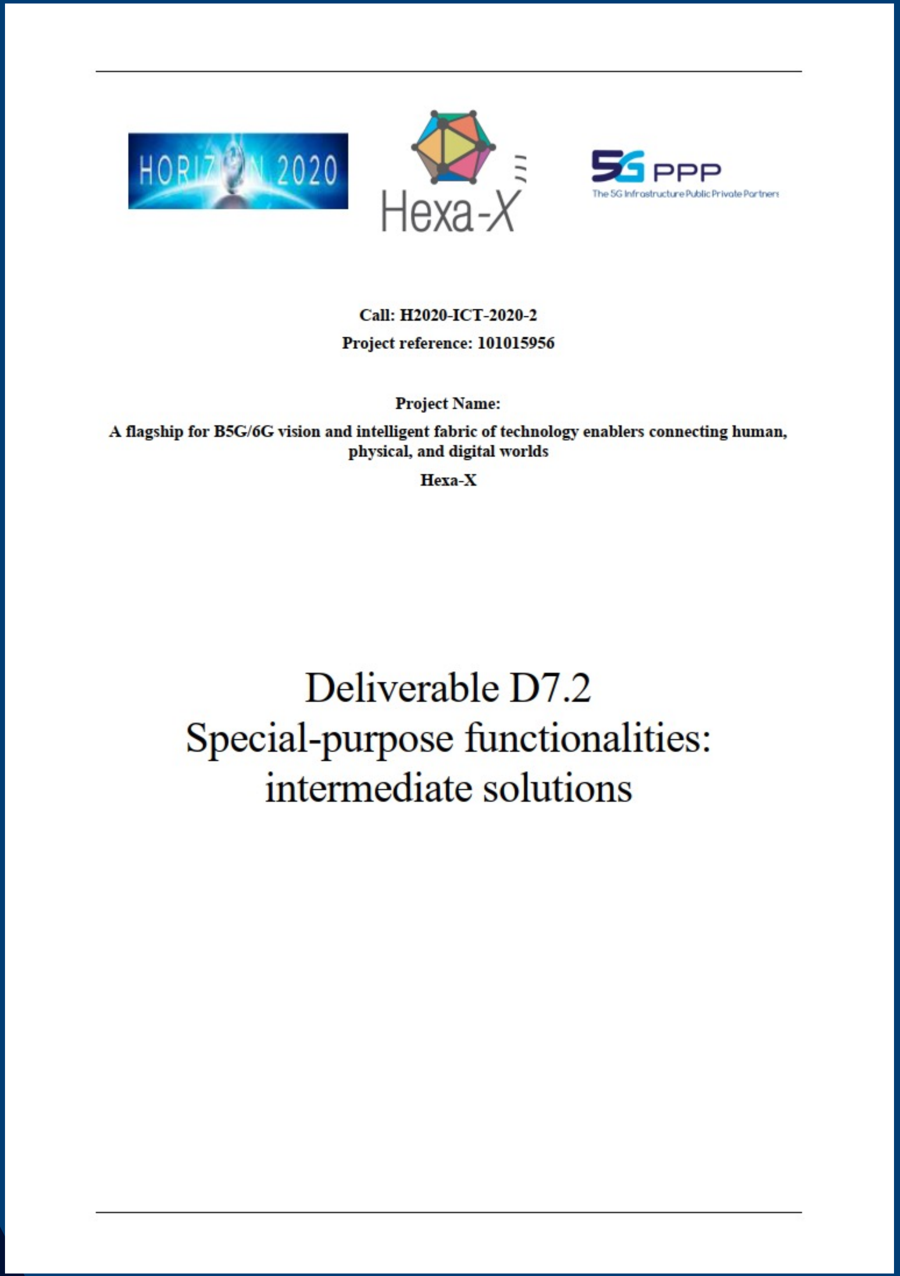
Mission and scope

- WP7 studies enablers for **increased dependability** and **sustainable coverage**, including **Digital Twins** and **novel HMIs** to enable extreme experiences
- It contributes to the expansion and evolution of the network into new use cases and value chains
- D7.2 contains an overview of intermediate solutions and their relation to other Hexa-X technical enablers and KPIs/KVIs



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Project Name:

A flagship for B5G/6G vision and intelligent fabric of technology enablers connecting human, physical, and digital worlds

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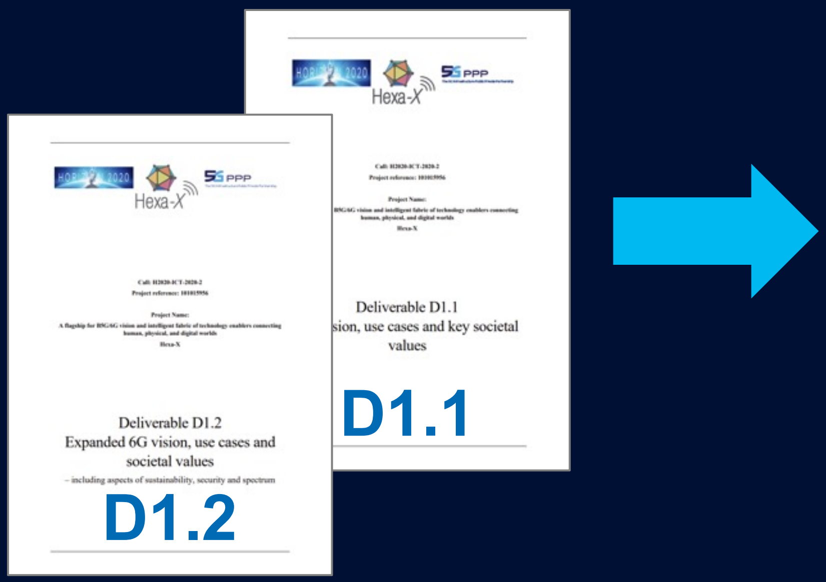
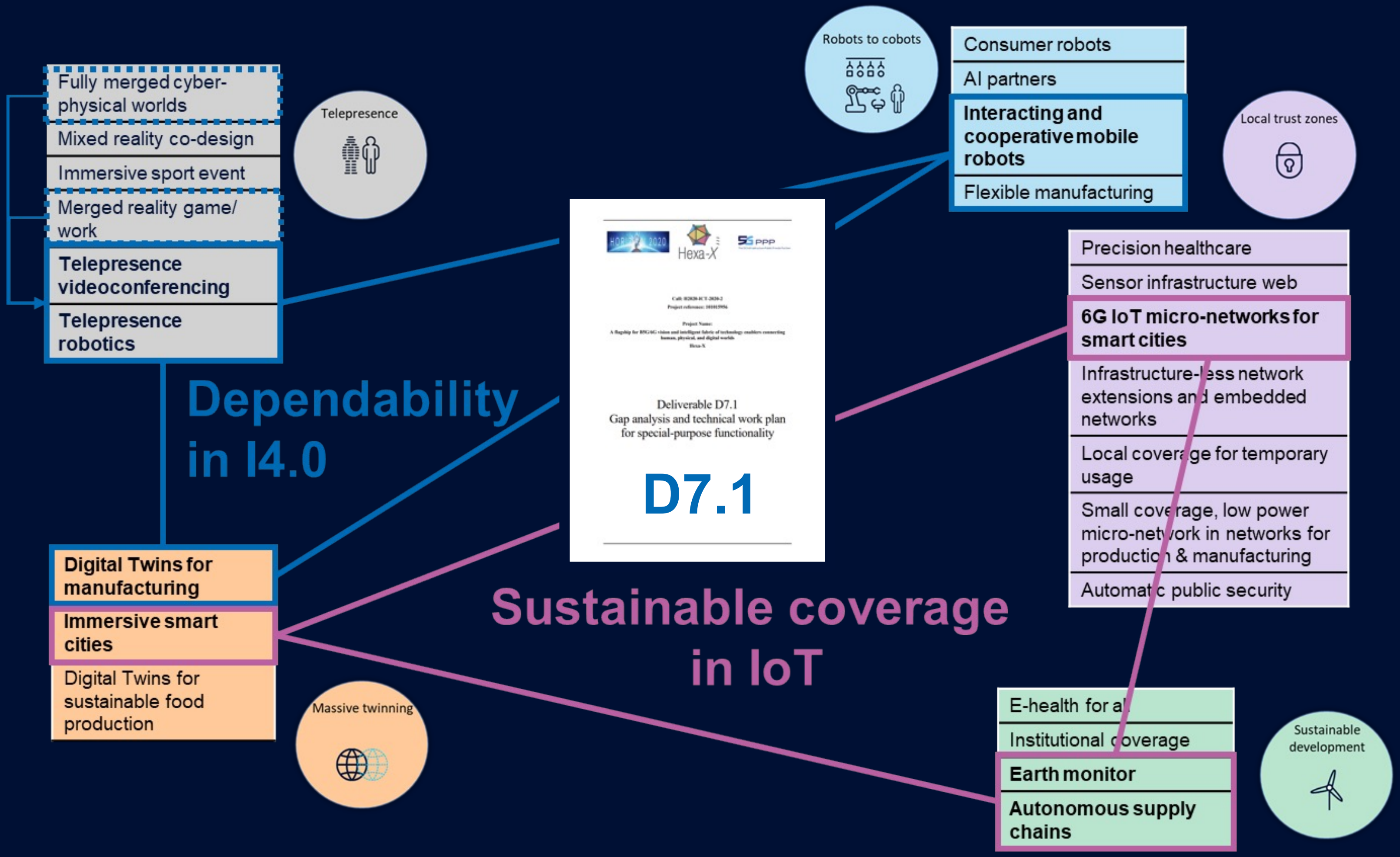
Deliverable D7.2

Special-purpose functionalities: intermediate solutions

Identification of key use cases for extreme experiences
(Recap of D7.1)

- Analysis of Hexa-X use cases
- Sharpened requirements (KPI and KVI definitions and target values in use cases)





Focus on dependability and sustainable coverage

(Recap of D7.1)

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Dependability is the "ability to perform as and when required".
The underlying KPIs serve as an indicator for the Hexa-X key value *trustworthiness*.

Sustainable coverage is the Hexa-X ambition to target spatial coverage and *inclusion* under explicit consideration of *sustainability* aspects and capabilities.

Cost of generated insight

increase in:
- required computational power
- energy consumption
- hardware production/distribution

Value of generated insight

reduction in:
- overall energy consumption
- environmental pollution
- electronic waste
- EMF exposure
- unnecessary behavior (e.g., traffic)

Flexibility - Ability to adapt to changing tasks related to sustainable coverage

- cost (monetary and resources) associated change
- grade of re-use of components

Three focus topics for special-purpose functionality

(Recap of D7.1)

Ultra-flexible resource allocation

Ultra-flexible resource allocation procedures in **challenging environments** such as those populated by mobile devices with special requirements and in need of coverage.

Dependability in I4.0

Mechanisms and enablers for **high dependability** in vertical scenarios, enabling efficient resource support of complex and dynamically changing availability requirements.

HMIs and digital twins

Convergence of the biological, digital and physical worlds with human interaction through **novel HMI** concepts and a **privacy-preserving high-availability Digital Twin**.

Intermediate solutions

Overview of technical contributions discussed in D7.2

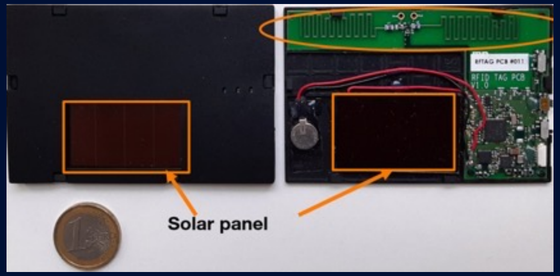
Enablers for ultra-flexible resource allocation

Network enablers in focus

WP5 In-Machine communication (NW-in-NW) in factories

WP5 Flexible functional split adaptation in factories

Crowd-detectable zero-energy devices for smart tracking



Dependability in I4.0

Sustainable coverage in IoT

Applications in focus

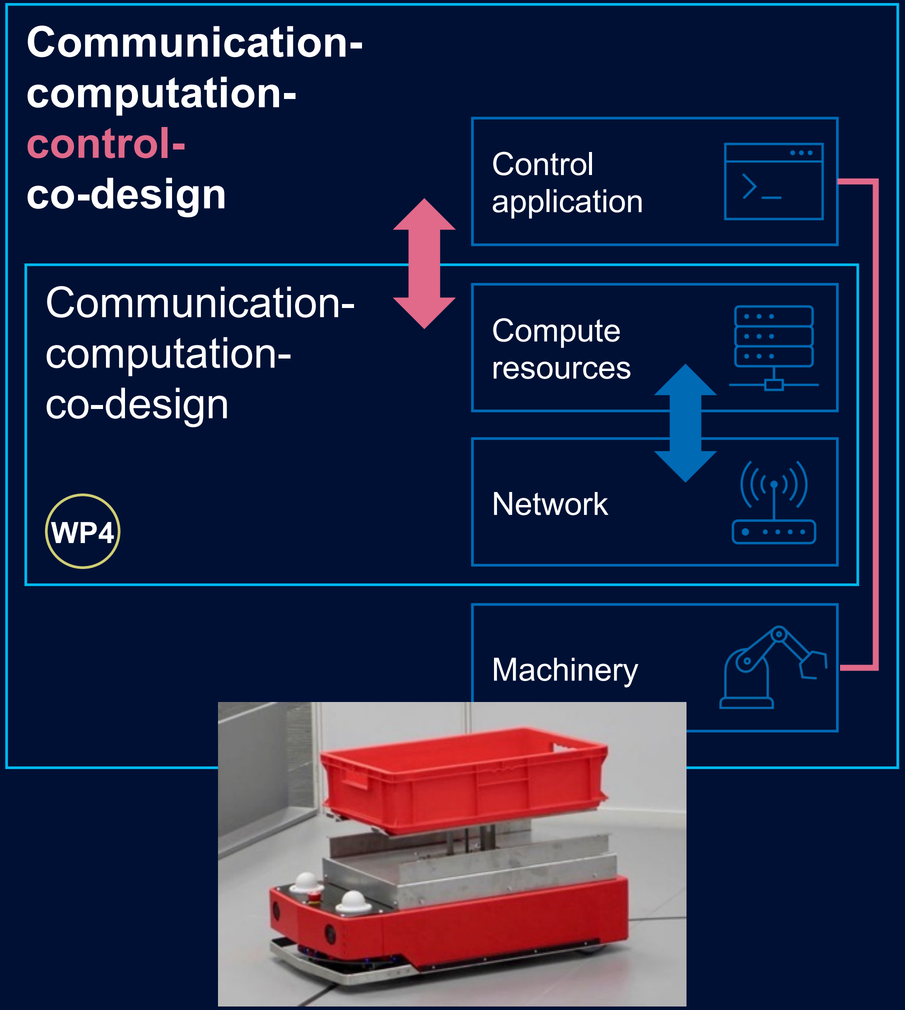
Radio-aware trajectory planning in factories, flexible radio mapping

Resource allocation and function (re-)distribution in factories

Resource provisioning for Federated Learning in IoT WP4

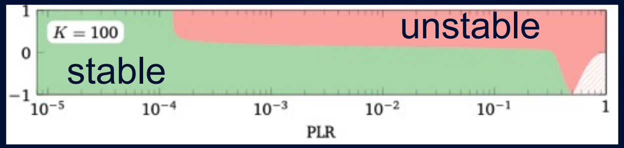
Enablers for dependability in I4.0

CoCoCo: understanding and modeling the impact of real-world constraints on applications



Focus topics

Impact of temporal correlation of packet losses on industrial control applications

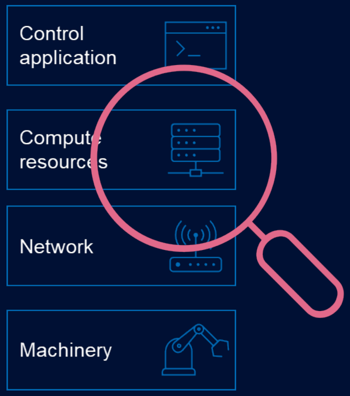


Cross-domain reliability modeling, demonstrated with inverted pendulum example

Development of method for best trade-off between sum-rate, power, delay and EMF exposure in computational offloading scenarios

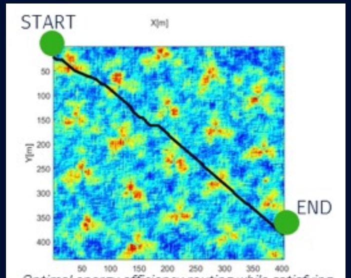
Enablers for dependability in I4.0

Quantifying and monitoring dependability, error identification



- Capture application, network, and infrastructure events
- Estimate impact on application productivity (→ CoCoCo)
- Utilize resource allocation strategies to mitigate failures

Increasing dependability with digital twins (c.f. WPO 7.4)

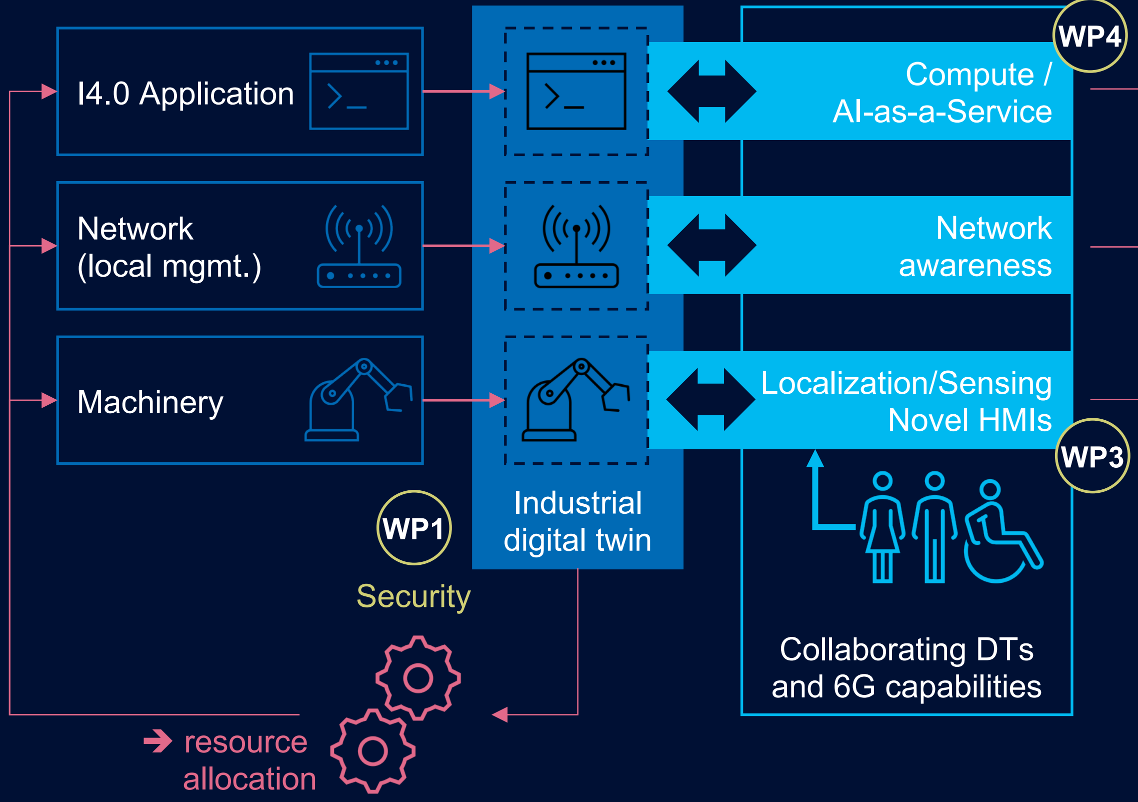


Optimal energy efficiency routing while satisfying minimum throughput constraint

- Incorporate BS/UE capabilities in models
- Properties of transmitting nodes (trajectories, positions)
- Create and maintain radio environment maps

HMIs and digital twins

Ecosystem of collaborating DTs in human-centric industrial environments

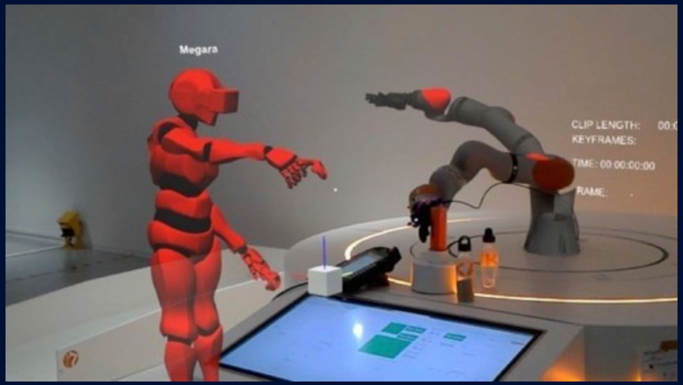


Focus topics

DT empowered collaborative robots
DTs for emergent intelligence

Impact of human presence on industrial deployments
Network-aware DTs for local insights

Novel HMIs for mobile human-machine interaction
Bringing the human in the loop



Relation to 6G KPIs/KVIs and technical enablers

Relation to targeted KPIs
(based on definitions in D1.3)

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		KPI	Contributions
Communication	Dependability	Availability	Understand and model the impact of packet losses etc. on application performance with Communication(-Computation)-Control-Codesign (4.1), with the goal to achieve high application productivity Quantification of end-to-end dependability (4.5) *refers to section in D7.2* *All contributions mentioned under "Quality of Service (QoS) Attributes"*
		Reliability	
		Safety	*No dedicated contributions*
		Integrity	
		Maintainability	Observability with dependability monitoring (4.5) Mechanisms for error identification (4.2)
	QoS Attributes	Service latency	Deterministic latency with control and data plane guarantees (4.5)
		Data rate	Increasing the efficiency of Radio Resource Management (RRM) with Digital Twin (4.4) Dependability in Massive MIMO (4.3) Utilizing ambient backscatter communications for resource constrained devices (3.5) Interference management (3.1)
		Resource constraints	
		Scalability	

Localization and Sensing	Utilization of location information in digital twins for more efficient resource utilization (3.2, 4.4). Modelling the impact of human presence, potentially augmented by 6G sensing capabilities (5.3). Selected aspects studied in collaboration with WP3 as described in [Hexa-X D3.1], Section 5.

Relation to targeted KPIs (cont'd)

(based on definitions in D1.3)

		KPI	Contributions
AI and computation	Dependability	Agent availability	Inclusion of "Computation" in Communication-Control-Codesign (CoCoCo) (4.1) Resource provisioning for Federated Learning in IoT (3.4)
		Agent reliability	
		Safety	*No dedicated contributions*
		Integrity	*No dedicated contributions*
		Maintainability	Observability with dependability monitoring (4.5) Mechanisms for error identification (4.2)
	QoS Attributes	AI service RTT	Optimal resource allocation and redistribution (3.3) Resource provisioning for Federated Learning in IoT (3.4) Communication-Computation-Control-Codesign (4.1)
		Inferencing accuracy	*No dedicated contributions*
		Interpretability level	
		Training/model transfer latency	Optimal resource allocation and redistribution (3.3) Resource provisioning for Federated Learning in IoT (3.4) Digital Twins for Emergent Intelligence (5.7)
		Resource constraints	
		Scalability	

Relation to targeted KVIs
(based on definitions in D1.3)

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KVI area	Contribution	Remarks
Sustainability	Ambient backscatter communication (3.5)	Novel zero-energy devices for massive IoT scenarios (e.g., earth monitor)
	Efficient ressource allocation (Sec. 3)	Efficient utilization of infrastructure, adapted to current load and conditions (c.f. flexibility KVI)
Trustworthiness	Dependability-related contributions (Sec. 4)	Increased and observable/quantifiable dependability is expected to contribute to the overall level of trust as an indicator of trustworthiness [Hexa-X D1.3]
	Trustworthy Digital Twin platform (5.1, 5.6, 5.7)	Privacy-preserving collaboration among digital twins, benefiting from novel 6G capabilities (e.g., localization, sensing)
Inclusiveness	Novel HMIs (5.2) and interaction with Digital Twins (5.4, 5.5)	Enable remote interaction, enable inclusion of a more diverse (remote/on-site) workforce. Reduced human exposure to hazardous/dangerous situations.
Flexibility	Flexible resource allocation (Sec. 3)	Mechanisms to adapt to changing requirements, mobility, device constraints, …

Relation to technical enablers
(based on definitions in D1.3)

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based on D1.3 *refers to Hexa-X deliverables*

Area	Enabler	Details	Activity in WP7
RAN	High data rate radio links	D2.1, D2.2	Observe performance bounds and constraints
	Distributed large MIMO	D2.2	Contributing with dependability in distributed massive MIMO (Sec. 4.3)
	Localization and sensing	D3.1	Formulate requirements and observe performance bounds and constraints, especially regarding utilization in the digital twin (Sec. 4.4., 5.3, 5.6)
Intelligent network	UE and network programmability	D5.1	UEs not yet explicitly considered - can be an enabler for novel HMI functionality or retrofitting.
	Network automation	D5.1	C.f. continuum management and orchestration.
	AI and AI as a Service	D5.1, D4.1	Special-purpose case of federated learning in IoT (Sec. 3.4), AI and Emergent Intelligence in digital twins (Sec. 5.7)
	Dynamic function placement	D5.1	Utilized as enabler for resource allocation in challenging environments (Sec. 3), impact on dependability (e.g., Sec. 4.5)

Relation to technical enablers (cont'd)

(based on definitions in D1.3)

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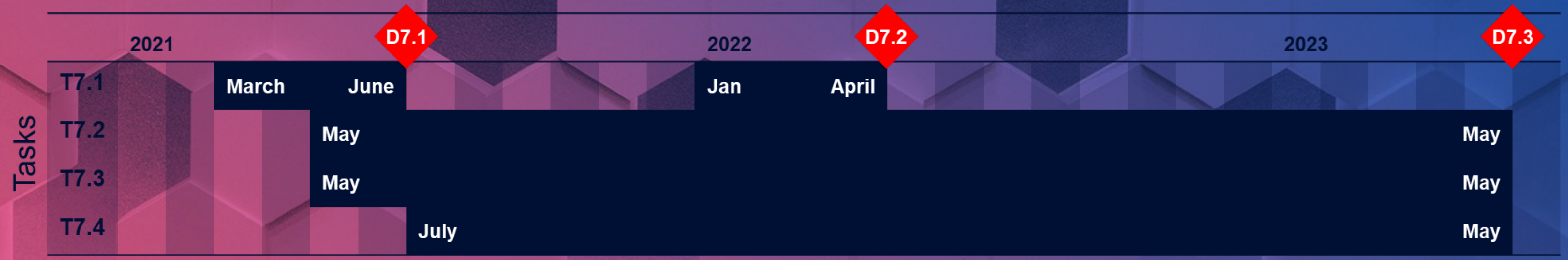
Area	Enabler	Details	Activity in WP7
Flexible network	Mobility solutions	D5.1	HetNet approach, considered for In-X networks in factory environments (Sec. 3.1) and works on D-MIMO (Sec. 4.3)
	Campus network	D5.1	Capability exposure and mutual benefit with collaborating digital twins (Sec. 5.6), utilization of CoCoCo (Sec. 4.1), compute resource allocation strategies (Sec. 3)
	Mesh / Device-to-Device	D5.1	In-X networks in factories (Sec. 3.1)
	Edge cloud integration	D5.1	Enabler for most resource allocation strategies (Sec. 3) and local placement of functions in low-latency and high-dependability scenarios
Efficient network	Cloud and service-based architecture	D5.1	Reduced dependencies between network functions enables more flexible placement and, thereby, adaptation to latency requirements. Relevant for industrial scenarios with increased dependability requirements (Sec. 5.6)
	Compute-as-a-Service	D5.1	Availability of (trustworthy) compute capabilities for the execution of digital twins (Sec. 5). Can be enriched with allocation strategies, e.g., for federated learning in IoT scenarios (Sec. 3.4)
Service management	Continuum management and orchestration	D6.1	Formulation of an ecosystem of digital twins to allow cross-domain optimization and collaboration in a privacy-preserving fashion (Sec. 5). Enabler for resource allocation, e.g., in In-X networks and networks-of-networks (Sec. 3.1)
	AI-driven orchestration	D6.1	Exposure of local (domain-)knowledge through network-aware collaborating digital twins to aid in overall resource coordination and management (Sec. 4.4, 5.6)

Outlook

- Technical work in WP7 is continuing along the topics outlined in D7.2
- Cross-WP alignment especially with WP1 and WP5 on e2e architecture
- Final project results will be reported in D7.3 (May 2023)
- Including results on the demonstrator / PoC



Thank you!

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