International collaboration in 6G

Research and Innovation   Japan – The Netherlands

October 17th , 2024

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V1.2

Introduction to the Netherlands

- Trends and challenges
- Netherlands 6G program
- Testbed and technology roadmap
- International collaboration

Recent technology trends Netherlands

Focusing on challenges related to 5G deployment and advances in 6G

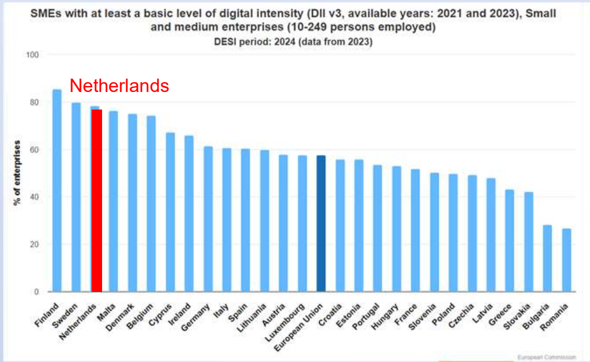
Netherlands 3 operators – top quality networks - Umlaut – despite late 3.5GHz

- Very high mobile network penetration: 99,6% built-up area covered, 99,9% of population covered
- High digital adoption in different parts of society (government, finance, etc.) – shown in DESI index

5G diversification and usage of features (like URLL) is still behind and monetisation is disappointing despite various attempts (various field labs)

6G research – large public private partnership – full national ecosystem involved - scope 6 years – EU alignment in development

- Leverage strong NL position in semicon



National 6G R&I program the Netherlands Future Network Services (FNS)

6G ecosystems and offering	Academia & RTO	SME	Large enterprise	Government & Public sector
Ecosystem support	Do IoT Fieldlab; TNO innovation for life; ICCS innovation center connected solutions; Hanzehogeschool Marian van Os Centre of Expertise Ondernemen	BTG; ECP Platform voor de InformatieSamenleving	ROM oost nl; ttt Thematische Technologie Transfer; Platform Talent voor Technologie	Ministerie van Economische Zaken; TOPSECTOR ICT
Applications	TNO innovation for life	PWXR; CORDIS SUITE; fectar; Future Mobility Network; COMFOREST; Drone Delivery Services	kpn; Odido; Ericsson; Philips; Vialis; ASML; alliander; Nokia; TenneT; Gomibo Platforms; Schiphol	Gemeente Amsterdam; Port of Rotterdam; Gemeente Rotterdam; provinsje fryslân provincie fryslân; provincie Drenthe; provincie groningen
Network intelligence & software	TU Delft; TNO innovation for life; SURF; VU Vrije Universiteit Amsterdam; University of Twente; Universiteit van Amsterdam	Solvinity Secure Managed IT Services; almende; is-wireless	vodafone; Ziggo; kpn; amsix; NVIDIA; Keysight; Nokia; Ericsson	
Chipset & hardware components	TU/e Eindhoven University of Technology; imec; TNO innovation for life; Chalmers; TU Delft; ASTRON; CITC	ANTENNEX; PRODRIVE Technologies; robin radar systems; ALTUM RF; ANTENNA Company; VTEC Lasers & Sensors; AIRCISION	NXP; Signify; sabic; AMPLEON; Ericsson; Bosch	

€315 million National 6G program 2024-2030

- €203 million Subsidies National Growth Fund
- €112 million Co-Financing by private partners

Program includes €90 million Open Calls

Start program 1 January 2024

Overall program coordination by TNO – National research institute

Netherlands international semicon ecosystem is key driver of the program

Consortium of 60 partners incl. companies like ASML, NXP, Ampleon, Philips and many others

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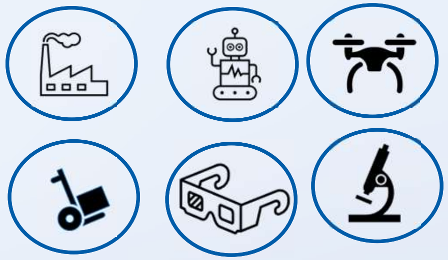
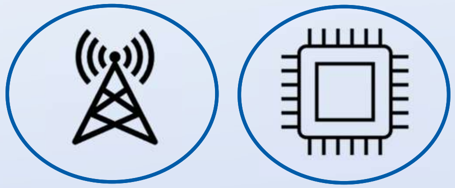
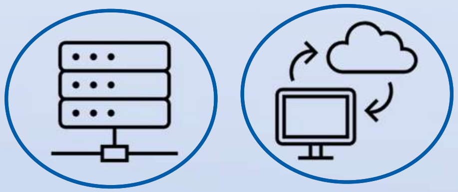
6G trends and Netherlands focus areas FNS R&I



1. 6G will be the enabler of new applications
   - FNS focus: Work with leaders in various application areas - important to understand future requirements to create value with 6G



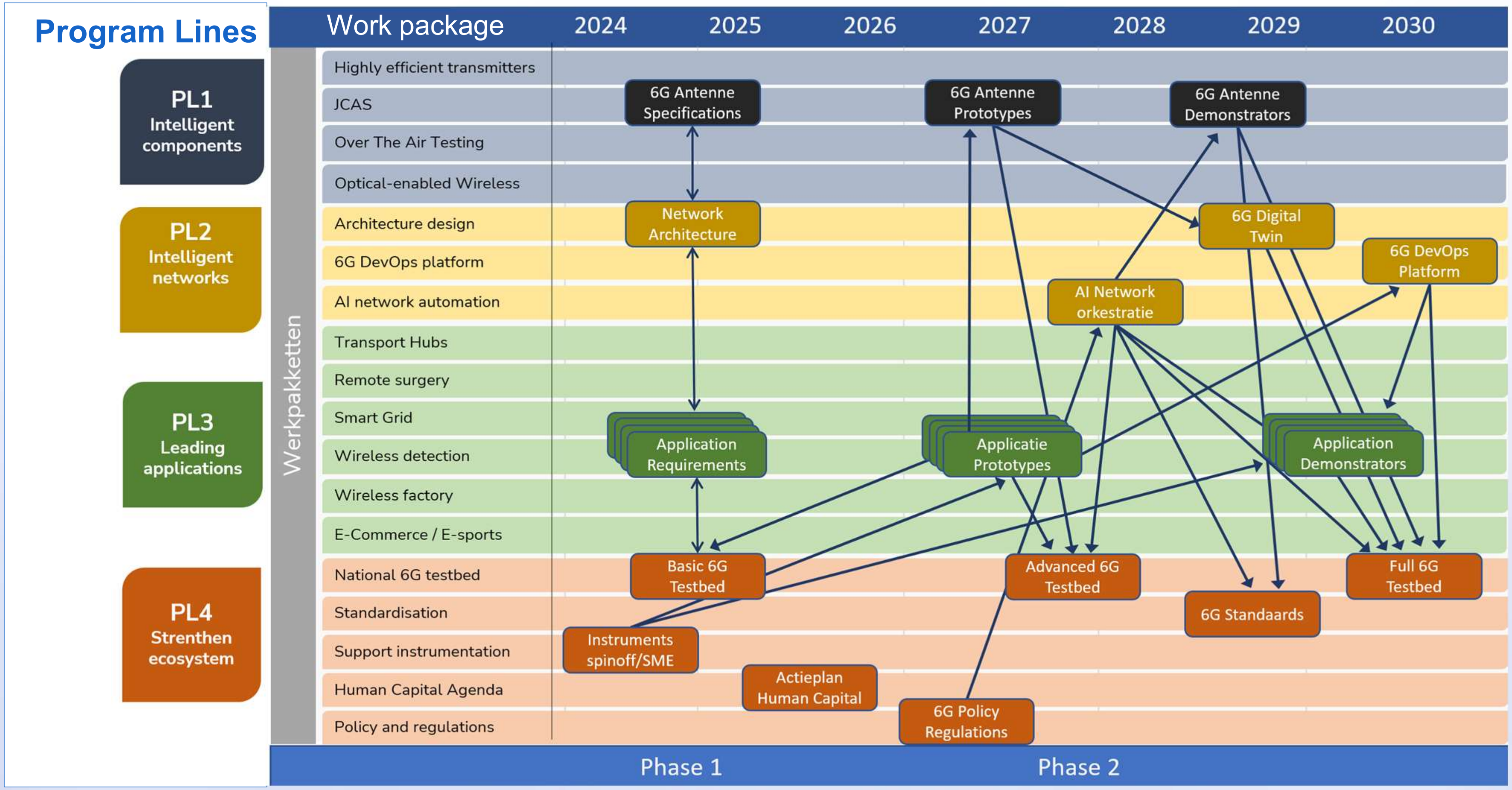
2. 6G will move to higher frequencies, MIMO antennas, more efficient amplifiers, transmitters and receivers to support array antennas
   - FNS focus: Research on Integrated Circuits / packaging - focus on RAN aspects - operate with frequencies above 6 GHz



3. 6G will be a Cloud & AI native network
   - FNS focus: Cloud native architecture, disaggregation (Open RAN), AI based orchestration, DevOps, Digital twin

Three main focus area's in one integrated and aligned program

Program Lines and Work Packages alignment FNS



Simplified overview of deliverables in time and relation between activities

Netherlands 6G testbed

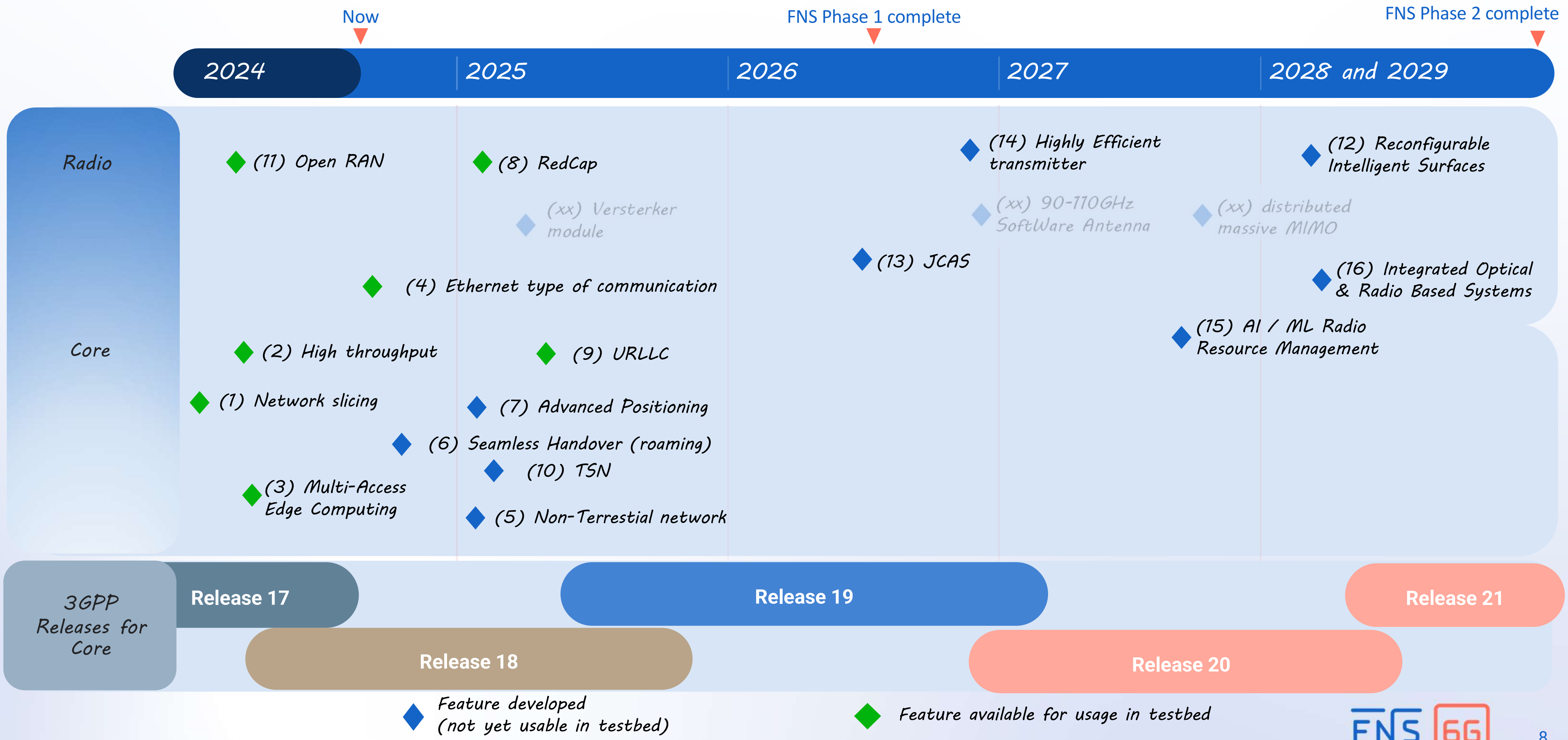
We're building the premier 6G testbed in the Netherlands, connected to other European testbeds, with a deeply committed ecosystem of partners who view the endeavour as integral to their business success.

Cutting-edge 6G testbed
- ✓ Central 6G core at TNO in The Hague.
- ✓ Field labs connected throughout the Netherlands.
- ✓ Based on flexible, open source solutions.

Stimulating innovation
- ✓ Eight signature use cases with companies.
- ✓ Supporting SMEs to test their use cases.
- ✓ Capacity building and knowledge exchange among field labs.

6G roadmap
- ✓ A fully integrated roadmap incorporating technologies developed in FNS aligned with 6G standardisation.

Technology Roadmap – Overview Features Testbed



Focus areas for international collaboration

1. Testbed
   - Investigate testbed concepts to see if collaboration can add value
   - Explore initiatives to cooperation (use cases, joint projects)

2. Establish joint view on leading applications for 6G
   - Knowledge sharing

3. International academic collaboration

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International (academic) collaboration - opportunities

- **Knowledge Exchange:** Discover the latest advancements and breakthroughs in 6G technology through the exchange of cutting-edge developments within each project.
- **Identifying Synergies:** Explore opportunities for synergy between FNS and XGMF, recognizing areas of complementarity and convergence to drive joint endeavors.
- **Networking:** Connect with fellow researchers and industry stakeholders to forge partnerships and collaborations.

First ideas for next steps in collaboration (open for discussion):

- Organize an NL-JP online conference to share 6G research area's (incl. ongoing PhD studies) as an introduction to find area's for cooperation which could be materialized in Postdoc of PhD exchanges
- International student hosting (Master, PhD – defined period, relevant research topic related to 6G or internship)
- Follow-up during international 6G research conference participation
- Follow-up during NL trade and Innovation mission Osaka World Expo (NL 6G delegation May 2025)
- For NL we can create funding in the phase 2 of the 6G research program (open calls as of Q3 2026) and/or we can jointly apply for other calls or funding instruments

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Background information

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https://futurenetworkservices.nl/en/

Netherlands 6G Program and Partners involved

PL1 Intelligent components

TU/e Eindhoven University of Technology, NXP, Ampleon, ItoM, TU Delft, Ericsson, TNO innovation for life, CITC Chip Integration Technology Center, imec, Altum RF, Signify, Antenna Company, vodafone Ziggo, Chalmers University of Technology, University of Twente, Antennex, Astron, Aircision empowering connectivity, robin radar systems, VTEC Lasers & Sensors, kpn, sabic Specialties, Prodrive Technologies

PL2 Intelligent networks

TU Delft, TNO innovation for life, SURF, NVIDIA, Nokia, TU/e Eindhoven University of Technology, Solvinity Secure Managed IT Services, Ericsson, amsix, kpn, vodafone Ziggo, Universiteit van Amsterdam, VU Vrije Universiteit Amsterdam, University of Twente, Keysight, almende organizing networks, is-wireless

PL4 Strengthen ecosystem

TU Delft, Do IoT Fieldlab, Topsector ICT dutch digital, oost nl, BTG, human capital agenda connect and create, Nokia, ECP Platform voor de InformatieSamenleving, ICCS innovation center connected solutions, kpn, Rijksinspectie Digitale Infrastructuur Ministerie van Economische Zaken en Klimaat, University of Twente, SURF, Ericsson, Ministerie van Economische Zaken en Klimaat, Thematic Technology Transfer ttt, Platform Talent voor Technologie, TNO innovation for life, Hanzehogeschool Groningen University of Applied Sciences

PL3 Leading applications

Drone Delivery Services fast, safe & smart, Philips, Vialis, ASML, robin radar systems, Cordis Suite, Future Mobility Network, Utility Connect, Ericsson, Gomibo Platforms, Gemeente Amsterdam, Port of Rotterdam, Comforest, TNO innovation for life, provincie groningen, kpn, provinsje fryslân provincie fryslân, TenneT Taking power further, alliander, TU/e Eindhoven University of Technology, provincie Drenthe, Schiphol, Tectdr, TU Delft, Gemeente Rotterdam, PWXR

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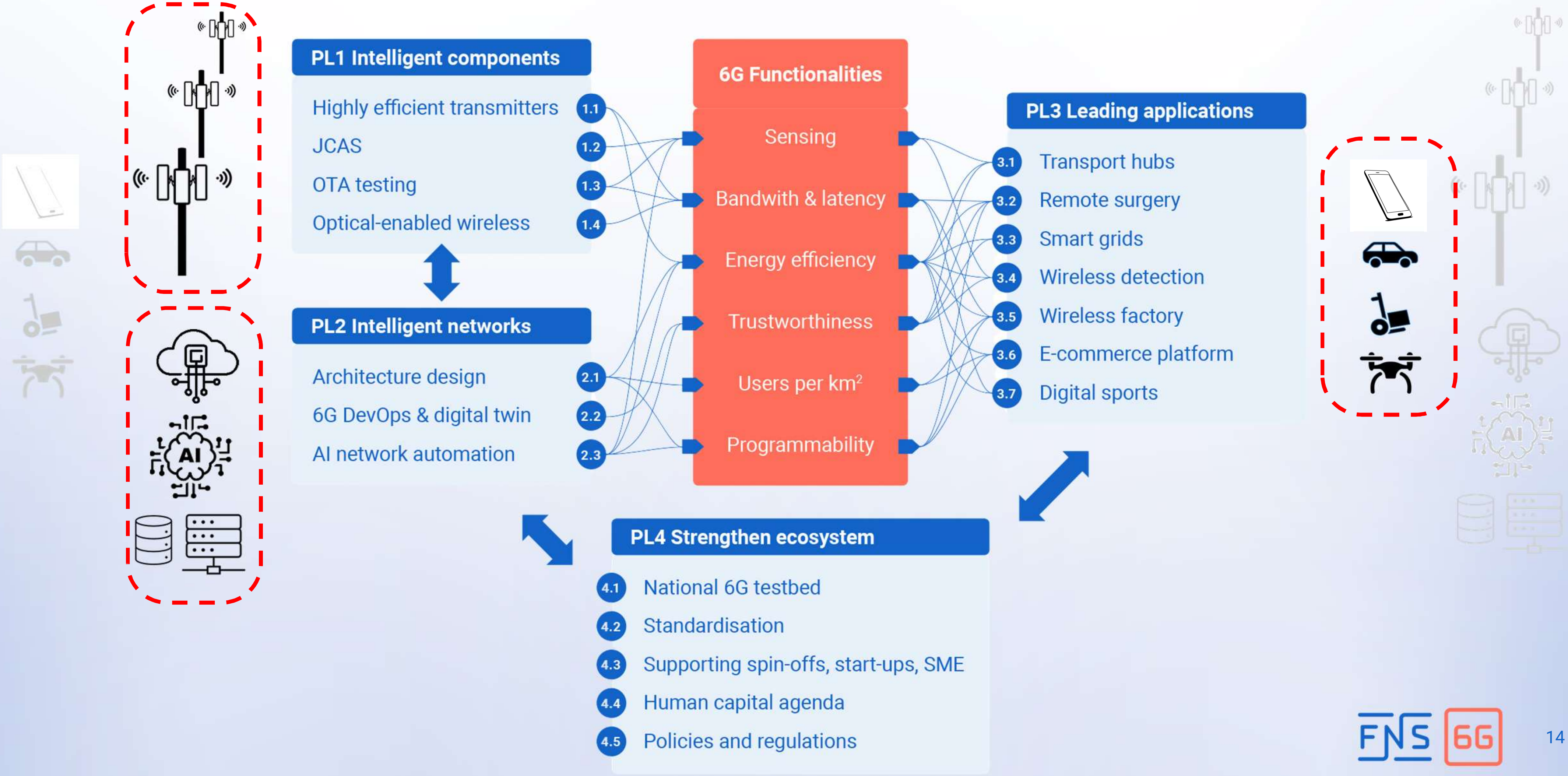
Netherlands 6G Program Lines and Work Packages

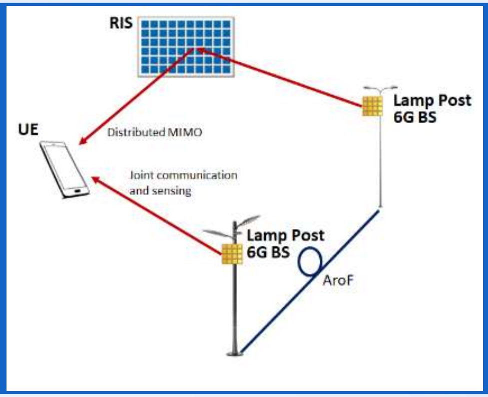


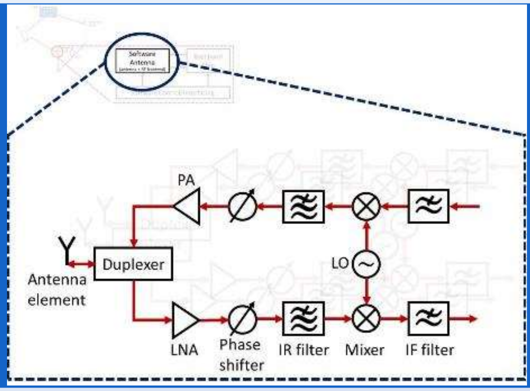
WP1.1 Highly Efficient Transmitters

The aim of this work package is to develop new concepts and further optimize existing semiconductor technologies to realize electronic chips (Integrated Circuits) and apply them in software antennas that can generate highly efficient electromagnetic power for 5G and 6G systems that operate with frequencies above 6 GHz.

What are Highly Efficient Transmitters?

Existing transmitter architectures currently simply provide insufficient energy efficiency, resulting in a large part of the supplied energy being converted into heat instead of electromagnetic energy that is emitted. Major gains can be achieved here by moving to novel mixed signal transmitter architectures implemented with a high degree of integration and miniaturization in the software antennas.





Why do we use highly efficient transmitters?

When using frequencies above 6 GHz, an array of a large number of small antennas is used to compensate for the increased propagation loss. Each antenna element is connected to a power amplifier (PA), which means that hundreds to thousands of PAs are required per base station. Achieving very high PA efficiency is crucial in combination with wideband digital architectures, excellent synchronization and thermal management.

Partners: University Eindhoven & Twente, Bosch, Prodrive Technologies, Sabic, TNO CITC & Nano- instruments

WP1.2 Joint Communication and Sensing (JCAS)

WorkPackage 1.2 develops prototypes to support the Joint Communication and Sensing (JCAS) such as hardware components, millimeter wave (mmW) signal synthesis and analysis and resource management.

In WP1.2, 13 partners collaborate on 7 tasks, aiming to deliver approximately 10 prototypes and 10 technical papers.

What is JCAS

The 6G network brings the connected world to the next level by combining communication and sensing in one system.

Applying beamforming in the 6G millimeter wave (mmW) bands enables sensing based on radar technologies.

This provides spatial knowledge of the physical surroundings and localisation of users.

Knowledge of location and surrounding enables series of services including safety features.

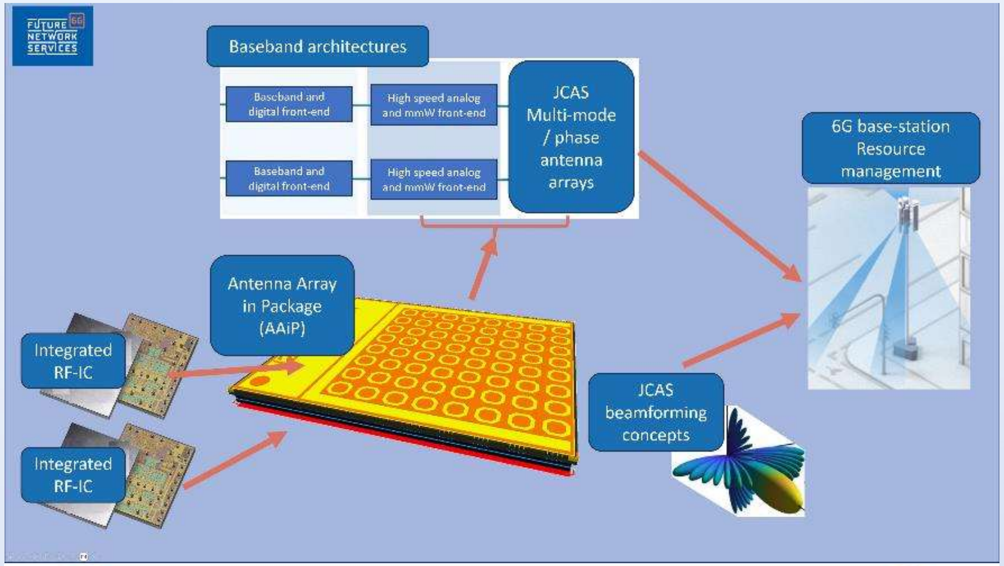
WP1.2 Joint Communication and Sensing (JCAS)

Hardware and architecture development

- Prototyping of efficient mmW integrated circuit RF components.
- Prototyping of Advanced Antenna Arrays in Package (AAiP) required for beamforming applications.
- Advanced baseband architectures supporting high data rates and sensing capabilities in future the 6G networks.

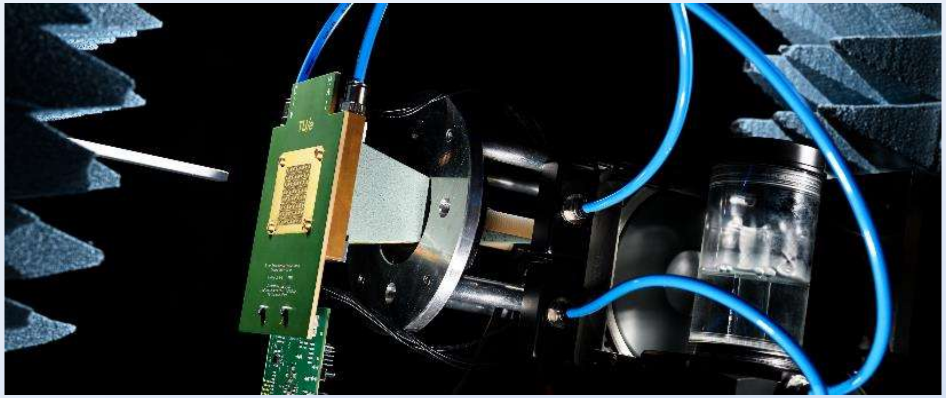
Beamforming and radio management

- Prototyping of dual band and dual mode phased arrays along with the synthesis of beamforming signals.
- Development of software and algorithms to ensure the high-speed data transfer **and** enhance surrounding and location sensing capabilities → received signal analysis.
- Implementation of radio management algorithms and system simulations to optimize the use of the hardware and available frequency resources.



WP1.3 Over-The-Air (OTA) Antenna Testing

6G software antennas behave as 'black boxes', converting bits to electromagnetic waves and vice versa. Unlike 4G and 5G, 6G components lack connectors, challenging testing methods. In response, WP 1.3 aims to address these testing challenges by enhancing OTA testing techniques. Additionally, the work package seeks to improve 6G propagation channel models and coverage by leveraging Reconfigurable Intelligent Surface (RIS) systems



Tasks

The project includes four tasks:

- defining OTA test specs for 6G components;
- devising efficient test strategies for software antennas with millions of settings;
- creating accurate 6G propagation channel models;
- developing RIS structures to enhance coverage.

Partners:

CHALMERS UNIVERSITY OF TECHNOLOGY

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

TU Delft

ANTENNEX

kpn

TNO innovation for life

ERICSSON

Deliverables

The project's deliverables include specifications and prototypes. Specifications will be developed by all partners, while prototypes include an OTA test facility for software antennas, RIS systems, and an upgraded channel sounder for 6G. Demonstrators consist of an OTA test facility and RIS systems for NLOS communication.

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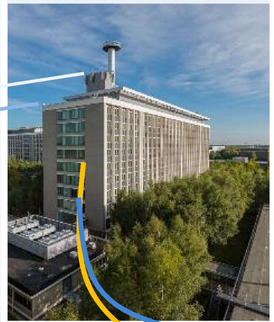
WP1.4 Optical - Enabled Wireless Communication Networks

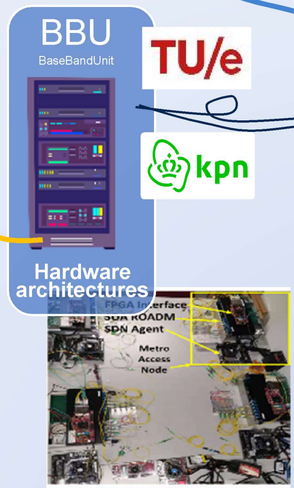
WP 1.4 studies the convergence of light and radio-based systems. Light can be used as an alternative communication concept (optical wireless) that offers interesting possibilities, not only in the network to connect base stations but also in the link to the subscriber.

Backhaul

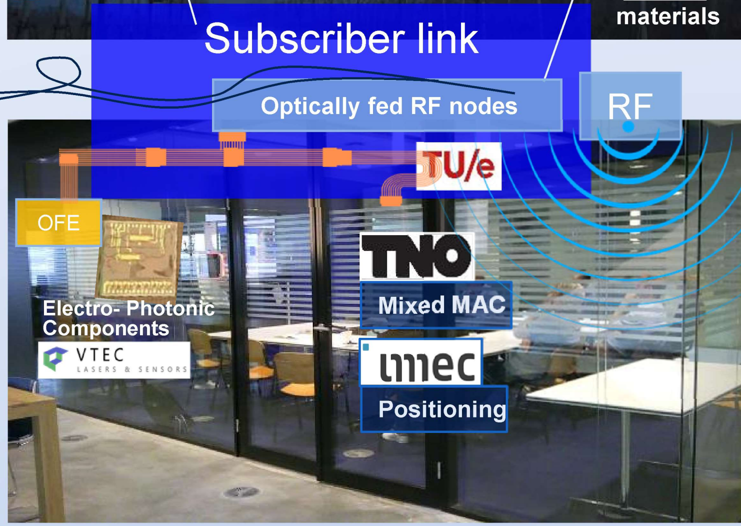


Fronthaul

Optical fronthaul to very dense net of cooperating APs
- over fiber
- wireless



Subscriber link



6G intends to vastly enhance network performance for every user, but also to connect for more devices. This calls for novel approaches in connecting a dense grid of access points, such as analog Radio-over-Fiber and optical links. TU/e and industrial partners smartly combine advanced optical and RF technologies to reach unprecedented rates at high Quality of Service.

Enhancing the performance of devices for 6G mass-market client devices and for the indoor infrastructure

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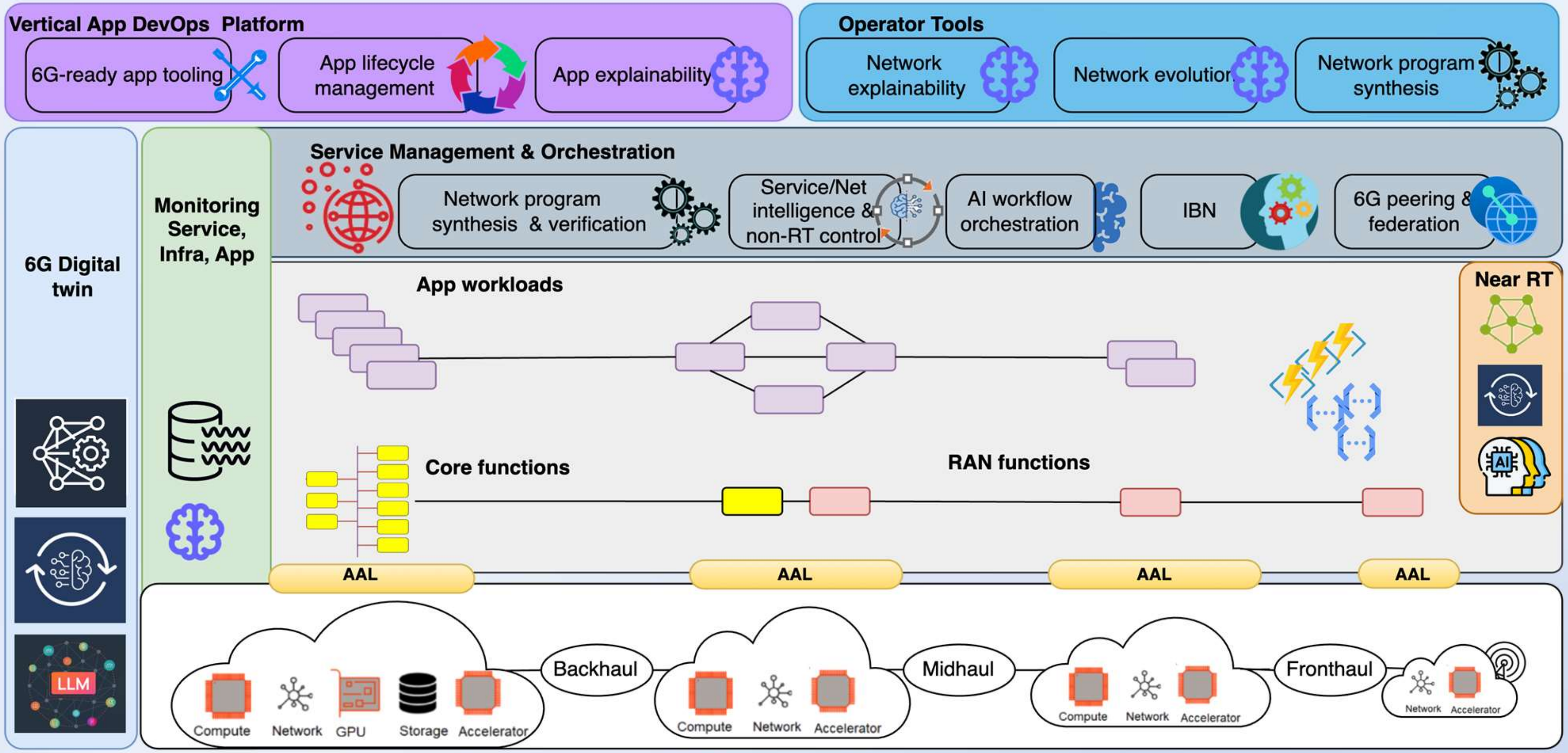
Partners: University Eindhoven, KPN, Signify, Sabic, TNO, IMEC, VTEC

Program Line 2 – Intelligent Networks system overview



Goal: To develop the AI-based algorithms and software modules for efficient and reliable 6G network orchestration and application development.

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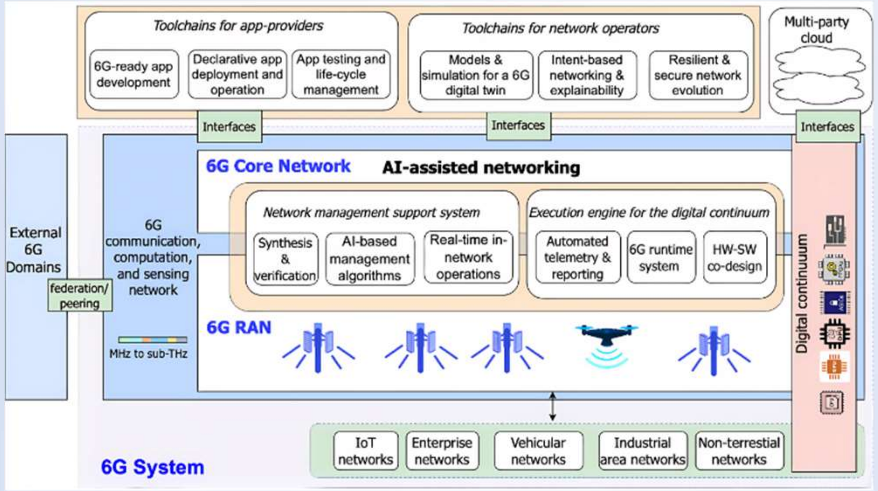
WP2.1 Requirements, architecture & integration

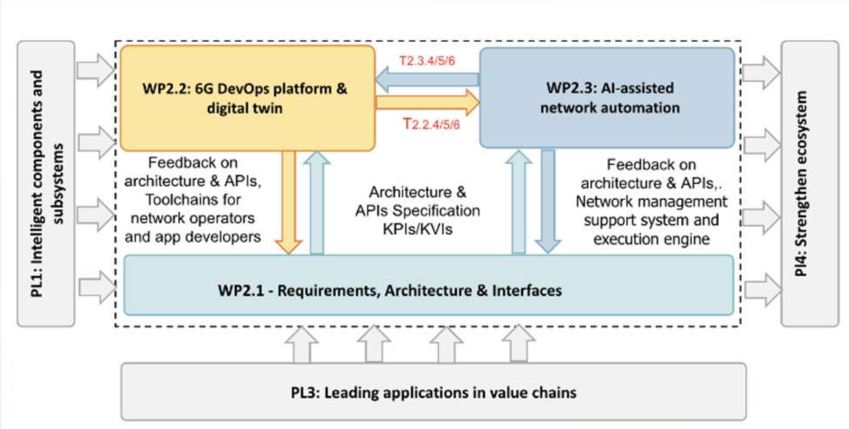
This work package focuses on the research and development of architectural principles, coordination frameworks, and innovative interfaces that provide applications ('agile') access to the underlying network infrastructure and allow realizing system-wide goals such as performance, sustainability and reliability.

Requirements (T2.1.1)

Defining requirements, KVI & KPIs for multi-stakeholder 6G:

- Requirements gathering from PL1 & PL3
- Alignment with international (SDO) ecosystem (PL4)
- Dataset collection & Data-driven requirements analysis





End-to-end architecture and demos (T2.1.2 & T2.1.3)

- Development of a multi-stakeholder end-to-end 6G architecture blueprint based on the T2.1.1 requirements
- Development of holistic coordination mechanisms and integration of demo systems into a demo of demos

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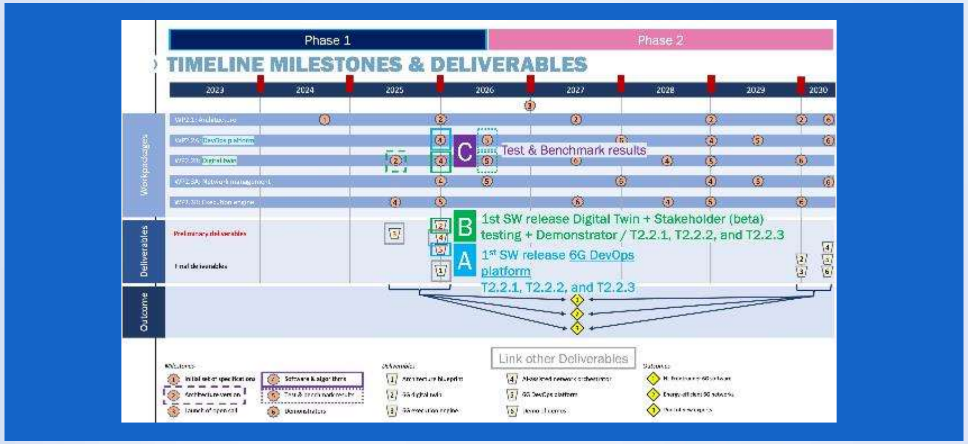
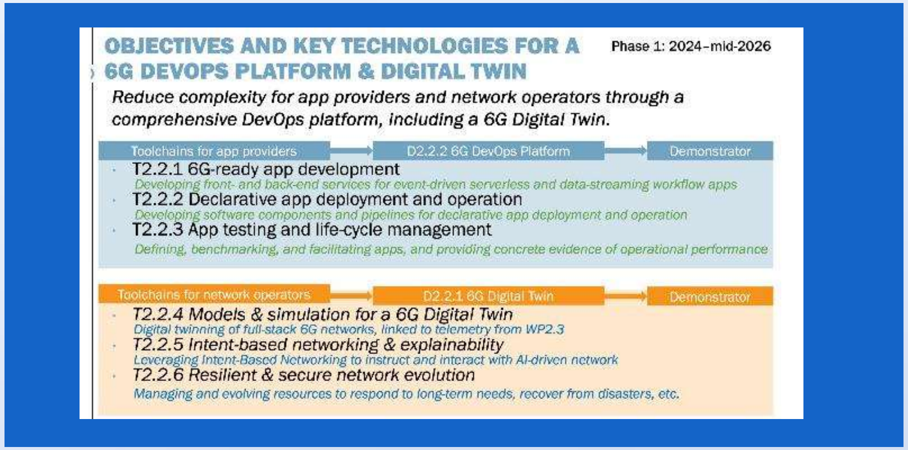
WP2.2 6G DevOps Platform & Digital Twin

This WP will reduce complexity for 6G app providers and network operators through a comprehensive DevOps platform, including a 6G Digital Twin. The WP will contribute to Program Line 2's architecture, and deliver software and algorithms, tested and benchmarked.

DevOps work will develop front- and back-end services for event-driven serverless and data-streaming workflow apps, and software components and pipelines for declarative app deployment and operation. It will also provide operational evidence.

Digital Twinning will cover full-stack 6G networks, linked to telemetry from WP2.3.





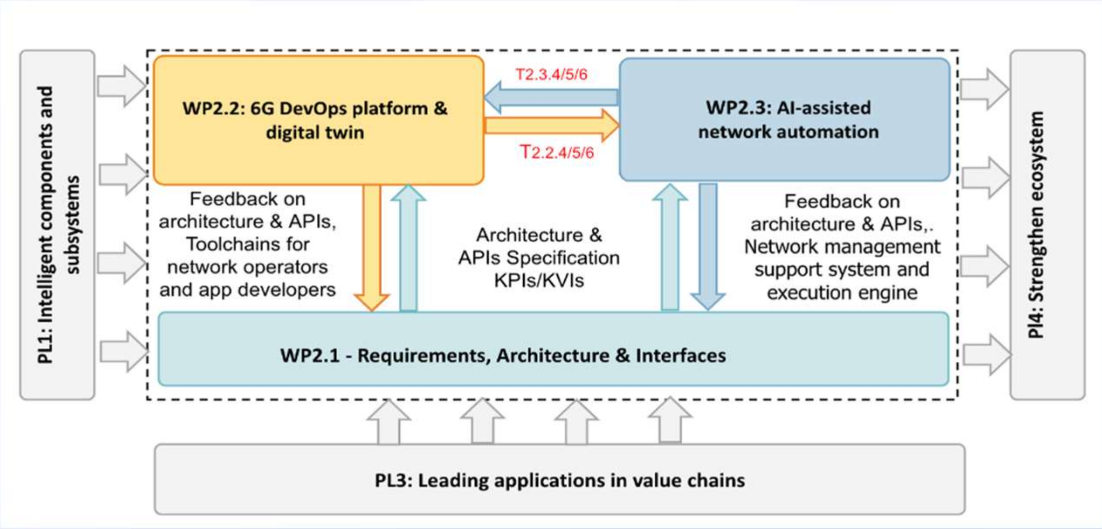
Partners:
VU, Almende, AMS-IX, ISRD, Keysight, KPN, Solvinity, SURF, TNO, TU Delft, TUE, UT, UvA, and VodafoneZiggo

WP2.3 AI-assisted networking

Goal: Design, prototype and demonstrate using PoCs the Orchestration, Management, Control and Data-plane of 6G system

Enable the underlying programmable network and computing infrastructure to operate autonomously, powered by artificial intelligence, ensuring dynamic adaptability to supported vertical applications and operator directives.

Partners:
Ericsson, Nokia, NVIDIA, Vodafone Ziggo, KPN, Solivinity, AMS-IX,SURF, TNO, IS Wireless, Keysight, UVA, TUD, UTWENTE, TU/e and VU



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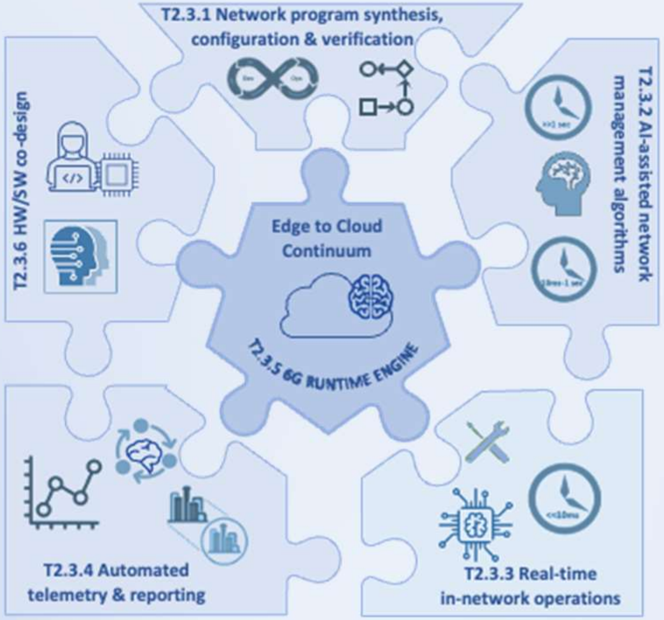

AI-native[1]: *Having intrinsic trustworthy AI capabilities, where AI is a natural part of the functionality, in terms of design, deployment, operation, and maintenance.*

Cloud-native[2]**:** *Cloud native is an approach to building and running network services that exploits the advantages of the cloud computing delivery mode, for improving the scalability, agility, and resilience of the telecom network.*

Deep Network Programmability[3]**:** *the ability to program the network fabric both vertically (control and data plane) and horizontally (end to end)*

Network Disaggregation, Reducing Complexity etc.

[1]Ericsson. *Defining AI native: A key enabler for advanced intelligent telecom networks*, White Paper 2023
[2]VMware. *Cloud Native Applications: Ship Faster, REDUCE Risk, and Grow Your Business*, Technical Report, 2022
[3]Foster N, McKeown N, Rexford J, Parulkar G, Peterson L, Sunay O. *Using deep programmability to put network owners in control*. ACM SIGCOMM Computer Communication Review. 2020

Program Line 3: Leading applications

Netherlands academic landscape for 6G

UNIVERSITEIT VAN AMSTERDAM

VU VRIJE UNIVERSITEIT AMSTERDAM

TU Delft

UNIVERSITY OF TWENTE.

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Universities involved in 6G FNS program (in the Netherlands)	Department	Description	Professor(s) involved in 6G FNS program	Area of expertise in relation to FNS 6G pogram (list of keywords)
Eindhoven University of Technology	Electrical Engineering	TU/e is a technical university at the heart of Brainport and focusses on Semiconductor technologies and applications	**Bart Smolders (Lead professor for FNS program)**	Active Array Antennas, over-the-air-testing, antenna metrology
			Peter Baltus	RFIC design
			Nicola Callabretti	Optical networking
			Ulf Johannsen	Integrated antennas for radar and space applications
			Jean-Paul Linnartz	Wireless networks and free-space optics
			Eduward Tangiongga	Optical networks and free-space optiscs
			George Exarchakos	Wireless networks
			Kishor Joshi	Wirelesss networks
			Marion Matters	Sub-THz RFIC design
			Ad Reniers	Antenna metrology
			Gabriele Federico	Active Array Antennas
			Robbert Schulpen	Wireless propagation channels, Channel sounder
			Elmine Meijer	Filters
Delft University of Technology	Electrical Engineering, Mathematics and Computer Science	The Delft University of Technology (TU Delft) is the oldest and largest Dutch public technical university. It specializes in engineering, technology, computing, design, and natural sciences.	**Fernando Kuipers (Lead professor for FNS program)**	Programmable networks, cellular networks, network resilience, Quality-of-Service, telemetry, network optimization, Internet-of-Things
			Nitinder Mohan	Edge computing, next-generation network protocols, Internet-wide measurements, critical application managment/deployment
			Georgios Smaragdakis	Cyber security
			Sebastijan Dumancic	Program synthesis, probabilistic programming
			Georgios Iosifidis	AI/ML, (meta)heuristics and approximation algorithms for resource allocation and network optimization
			Sebastian Proksch	Software engineering
			Olexander Yarovyi	microwave systems, radar
			Leo de Vreede	RF, Microwave, Power Amplifiers, Device Characterization & modeling
			Andrea Neto	Applied electromagnetics, THz broadband imaging systems, antennas
			Peter Palensky	Power systems, power engineering, smart grids
VU Amsterdam	Faculty of Science	VU Amsterdam is a unique university with faculties in the humanities, STEM, social sciences and medical sciences.	**Alexandru Iosup (Lead professor for FNS program)**	Cloud-edge continuum; design, development, deployment, and analysis of distributed systems; performance, availability, sustainability, and other non-functional system properties; resource management and scheduling; operational techniques; digital twins; Open Science; data archives
			Tiziano De Matteis	High-Performance Computing (HPC); High-Throughput Computing (HTC); co-design hardware and software; parallel communication; stream processing; accelerated computing (GPU, FPGA, TPU, DPU, etc.); performance measurement; large-scale experimentation
			Jesse Donkervliet	Digital twins; design, development, deployment, and analysis of distributed systems; scalability, consistency, other non-functional system properties; large-scale experimentation; metaverse; online gaming systems
			Daniele Bonetta	Language runtimes (e.g., Java Virtual Machines, JavaScript, etc.); optimization; virtualization; containerization; container-image registries; performance, scalability, and other non-functional system properties; measurement; experimentation
University of Amsterdam	Faculty of Science	The University of Amsterdam is ambitious, creative and committed: a leader in international science and a partner in innovation, the UvA has been inspiring generations since 1632.	**Chrysa Papagianni (Lead professor for FNS program)**	Network programability, intelligent network orchestration and management - AI/ML, (meta)heuristics and approximation algorithms for resource allocation and network optimizations, network control, network telemetry, network federation, xG system architectures - MANO and protocols.
			Paola Grosso	Network architectures, network protocols, network programmability, n intent-based networking, (in-host) network security, quantum networking, control planes
			Marios Avgeris	Control-theoretic and reinforcement learning-based optimization for virtualized networks
			Adam Belloum	Distributed systems, federated learning for data privacy, and cloud stack
			Thomas van Binsbergen	Design, formalisation and implementation of software languages and domain-specific languages
University of Twente	Electrical Engineering, Mathematics and Computer Science	The University of Twente is a public technical university located in Enschede, Netherlands.	**Geert Heijenk (Lead professor for FNS program)**	Wireless Networks, Vehicular Networking, Internet Technology & Protocols
			Suzan Bayhan	Wireless Networks, Optimization, Spectrum sharing
			Hans van den Berg	Wireless Network Performance
			Ana-Lucia Varbanescu	Performance Engineering, Compute Continuum
			Alex Chiumento	Distributed Intelligence
			Yanqiu Huang	IoT, in-network processing
			Jeroen Klein Brinke	Wireless networks and Human Activity Recognition
			Bram Nauta	IC Design
			Emiel Zijlma	IC Design
			Yang Miao	Joint Communication and Sensing
			Mensah Obeng Afrane	Joint Communication and Sensing
			André Kokkeler	Digital Designa and Algorithms

International collaboration in 6G

Extension of scope of 6G FNS program

- For the 6G FNS program phase 1 there is a clear and defined scope in 19 Work Packages.
  - Program is based upon Consortium Agreement and public private partnership funding form the Dutch National Growth Fund.
  - For the first two and a half year the partners involved will work on defined tasks and deliverables.
- We are open to discuss collaboration outside the current scope of the FNS program.
  - Work Package leaders will get involved to review if additional collaboration adds value to achieve deliverables.
  - If this is the case, partnership agreements can be discussed based upon the principles of the FNS Consortium Agreement and the agreed additional contribution of new partners.
- More details of 6G FNS Work Packages and Task plans can be shared to make an assessment for potential additional area's of collaboration.

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