TIMES

THz Industrial Mesh Networks in Smart Sensing and Propagation Environments

Tommaso Zugno

Huawei Technologies MRC

tommaso.zugno@huawei.com

TIMES Work Package 4 leader

Hexa-X-II Workshop on 6G

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Project Overview

- Funding framework
  - first call of EU's Smart Networks and Services Joint Undertaking
  - 35 Research and Innovation (R&I) projects selected
  - STREAM B-01-02 on wireless communications and signal processing
- TIMES run-time
  - 1 January 2023 – 31 December 2025
- Consortium

Universities	Technische Universität Braunschweig	Universität Stuttgart	CNRS Centre National de la Recherche Scientifique; cnit
Research institutes	Fraunhofer	bi-rex Big Data Innovation & Research Excellence	
Industries	HUAWEI	telenor	AETNAGROUP
SMEs	Anteral		

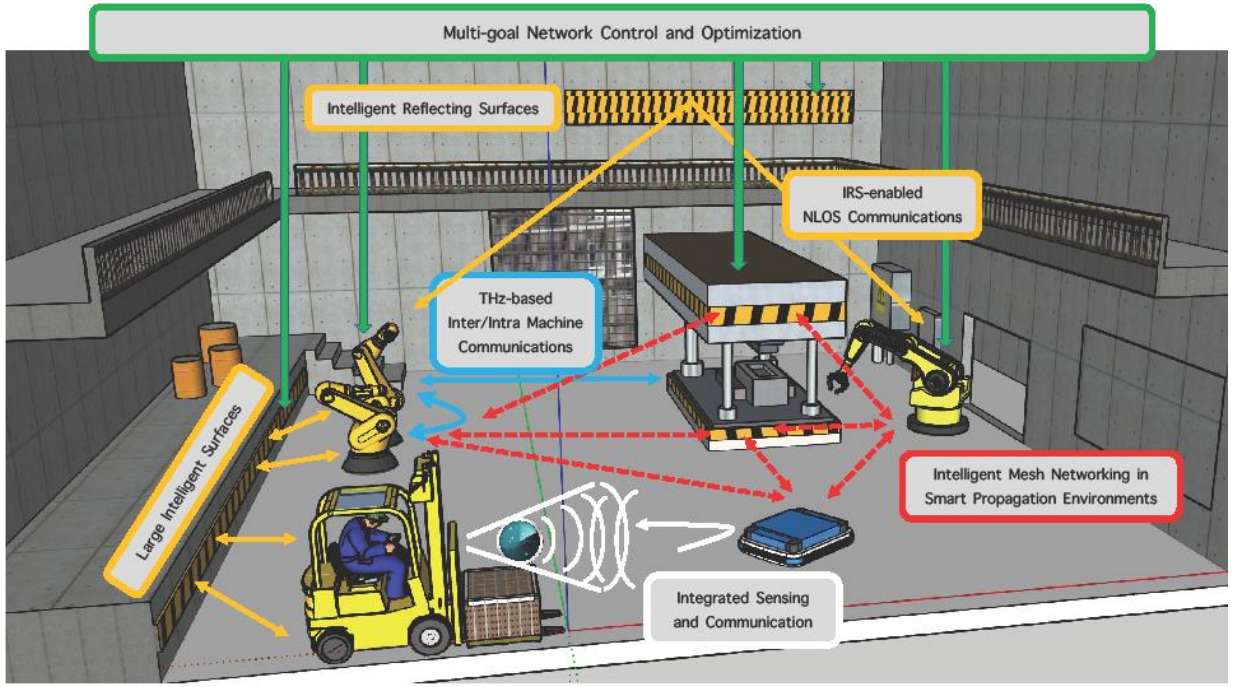
Project vision and pillars

- TIMES long-term vision

  "Smart radio ecosystem in complex scenarios offering similar performance as wired networks."

- Pillars

  - Exploiting ultra-wide bandwidth and sensing-friendly characteristics of **THz communications**.
  - Deploying **intelligent mesh THz networks** in **smart propagation environments**.
  - Enabling high-definition **integrated communications and sensing at THz**.



- Verticals: Manufacturing (I4.0, I5.0), Healthcare, Automotive

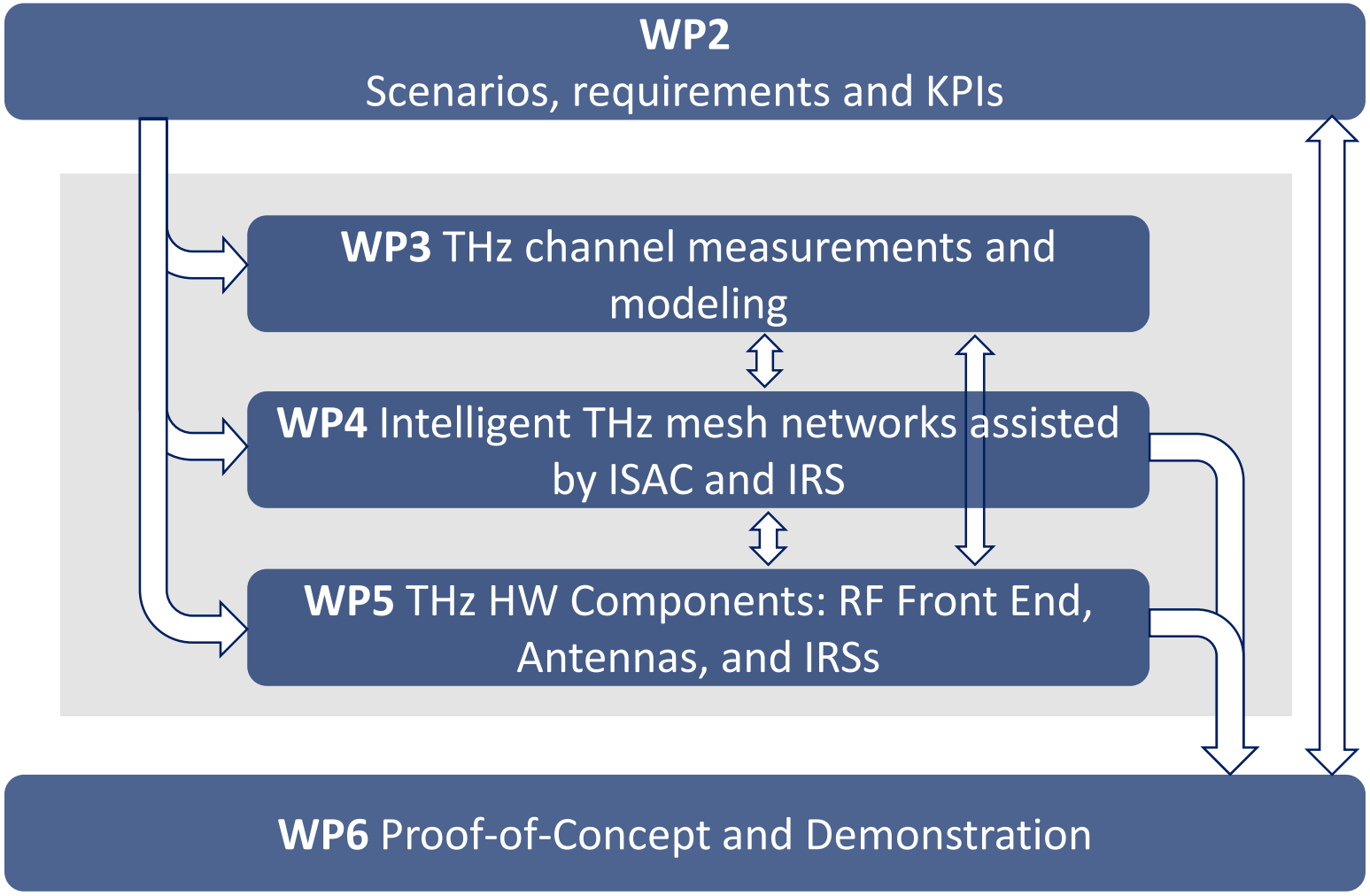
Key objectives

1. Definition of **use cases and requirements** for future industrial applications
2. Derivation of **new THz channel models** in industrial scenarios
3. Design of novel **solutions** at the **PHY and MAC layers**
4. Realization of **THz front-ends, antennas, and IRSs**
5. Design of a **multi-goal mesh-based RAN** composed of active and passive nodes
6. Design of **integrated sensing and communications functionalities and waveforms**
7. Realization and validation of **a PoC in real industrial environments**

Main Innovations

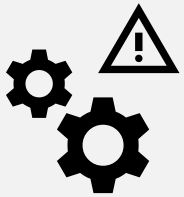
	• Identification of potential use cases • Definition of KPIs
THz communications	• THz channel measurements and modelling • LOS MIMO, fast beamforming, electromagnetic signal processing • 250-300 GHz higly integrated THz RF front-ends
Intelligent Mesh Networking in Smart Propagation enviroements	• Mesh-based RAN topology with active/passive devices • Efficient and reliable transmission over multiple THz links • 300 GHz IRS made of metamaterials
Integrated sensing and communications	• Enable see-around-the-corner functionality with IRSs • Enhanced localization functionalities through near-field THz propogation conditions
Proof-of-concept	• Integration of THz RF front-ends, antennas, IRSs • Multiple THz links between static and mobile devices through direct/reflected paths

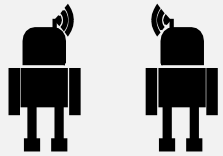
Project Implementation



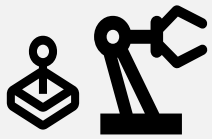
WP2 - Scenarios, requirements and key performance indicators

- 6 application areas and 15 use cases


Predictive maintenance


Mobile robot management


Flexible and modular factory


Highly dynamic control


AR/VR and digital twin


Seamless field bus substitution

Class	Use case	Latency	Data rate	Timeline
A	Automated and guided vehicles and mobile	⌛⌛⌛	**	⇨⇨
	Online cooperative 3D map building	⌛⌛	***	⇨⇨
B	Predictive Maintenance	⌛⌛	***	⇨⇨
	Fast process monitoring	⌛	****	⇨/⇨⇨
	Process automation	⌛⌛⌛	**	⇨/⇨⇨
C	Virtual Simulation and Commissioning	⌛⌛	**	⇨⇨
	Ultimate immersive cloud VR/AR	⌛⌛⌛	****	⇨⇨
D	Virtual PLC	⌛	****	⇨⇨⇨
	Control-to-control communication	⌛⌛	***	⇨⇨⇨
	Motion Control	⌛/⌛⌛	***	⇨⇨⇨
E	Mobile control panels with safety functions	⌛⌛⌛	**	⇨⇨⇨
	Real-time cooperative safety protection	⌛⌛⌛	**	⇨⇨
F	Flexible and modular assembly area	⌛⌛	**	⇨⇨⇨
	Collaborative robots in groups	⌛⌛	**	⇨⇨⇨
	Variable message reliability	⌛⌛⌛	*	⇨⇨

Latency: ⌛⌛⌛Not-RT ⌛⌛Near-RT ⌛RT
Data rate: *Low **Medium ***High ****Ultra-high
Timeline: ⇨Short ⇨⇨Mid ⇨⇨⇨Long-term

WP3 - THz channel measurements and modeling

- Channel measurements in different industrial scenarios

Small workshop

- Intra and inter machine links
- Mono and bi-static ISAC
- Blockage

Big workspace

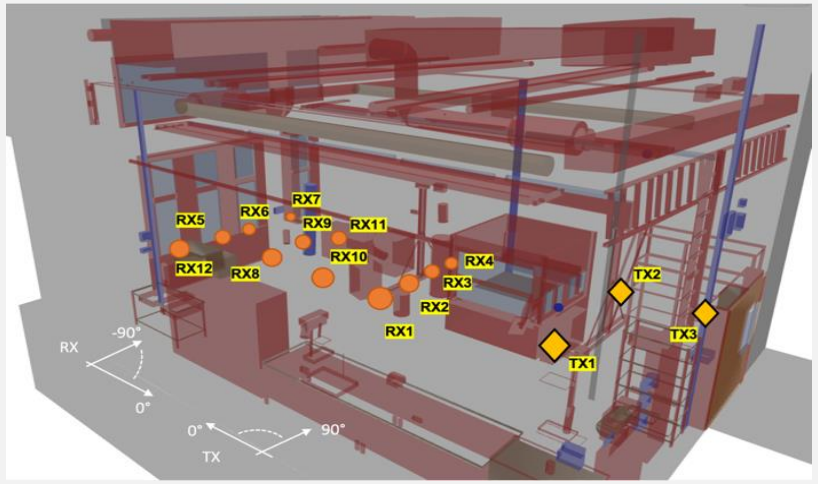
- Directional measurements
- Aligned and mismatched configurations

Robotic lab

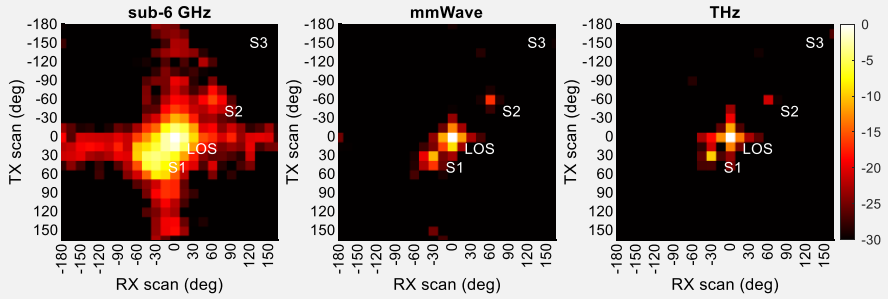
- Links between two robotic arms
- Static and moving blockers

Initial measurements results

Pathloss and large scale parameters in LOS and NLOS

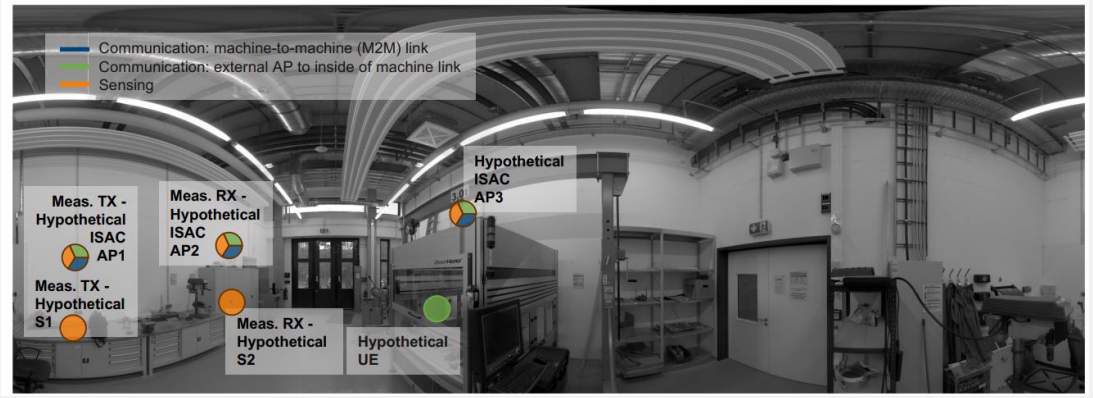


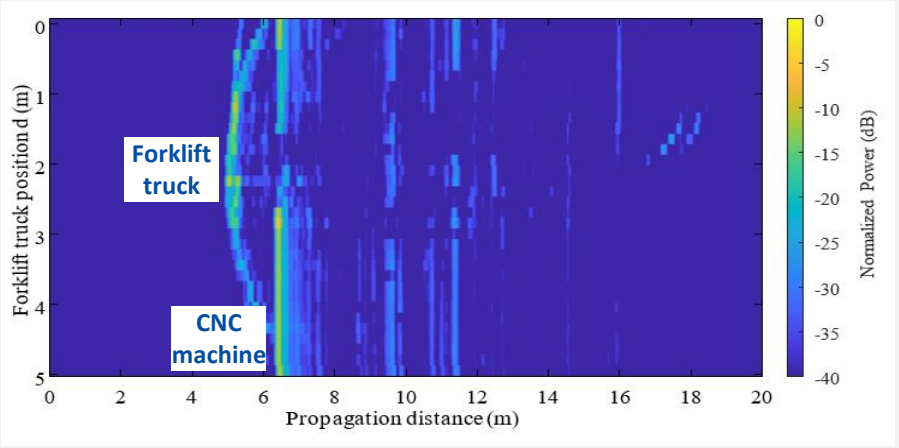
Measurements in multiple positions at 3 frequency bands



Bi-azimuth power profile for TX1-RX1 link

Detecting a forklift truck and CNC machine

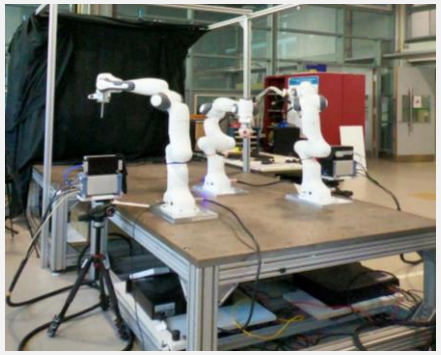




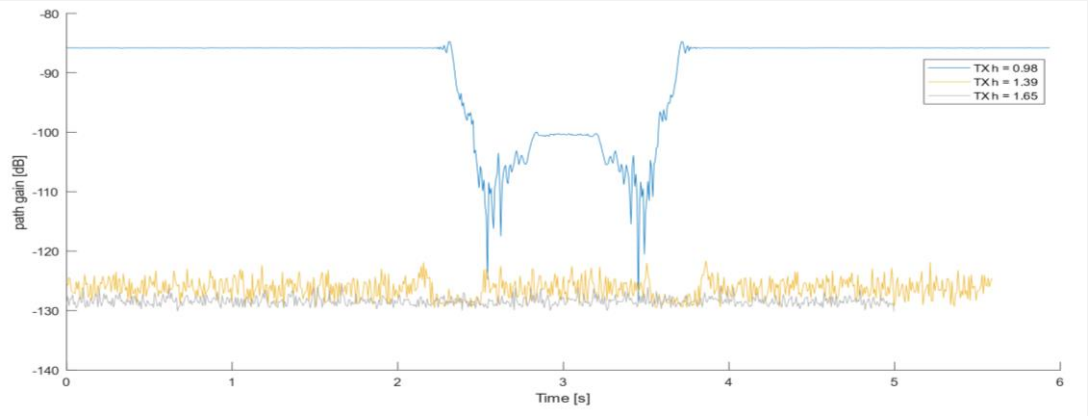
CIR for different positions of forklift

Initial measurements results

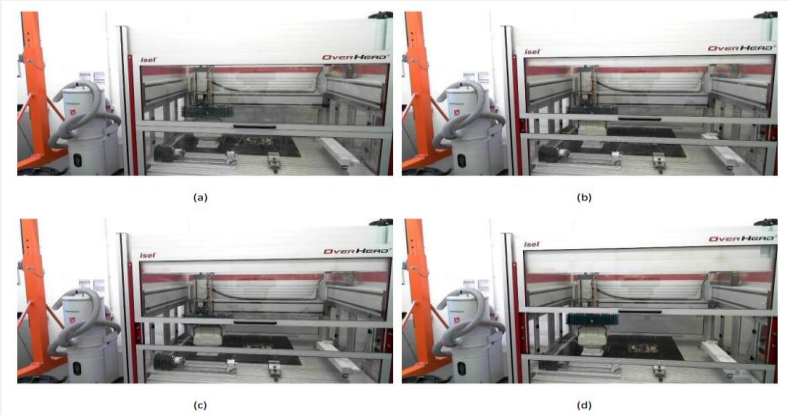
Measurements with blocking obstacle



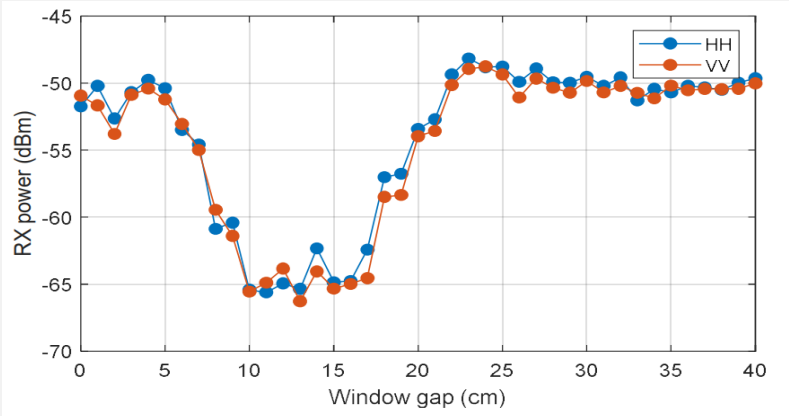
Wireless link between robotic arms with moving obstacle in the middle



Measurements with blocking window



Different opening gaps of protective window



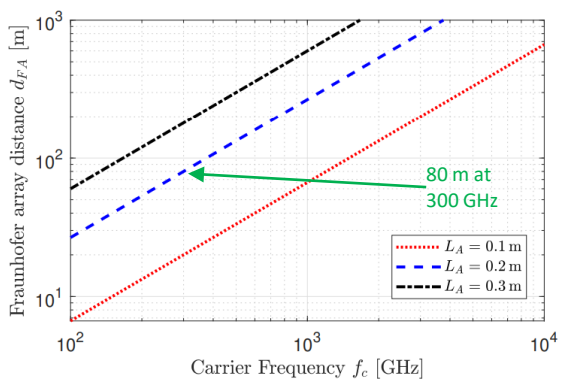
RX power for different opening gaps of window

WP4 - Intelligent THz mesh networks assisted by ISAC and IRSs

- PHY layer enhancements for THz links
- Integration of sensing and communication functionalities
- Enable THz communications in smart propagation environments
- Network design and optimization for intelligent multi-goal mesh networks

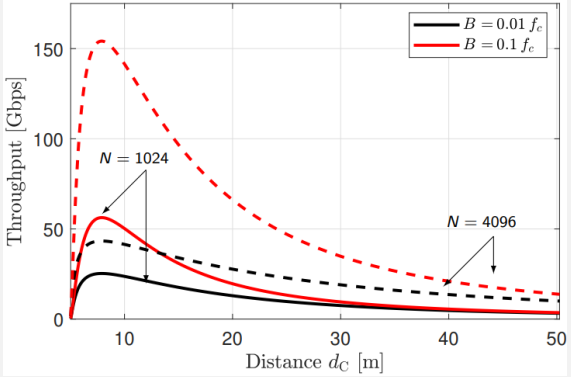
PHY layer enhancements for THz links

Exploit THz near-field propagation through LOS MIMO

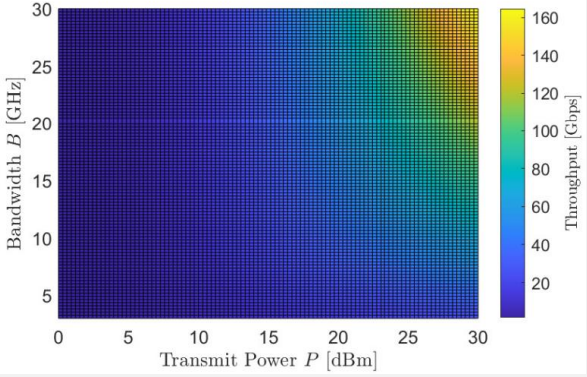


At THz frequencies the typical communication ranges in indoor environments are entirely in the near-field region

Impact of bandwidth and array size

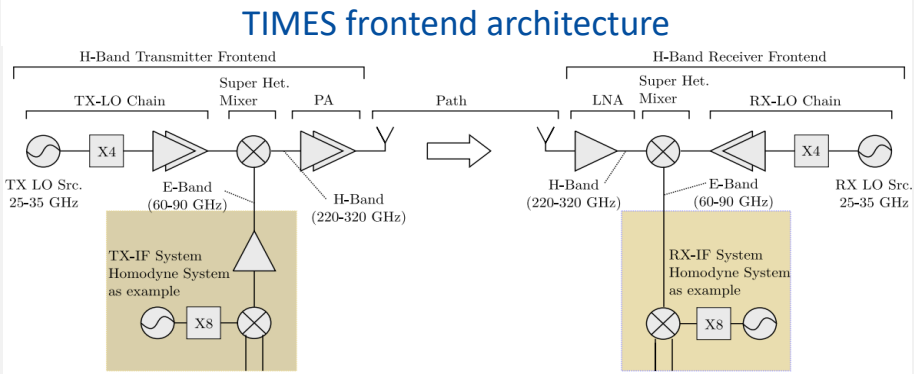


Impact of TX power

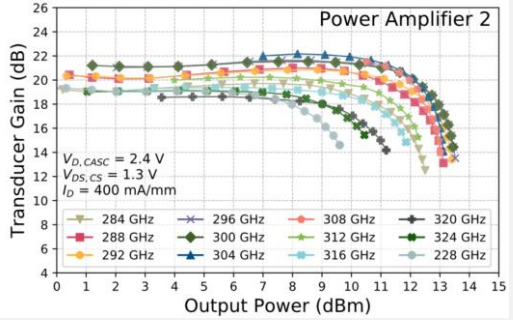


Measurement, modeling, mitigation of RF impairments

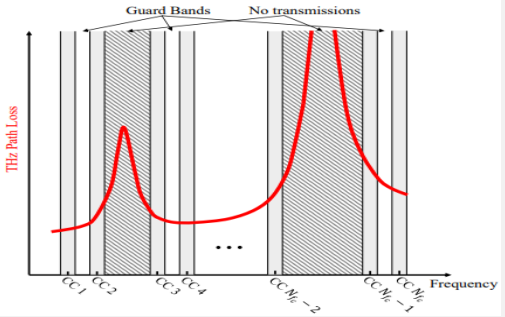
TIMES frontend architecture



Measurement and modeling of non-linearities

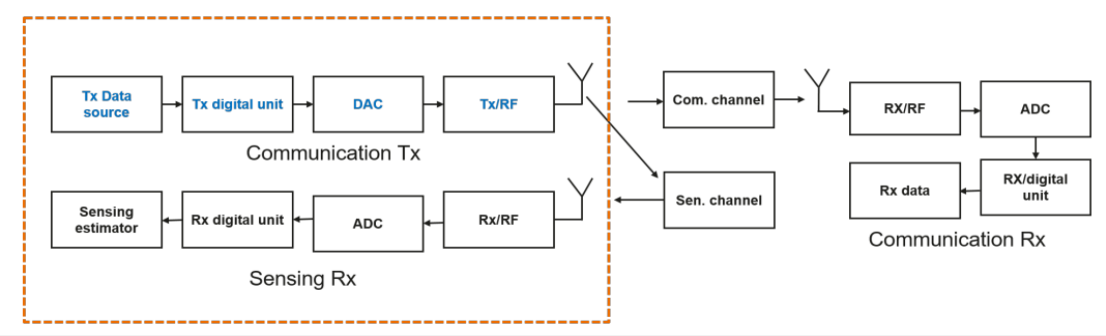


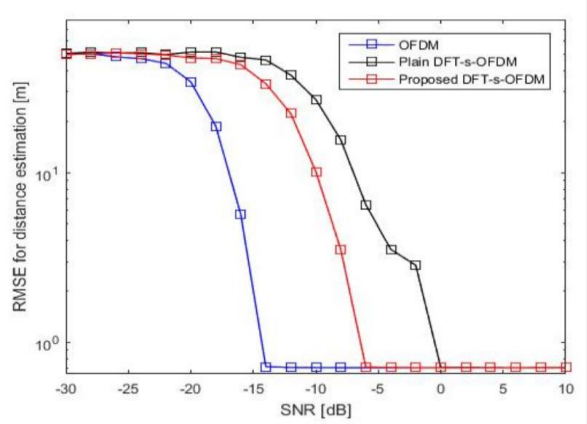
Mitigation of time-frequency synchronization errors



Integration of sensing and communication functionalities

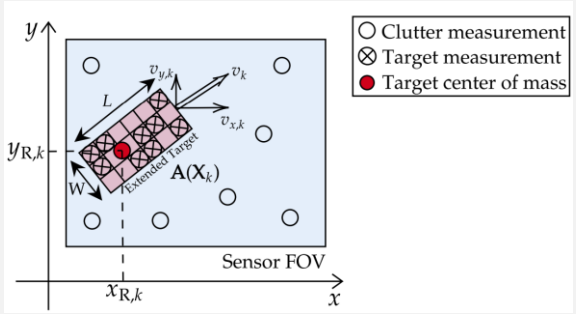
New ISAC waveform design based on DFT-S-OFDM



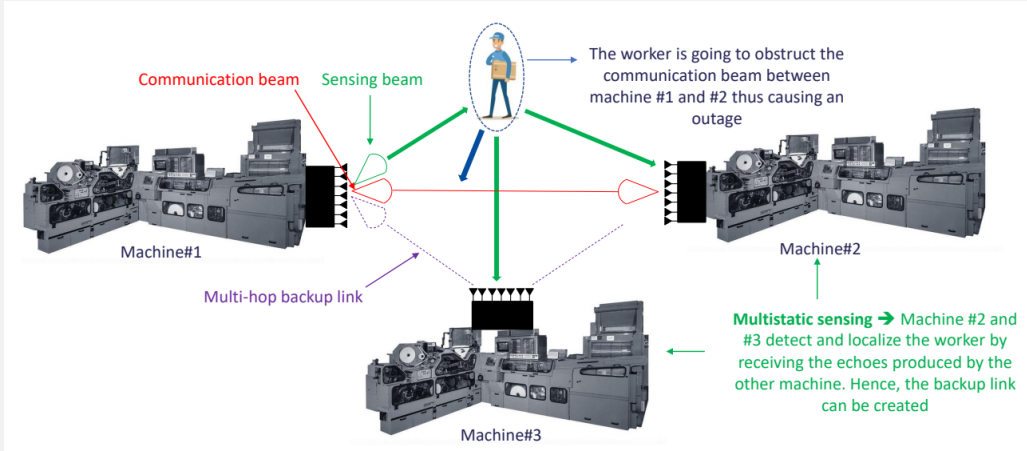


The proposed design offers high estimation accuracy and low PAPR

Enable sensing-assisted THz communications



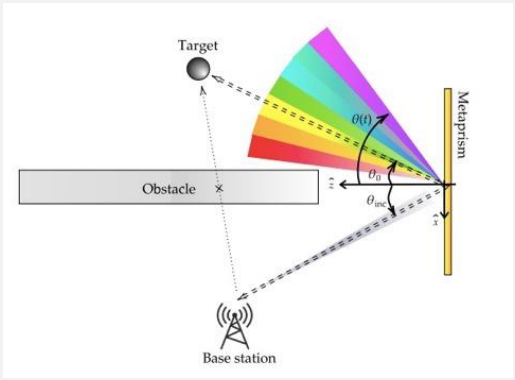
Detection and tracking of extended objects through THz ISAC

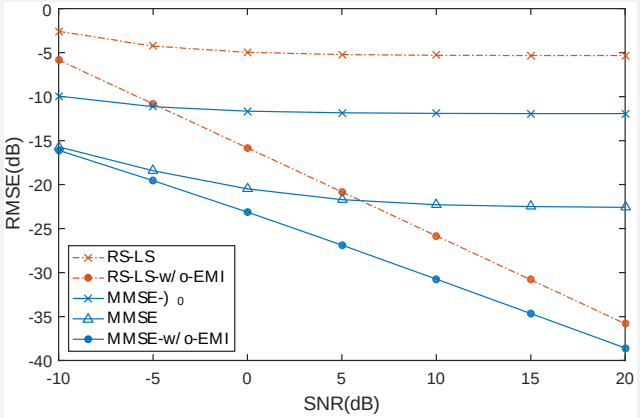


THz communication and sensing in smart propagation environments

High-rank NLOS communication and sensing using IRS

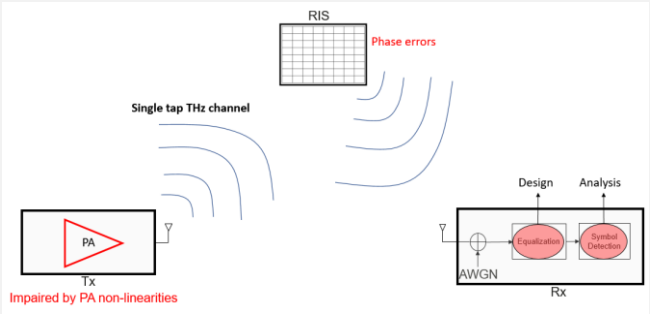
Communication and sensing schemes exploiting frequency-selective IRS concept

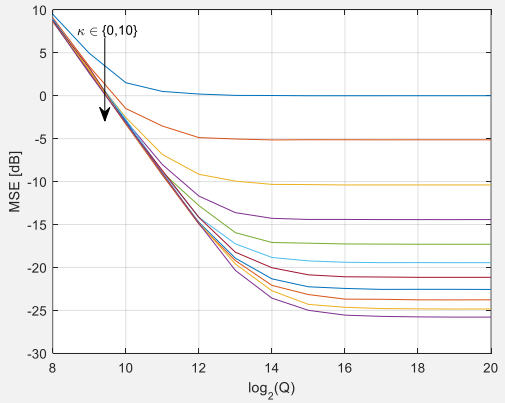




Channel estimation of IRS-aided communications in presence of interference

Characterization and mitigation of RF impairments on IRS-aided links

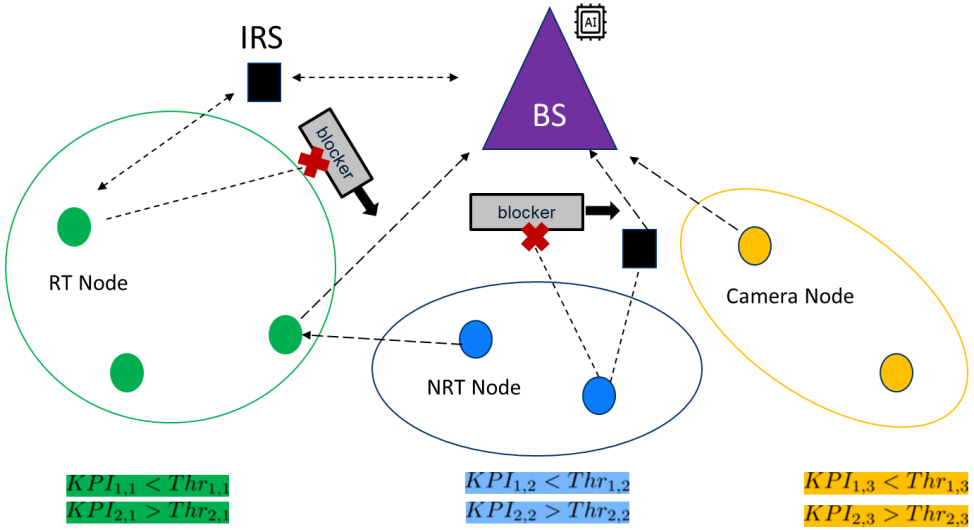




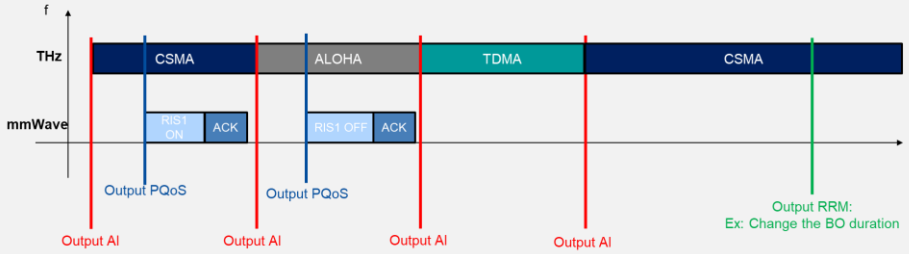
Impact of phase errors on IRS elements for optimal beam design

Design and optimization of intelligent multi-goal mesh networks

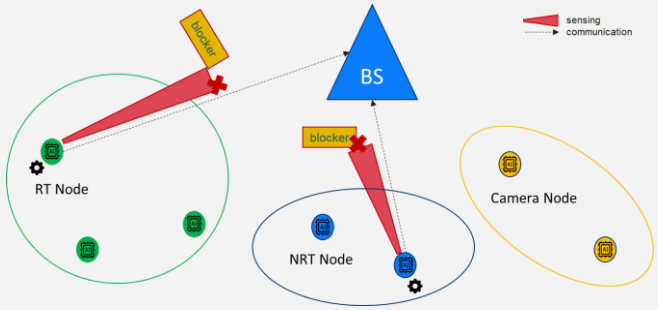
- **Goal:** AI-aided network intelligence able to manage a dynamic environment with diverse communication and sensing constraints



Adaptive and Multi-goal MAC design

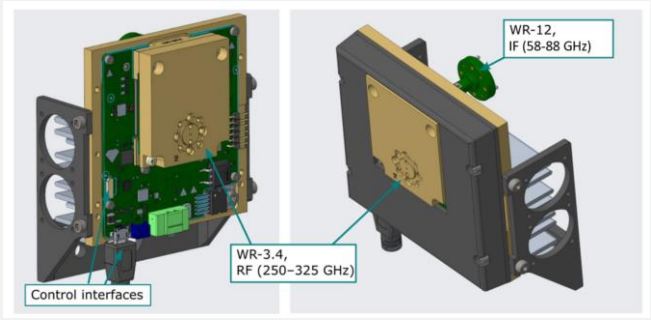


Distributed and cooperative blockage prediction

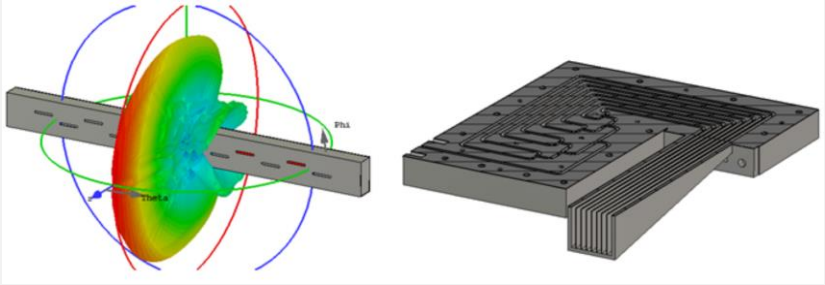


WP5 - THz Hardware Components: RF Front End, Antennas, and IRSs

Design and fabrication of 300 GHz THz frontends



Design and fabrication of THz antennas

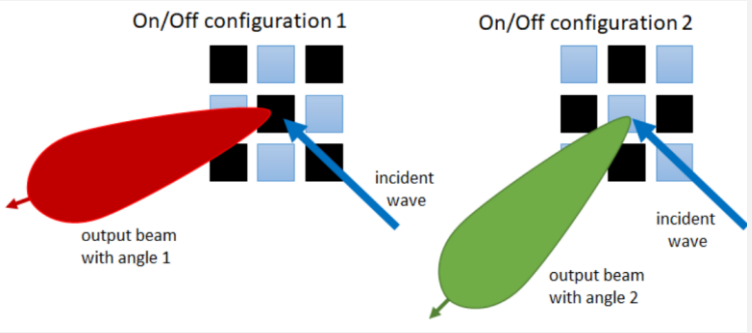


Slotted waveguide

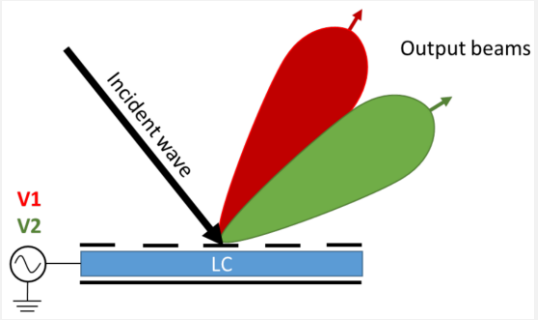
Phase-delay line

Design and fabrication of IRSs at 300 GHz

Multiple static metasurfaces with ON/OFF capabilities



Reconfigurable IRS based on liquid crystal



WP6 - Proof of concept and demonstration in real scenarios

- Planned demonstrations
  - THz link with high-gain antenna and static IRS
  - THz link with beam-steerable antennas and reconfigurable IRS

- Two industrial scenarios

BI-REX Pilot Line

Example of a digital factory of the future designed to support industrial manufacturers in digital transformation processes and technological innovation

AETNA TechLab

The most advanced laboratory in the packaging field with the aim of a continuous process and product development

Public deliverables

- WP2
  - D2.1 - Definition of use cases, KPIs, and scenarios for channel measurements
  - D2.2 - Definition of scenarios for software simulation
  - D2.3 - Definition of scenarios and KPI for hardware demonstration and PoC
- WP3
  - D3.1 - Initial channel measurements in industrial environments at sub-THz frequencies
- WP4
  - D4.1 - Intermediate report on PHY layer enhancements for THz links supporting sensing and communication functionalities

Available at
times6g.eu/deliverables

Standardization and dissemination

- ETSI ISG THz
  - 5 founding members of ISG THz
    - TUBS (chair), HUAWEI (vice-chair), TELENOR (rapporteur), CNRS, FRAUNHOFER
  - Joint TIMES contributions submitted on THz use cases
    - 4 SNS TIMES use cases included in final ISG THz Group Report
  - Industrial THz channel measurements contributed
- COST INTERACT
  - Joint TDs on channel measurements and modelling
- Dissemination activities (joint TIMES/6G-SHINE/TERRAMETA)
  - Organized successful special session at IEEE CSCN 2023
  - Joint TIMES/6G-SHINE/TERRAMETA workshop (Feb. ’24)
  - Joint IEEE ICC 2024 industrial session accepted (Jun. ’24)

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