10 PhD Positions in the Horizon Europe Marie Curie Doctoral Network

6th Sense

Innovative Training Network on Joint Communication and Sensing in 6G Networks

Applications are invited for 10 PhD positions ("Doctoral Candidates", DCs) to be funded by the Marie-Sklodowska-Curie Innovative Training Network "6thSense – Joint Communication and Sensing in 6G Networks" within the Horizon Europe programme of the European Commission.

6thSense follows a holistic approach to address these challenges by: (WP1) Going beyond traditional sub-6GHz systems and enabling sensing in new B5G/6G communication bands, i.e., millimetre-wave and visible light; (WP2) Addressing distributed sensing and networking challenges through architecture and protocol design; (WP3) Handling the analytical complexity of JCAS by combining the strengths of classical signal processing and optimisation models with advanced machine learning techniques; (WP4) Transferring these research contributions to industry-relevant applications in healthcare, manufacturing, and automotive sectors. 6thSense is an intersectoral and interdisciplinary cluster of excellence formed by electrical engineers and computer scientists that has pooled leading members of large EU initiatives (5G PPP), industry leaders (e.g., Nokia, Ford, Bosch) and academic institutions (e.g., KUL, TUDelft, Princeton, UCLA). Benefitting from this consortium, a comprehensive soft-skill training (WP5) and a tailored dissemination and exploitation strategy (WP6), the 10 PhD fellows will become highly employable in various industries, academia, or public government bodies.

Key dates:

- **October 15, 2023: Launch of 10 DC Positions**
- **Jan 25, 2024: Deadline for on-line application**
- Jan 31, 2024: Circulation list "preselected candidates" Recruitment Event
- Feb 8, 2024: 6thSense Recruitment Event (**online**)
- Feb 15 2024: Circulation list "recruited 6thSense DCs" (within one week after the Recruitment Event)
- March 1-Sept 1, 2024: Targeted starting date for DC contracts

Key Information Background

Number of positions available

10 PhD Positions

Research Fields

Wireless communications – Mobile Networks – Signal Processing – Electronic Engineering – Computer Science

Keywords

JC&S – ICAS – 6G - Sensing – Networking – Application – Beamforming – Software defined radio

Career State

Doctoral Candidate (DC) or 0-4 yrs (Post Graduate)

Benefits and salary

The successful candidates will receive an attractive salary in accordance with the MSCA regulations for DCs. **The fellowship will consist of a competitive salary of about € 46,440 (before taxes) per year**, with a country correction factor that depends on the cost of living in the different EU Member States, plus an additional allowance in case of family obligations, and an allocation for research and training costs. The exact salary (net) will be confirmed upon appointment and depends on local tax regulations. **The guaranteed PhD funding covered by the training network is for 36 months** (i.e., EC funding, additional funding is possible, depending on the local Supervisor, and in accordance with the regular PhD time in the country of the hiring host). In addition to their individual scientific projects, all fellows will benefit from further continuing education, which includes internships and secondments, a variety of training modules as well as transferable skills courses and active participation in workshops and conferences.

On-line Recruitment Procedure (see Appendix 1 for full description)

All applications proceed through the on-line recruitment portal on the website. Candidates apply electronically for one to maximum three positions and indicate their preference. Candidates provide all requested information including a detailed CV - **Europass format obligatory** - and motivation letter. During the registration, applicants will need to prove that they are eligible (cf. DC definition, mobility criteria, and English language proficiency). The deadline for the on-line registration is **Jan 25, 2024**.

The 6thSense Recruitment Committee selects between 20 and maximum of 30 candidates for the Recruitment Event which will take place in Leuven (Belgium) (**Feb 2024**). The selected candidates provide a 20-minute presentation and are interviewed by the Recruitment Committee. Candidates will be given a domain-relevant peer-reviewed paper (prior to the recruitment event) by their prioritised Supervisor and will be asked questions about this paper during the interview to check if the candidate has the right background/profile for the DC position. Prior to the recruitment event, skype interviews between the Supervisors and the candidates are recommended, along with on-line personality tests. In order to facilitate their travel, selected candidates (from outside Belgium) receive a reimbursement up to 500 euros (paid by the prioritised Supervisor). In order to avoid delays in reimbursements, candidates are asked to keep all invoices and tickets (cf. train, plane, hotel...). The final decision on who to recruit is communicated the day after the Recruitment Event (**Feb 2024**). The selected DCs are to start their research as quickly as possible (target: Before October 1, 2024, and at the earliest immediately after the recruitment event).

Applicants need to fully respect three eligibility criteria (to be demonstrated in the Europass CV):

Early-stage researchers (DCs) are those who are, at the time of recruitment by the host, in the first four years (full-time equivalent) of their research careers. This is measured from the date when they obtained the degree which formally entitles them to embark on a doctorate, either in the country in which the degree was obtained or in the country in which the research training is provided, irrespective of whether or not a doctorate was envisaged.

Conditions of international mobility of researchers:
Researchers are required to undertake trans-national mobility (i.e., move from one country to another) when taking up the appointment. At the time of selection by the host organisation, researchers must not have resided or carried out their main activity (work, studies, etc.) in the country of their host organisation for more than 12 months in the 3 years immediately prior to their recruitment. Short stays, such as holidays, are not taken into account.

English language: Network fellows (DCs) must demonstrate that their ability to understand and express themselves in both written and spoken English is sufficiently high for them to derive the full benefit from the network training.

The 10 available PhD positions (see Figure 2 for interactions between DCs/WPs)

DC1: **CSI-based obstacle/human detection and tracking at mmWave**
Host: IMDEA Networks Institute, Madrid, Spain
Main supervisor: Prof. Joerg Widmer [IMDEA Networks]
Co-supervisors/mentors: Dr. Jesus O. Lacruz [IMDEA Networks], Dr. A. Lutu [Telefonica]
Required profile: Telecommunication, Electrical Engineering
Desirable skills/interests: Signal processing, array processing, wireless communications, wireless networking, optimization, hands-on experience with hardware and systems (the applicant should be proficient in at least one or two of the skills)
Objectives: To investigate methods for accurate angle, range and (micro-)Doppler estimations from CSI in presence of hardware imperfection; To design practical solutions for cooperative sensing with multiple access points and with several systems in a dense mmWave network; To evaluate the solutions on off-the-shelf devices such an off-the-shelf 802.11 ad/ay testbed and Xilinx RF-SOC based software-defined radio testbed.

DC2: Robust mmWave communication and sensing in smart environments
Host: TU Darmstadt, Darmstdt, Germany
Main supervisor: Dr. Arash Asadi [TUDa]
Co-supervisors/mentors: Dr. Gek Hong Sim, Dr. Uusitalo
Required profile: Telecommunications, Electrical Engineering
Desirable skills/interests: signal processing, optimization, machine learning, programming & implementation skills (the applicant should be proficient in at least one or two of the skills)
Objectives:
To detect/track objects based on the Doppler shift and the AoA analysis of the CSI at the mmWave receiver; To dynamically configure and allocate the RIS elements for optimising dedicated sensing and communication task;

DC3: Visible light-based sub-meter single-anchor localisation and (passive) communication
Host: TU Delft, Delft, The Netherlands
Main supervisor: Prof. M. Zuniga [TU Delft]
Co-supervisors/mentors: Prof. Q. Wang [TU Delft], Dr. R. Bian [PureLiFi]
Required profile: Electrical Engineering, Computer Science, or Mechanical Engineering.
Desirable skills, interests and background: Wireless communication, visible light communication, machine learning, indoor localization (the applicant should be proficient in at least one or two of the skills)
Objectives: To localize drones with lights. We will consider two scenarios. 1) Active scenario: Similar to the way old lighthouses guided ships in the ocean, we want to use the LEDs in our buildings and cities to provide communication and localization to drones. LEDs can be seen as “internal GPS satellites” guiding drones. 2) Passive scenario: When you are in a car at night, you see that road signs reflect the car’s light. We will use a similar technique with drones. The drone will have a light and retroreflectors in the environment will provide communication and localization. For these two scenarios, the aim is to develop

machine learning and mathematical methods, and to implement a testbed. The result will be a novel open-source platform for drones designed in TU Delft.

DC4: Architecture and algorithm design for large-scale privacy-preserving JCAS
Host: Nokia, Espoo, Finland
Main supervisor: Dr. M. Uusitalo [Nokia-FI]
Co-supervisors/mentors: Dr. A. Asadi [TU Darmstadt], Dr. T. Abrudan [Nokia-FI]
Required profile: Electrical Engineering, Telecommunications Engineering, Computer Science or equivalent disciplines
Desirable skills/interests: Multi-channel/array signal processing, estimation and detection theory, wireless communications, mathematical modeling and analysis, optimisation. In addition, the applicant should be proficient at programming in Matlab or Python (preferably in both).
Objectives: To develop algorithms for distributed sensing and fusion relying on MAC layer coordination of multiple base stations; To propose solutions to minimise the impact of sensing on the communication capacity of the network. To improve the privacy-preserving functionalities in the 5G standard to avoid adversarial use of the JCAS capabilities.

DC5: Security issues of JCAS
Host: TU Darmstadt, Darmstadt, Germany
Main supervisor: Prof. Matthias Hollick,
Co-supervisors/mentors: Dr. Arash Asadi [TUDa], Dr. Gek Hong Sim, Dr. M. Uusitalo
Required profile: Telecommunications, Electrical Engineering
Desirable skills/interests: Wireles Physical layer, Security (MAC and PHY), signal processing, optimization, programming & implementation skills (the applicant should be proficient in at least one or two of the skills)
Objectives:
Mechanism that can mitigate the impact of attacks on JCAS is designed (M18); The proposed security mechanism is successfully implemented and evaluated in FPGA-based SDR.

DC6: Non-coherent distributed-MIMO for JCAS
Host: KU Leuven, Leuven, Belgium
Main supervisor: Prof. Sofie Pollin [KU Leuven]
Co-supervisors/mentors: Dr. Hazem Sallouha [KU Leuven], Dr. Pieter Crombez [Televic]
Required profile: Electrical Engineering, Information and Communication Technology, Engineering Physics, Engineering Mathematics
Desirable skills, interests and background: Wireless communication and signal processing, wireless networking and protocols, mathematical modelling and analysis, algorithm design, estimation theory, embedded hardware.
Objectives:
To develop synchronisation algorithms for maximal combining of the transmit/receive signals from various devices, enabling cooperative processing in non-coherent systems; To develop algorithms to maximise the sensing accuracy by optimising the allocation the set of antennas; To implement and evaluate the proposed solutions in the distributed KUL cell-free testbed.

DC7: TinyML-empowered JCAS on embedded devices
Host: TU Delft, Delft, The Netherlands
Main supervisor: Prof. Q. Wang [TU Delft]
Co-supervisors/mentors: Prof. J. Yang [TU Delft], Dr. A. Mueller [Bosch]
Required profile: Telecommunications engineering, Embedded systems, Computer engineering, or equivalent disciplines
Desirable skills/interests: Deep learning, tiny machine learning (TinyML), TensorFlow Lite micro, embedded systems, wireless communications (the applicant should be proficient in at least two of the skills)
Objectives:

To design self-optimizing algorithms for allocation of on-board computational and communication resources for JCAS; To employ knowledge distillation techniques to create performant and low-complexity models for embedded devices; To implement and evaluate the proposed solutions using facilities of the Embedded AI Lab at TU Delft.

DC8: Multi-band channel analysis for accurate JCAS
Host: KU Leuven, Leuven, Belgium
Main supervisor: Prof. Sofie Pollin [KU Leuven]
Co-supervisors/mentors: Dr. Yang Miao [KU Leuven]; Dr. W. Nitzold [NI]
Required profile: Telecommunications, Electrical Engineering, Computer Science
Desirable skills/interests: Wireless communication and signal processing, mathematical modelling and analysis, algorithm design, electromagnetics, estimation theory, measurement equipment.
Objectives:
To develop techniques to match the channel observation across different bands; To exploit the feature richness of multi-band sensing to detect minute changes of the environment; To exploit federated learning for low-overhead and accurate model training.

DC9: Adaptive algorithms for object detection in JCAS
Host: University of Trento, Italy
Main supervisor: Prof. Paolo Casari [UNITN]
Co-supervisors/mentors: Prof F. Granelli [UNITN]; Dr. Mikko Uusitalo [Nokia];
Required profile: Electrical Engineering, Telecommunications, Computer Science
Desirable skills/interests: Wireless networking, 4G/5G protocols, signal/array processing, machine learning, optimization, hands-on experience with hardware and systems (the applicant should be proficient in at least one or two of the skills).
Objectives:
To design and test algorithms for object detection and sensing by minimising the signalling overhead of sensing through intelligent radio resource allocation; To exploit multi-agent reinforcement learning techniques to provide adaptive and near-optimal strategies in highly dynamic scenarios; To implement the proposed solutions in COTS sub-6 GHz testbeds for performance evaluation.

DC10: Multi-modal sensor fusion for JCAS systems
Host: Bosch
Main supervisor: Prof. M. Hollick [TU Darmstadt]
Co-supervisors/mentors: Dr. G. H. Sim [TU Darstadt]; Dr. A. Mueller [Bosch]
Required profile: telecommunication engineering, applied mathematics, electrical engineering, computer science (in order of preference)
Desirable skills/interests: signal processing, statistical filtering, machine learning, applied optimization (the applicant should be proficient in at least one or two of the skills)
Objectives:
To devise effective context-aware algorithms to fuse multi-modal sensor information (e.g., from gyroscope, camera, etc.) in JCAS systems to enhance their robustness; To minimise the energy consumption and computational resource requirements by choosing the most effective sensor modalities given the conditions of the network.

6thSense project abstract and key project information

Having lost a significant share of the market to big players from the US and Asia, Europe is no longer at the forefront of the telecommunication industry. However, new services focusing on remote health monitoring, industry 4.0, and autonomous vehicles have created a unique opportunity for Europe to regain a leading position in 6G. Unlike traditional mobile broadband that mainly connect people, these emerging services not only exchange data but also critically rely on accurate information from their surroundings (i.e., sensing). Consequently, joint communication and sensing (JCAS) is a key feature of 6G networks, where devices will embed wireless sensing capabilities (e.g., localisation, activity recognition). JCAS faces major challenges since it demands fundamental changes to current communication systems. 6thSense follows a holistic approach to address these challenges by: (WP1) Going beyond traditional sub-6GHz systems and enabling sensing in new B5G/6G communication bands, i.e., millimetre-wave and visible light; (WP2) Addressing distributed sensing and networking challenges through architecture and protocol design; (WP3) Handling the analytical complexity of JCAS by combining the strengths of classical signal processing and optimisation models with advanced machine learning techniques; (WP4) Transferring these research contributions to industry-relevant applications in healthcare, manufacturing, and automotive sectors. 6thSense is an intersectoral and interdisciplinary cluster of excellence formed by electrical engineers and computer scientists that has pooled leading members of large EU initiatives (5G PPP), industry leaders (e.g., Nokia, Ford, Bosch) and academic institutions (e.g., KUL, TUDelft, Princeton, UCLA). Benefitting from this consortium, a comprehensive soft-skill training (WP5) and a tailored dissemination and exploitation strategy (WP6), the 10 PhD fellows will become highly employable in various industries, academia, or public government bodies.

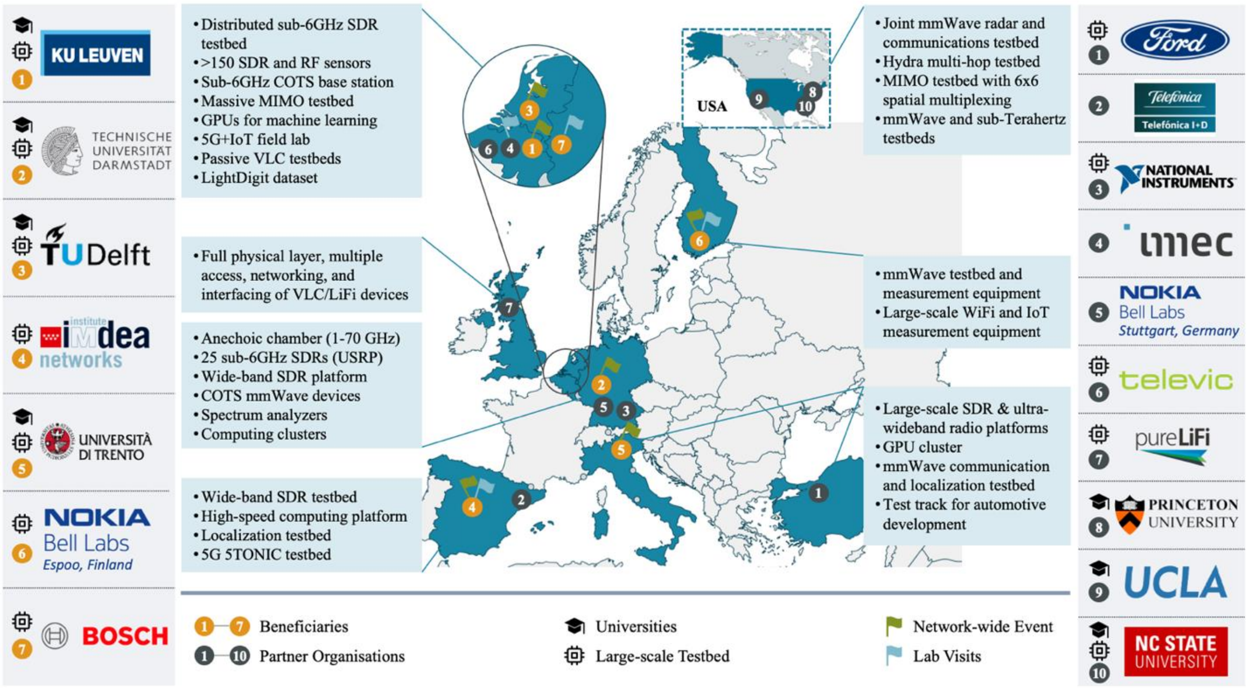

Figure 1. *6thSense Consortium*

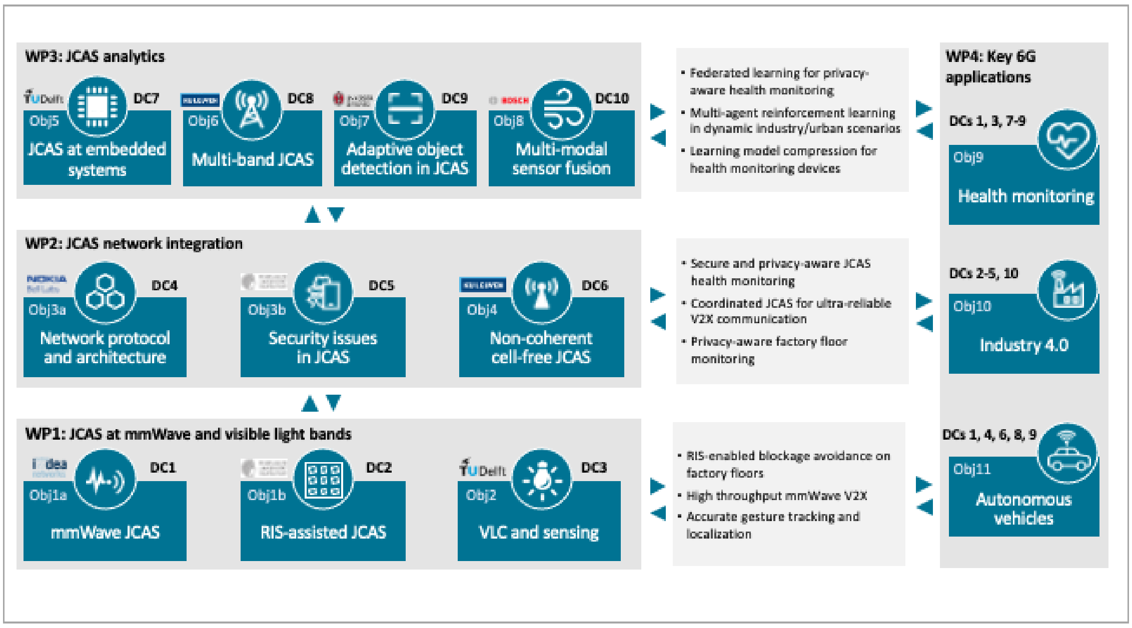

Figure 2. *6thSense WPs and DCs*

6thSense contains 7 WPs, four of which are S&T WPs (WP1–4), one for training (WP5), one for Exploitation, Dissemination and Communication (WP6) and one for Management (WP7). In the following paragraphs, we provide a general overview of the S/T WPs.

WP1: JCAS in new frequency bands

WiFi and ultra-wide band (UWB) signals at sub-6GHz frequency bands have been widely used for a plethora of sensing tasks including the detection of people or obstacles (even through walls) as well as activity, posture, and gesture recognition. These frequencies have the advantage of a rich multipath environment and low penetration loss, thus allowing to "see" much of the changes in the environment, and even illuminate the space behind obstacles or walls. However, the widely used WiFi systems are typically narrowband and exposed to higher interference, since they operate in unlicensed and congested parts of the RF spectrum. Furthermore, sub-6GHz systems have lower angular resolution, because the antenna form factor does not allow for large arrays. In contrast, the channel at frequencies beyond 30 GHz is sparse, and obstacles typically block the signal completely. Hence, the "view" of such systems is limited, but *the wide bandwidth and small wavelength enables significantly more accurate sensing (down to detecting minute details of obstacles) while providing multi-Gbps data rate at short/medium range*. Furthermore, highly directional beamforming via phased antenna arrays or optical lenses provides additional spatial information at an accuracy that is not present at lower frequency low-order MIMO systems. The three DCs in WP1 will develop techniques for highly accurate sensing at mmWave bands (30-300 GHz) and visible light (400-800 THz) leveraging the high-bandwidth and high directionality properties of these systems. This unprecedented accuracy is crucial for future applications (e.g., industry 4.0, breathing rate monitoring) where minute movements and changes in the environment have to be measured. Furthermore, the precise localisation and tracking of obstacles can help circumvent blockages disrupting communication links. To this aim, **DC1** investigates methods for object detection and environment sensing from channel state information (CSI) provided by mmWave communication chipsets (**Obj1a**). In particular, the DC exploits the high bandwidth and directivity of mmWave arrays to enhance the accuracy of angle, range and (micro-) Doppler estimates from mmWave communication signals. Concurrently, **DC2** enhances the range and accuracy of mmWave JCAS using reconfigurable intelligent surfaces (RISs) to control the phase and direction

of the reflected signal (**Obj1b**). By influencing the reflected signals, RISs yield an additional degree of freedom via the control of non-line-of-sight (NLOS) paths. This helps circumvent blockage and enhance sensing, i.e., by directing the NLOS signals to the area/object of interest. **DC3** taps into the omni-presence of lighting systems and their unique vantage point (typically from the ceiling/top) for visible light communication (VLC), localisation and sensing (**Obj2**). Specifically, **DC3** studies bidirectional communication via photodiodes for active VLC and retroreflectors for passive VLC (suited to low-power IoT devices). The DC also derives a mathematical framework for sub-decimetre 3D localisation and human counting via a single light source by exploiting Lambertian light diffusion patterns.

WP2: JCAS network integration

Early industry trials confirm that today's communication devices provide primitive sensing capabilities.[1] However, these trials are still far from the accuracy and scalability requirements of complex 6G use-cases. Moreover, prior works on RF-sensing dominantly focused on WiFi systems, leaving integration of JCAS in cellular networks and its associated networking aspects an open challenge. The DCs in WP2 tackle the network integration challenges of JCAS at their root *by designing an innovative architecture for future JCAS networks, considering user privacy and security* (**Obj3**). Moreover, *they improve the synchronisation of large-scale and cost-efficient deployments.* Although wireless sensing is significantly less intrusive than cameras, it is still subject to adversarial exploitation violating user privacy, e.g., collecting the geo-location of users. Given the massive scale of JCAS in 6G networks, it is crucial to enable privacy by design. Focusing on 3GPP 5G-NR, **DC4** investigates architectural and functional modifications to maintain user privacy while enabling the exchange of sensing information among several base stations for collaborative sensing (**Obj3a**). Complementary to this, **DC5** investigates the potential security vulnerabilities that arise from integrated communication and sensing, e.g., spoofing sensing signals and jamming the sensing sub-frames. Moreover, the DC designs adaptive security protocols that use multi-band and multi-beam hopping to enhance the resilience of sensing against adversaries (**Obj3b**). Leveraging the spatial diversity and processing gains, cell-free JCAS is a cost-effective and scalable method to provide high data-rate and accurate sensing in dense scenarios. However, the practicality of cell-free JCAS systems depends on the accurate synchronisation among distributed antennas. To this aim, **DC6** devises high precision synchronisation mechanisms for non-coherent systems by compensating for hardware imperfections, particularly clock drifts, that constrain communication quality and hamper the angular estimation needed for sensing (**Obj4**).

WP3: JCAS analytics [M7-M42]

The integration of communication and sensing requires innovative solutions to deal with the complexity of accurate parameter extraction, signal recovery, data analysis for recognition/detection, optimising spectrum and computational resource allocation between communication and sensing, and fusing information from multi-modal sensors. *Some of these tasks are better solved via classic optimisation and signal processing techniques, whereas others are better tackled by modern machine learning algorithms. This is addressed in WP3, where DCs 7-10 investigate the suitable methodologies to address the challenges of JCAS for different scenarios.* Targeting the processing and power limitations of embedded devices common in IoT ecosystems, **DC7** designs self-optimising algorithms for the allocation of on-board computational and communication resources based on the sensing task (e.g., localisation, tracking, detection). Moreover, **DC7** investigates knowledge distillation techniques to compress large ML models into

[1] Source: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9097124

simpler but performant embedded-ML models for human activity/gesture recognition (**Obj5**). Leveraging the complementary nature of different frequency bands (sub-6GHz, mmWave) is crucial for accurate and robust JCAS. However, this entails dealing with mixed channel observations, e.g., determining if reflections from a similar direction at different bands come from the same object or not. **DC8** exploits gradient-maximum likelihood algorithms to accurately estimate multipath channel parameters in the delay-angular-polarization-Doppler domain. Using the feature richness of multi-band sensing, the DC develops privacy-aware human activity recognition relying on a combination of signal processing and federated learning models (**Obj6**). Scheduling for JCAS is very complex because it requires to jointly consider communication and sensing QoS requirements. For example, detecting a high-speed object with sharp edges requires very high-rate sensing signal transmission to accurately sample the object boundaries, as opposed to static objects. **DC9** designs optimal JCAS schedulers for object detection and tracking via intelligent allocation of sensing signals in time and frequency domains. Based on the analytical insights from the optimal strategy, **DC9** develops multi-agent reinforcement learning techniques for real-time scheduling in highly dynamic scenarios (**Obj7**). In many use cases, JCAS systems co-exist with an array of other modalities (e.g., gyroscope, camera, LIDAR, tachometer). **DC10** investigates multi-modal sensing to improve the accuracy and robustness of both JCAS and other available sensors. (**Obj8**). For example, JCAS can help cameras and LIDARs in low-visibility conditions, whereas cameras can enhance JCAS in high-interference communication scenarios. **DC10** considers the advantages and limitations of each sensing system to optimize the joint effectiveness of sensing as a whole.

WP4: Key 6G applications

JCAS is a disruptive paradigm shift in telecommunication, enabling comprehensive solutions for new applications where environment-awareness is as important as connectivity, i.e., remote health monitoring, industry 4.0, and autonomous driving. Unfortunately, there is no one-size-fits-all solution for these applications because of subtle but important differences in the operating environment (e.g., indoor, outdoor), conditions (e.g., mobility, density) and QoS requirements (e.g., reliability, throughput, accuracy, latency). In WP4, **DCs 1-10** collaboratively target these application-specific JCAS challenges within the three aforementioned areas. *This WP is specifically designed to train DCs to transfer fundamental research contributions to industry-relevant application*. The WP starts during NWE 4 (**M24**), when the DCs have sufficiently progressed in their research and are ready to collaborate effectively.

Health monitoring. Europe has a large, aging population demanding high-quality healthcare from a system whose vulnerabilities have been revealed during the COVID-19 pandemic, triggering major EU funding to move towards scalable digital health technologies[2]. JCAS boosts this transformation through remote health/patient monitoring, reducing hospital visits while allowing for early symptom detection. **DCs 1, 3, 7-9** develop passive monitoring solutions (i.e., the person does not need to wear sensors) for activity and vital signs using commodity wireless devices which are present in nearly every household, e.g., WiFi routers, light bulbs, and other IoT gadgets (**Obj9**). A major limitation of current passive sensing is the poor accuracy in the presence multiple persons, its susceptibility to small changes in the environment, and lack of privacy and security considerations. Leveraging their expertise, the DCs devise a secure multi-person posture/activity and vital sign monitoring. Specifically, the DCs exploit federated learning as a privacy-preserving approach to train sensing solutions to quickly adapt to new situations.

Industry 4.0. As pointed out by the EC[3], Europe's manufacturing is in dire need of automation to enhance production and reduce dependency on humans for trivial and repetitive tasks. Such dependency was in fact part of Europe's manufacturing issues during the pandemic. However, high levels of automation require accurate real-time information from the whole plant, something

[2] Source: https://ec.europa.eu/digital-single-market/en/digital-health-technologies-addressing-pandemic
[3] Source: https://ec.europa.eu/digital-single-market/en/digitising-european-industry

which today's camera-based systems cannot deliver because they often lack the perception of depth, which makes accurate localisation and sensing very complex. Moreover, due to privacy concerns, many EU states do not allow using cameras to supervise humans, whose presence is inevitable in the foreseeable future, at least as supervisors/operators. To this aim, the **DCs 2-5**, and **10** work toward JCAS techniques to build an accurate real-time digital twin of an industrial plant without violating labour privacy laws (**Obj10**). In addition, the DCs develop techniques to enhance the reliability of communications in dynamic industrial scenarios and low-overhead processing technique to build an accurate real-time digital twin.

Autonomous vehicles are among the first applications for JCAS since the vehicles should constantly sense their surroundings and communicate with other parts of the intelligent transport system for safe navigation. Although autonomous vehicles possess an array of sensory devices, their "perception" of the surrounding environment is short-range and limited to their vicinity. In contrast, network operators are in a unique position to use their extensive infrastructure and thus obtain a *comprehensive perception* of the environment using cooperative sensing techniques. **DCs 1, 4, 6, 8,** and **9** work towards "perception fusion" techniques in which the sensing information from the networks is communicated and combined with the on-board sensory information of the vehicles (**Obj11**). In particular, the DCs investigate novel methods to use this information in a privacy and security-preserving manner to provide a more accurate real-time view of the traffic situation to autonomous vehicle, so as to improve road and navigation safety.

General Coordinator for 6thSense:
Prof. Sofie Pollin (KU Leuven)
sofie.pollin@kuleuven.be
+32 16 32 10 51

Scientific Coordinator:
Dr. Arash Asadi (TU Darmstadt)
aasadi@seemoo.tu-darmstadt.de
+49 6151 16 25480

Appendix 1: Recruitment Procedure and Principles

Advertisement Process: The search for appropriate candidates is initially based on normal recruitment strategies (e.g. publication on ec.europa.eu/euraxess, etc.; personal contacts of the network partners). All the recruitment is in line with the European Charter for Researchers, providing the overarching framework for the roles, responsibilities of both the researchers and employers. The Code of Conduct for the Recruitment of Researchers functions as a set of principles and ensures that the selection procedures are transparent and fair. The recruitment strategy for 6thSense will fully comply with the Code of Conduct's definition of merit. For example, merit is not just measured on researchers' grades, but on a range of evaluation criteria, such as teamwork, interdisciplinary knowledge, soft-skills and awareness of the policy and economic impact of science. The RC has members of each gender and considers the promotion of equal opportunities and gender balance as part of the recruitment strategy. Special efforts are made to attract women and DCs from new EU Member States.

Selection Process: The pre and final selection will be made in a collective progress, led by the Recruitment Committee (RC), which consists of all the people who will be involved in the supervision process. Every member of the RC will receive 4 hours of training on recruitment procedures and will be made aware of factors like unconscious gender bias. The candidates can apply for a maximum of three projects and list their order of preference. The 30 most suitable are invited to a Recruitment Workshop (Leuven, Belgium, Dec 2019). In order to facilitate their travel, selected candidates (from outside Belgium) receive a reimbursement up to 500 euros (paid by the prioritised Supervisor). In order to avoid delays in reimbursements, candidates are asked to keep all invoices and tickets (cf. train, plane, hotel...).

Each candidate gives a presentation and is interviewed. Each candidate will give a presentation and be interviewed. Candidates will be given a domain-relevant peer-reviewed paper (prior to the recruitment event) by their prioritised Supervisor and will be asked questions about this paper during the interview to check if the candidate has the right background/profile for the DC position. Prior to the recruitment event, skype interviews between the Supervisors and the candidates are recommended, along with on- line personality tests.

The committee selects the DCs (1) based on their scientific background and potential, (2) based on the expected benefit of scientific exchange between the trainees' home countries and institutions and the hosts, and (3) in accordance with gender equality and minority rights. The candidates are ranked and a collective decision is made, taking into account the order of preference. In this way a complementary team of DCs can be assembled. All non-selected candidates will receive a letter explaining the reasons why they were not selected (in line with the Code of Conduct). The DCs are employed on fixed-term contracts and are registered as staff candidates for PhD degrees. Therefore, they are entitled to pension contributions, paid holidays, and other employment benefits, as governed by the universities, non-academic partners and industrial companies.

In case not all 10 DCs can be recruited during the collective Recruitment Event, the recruitment procedure is "decentralised", meaning that the involved supervisors continue the search for good candidates. The RC is kept informed at all times when new eligible candidates appear. The RC makes an official complaint in case the Code of Conduct for the Recruitment of Researchers is breached. The involved supervisor is then expected to find another candidate. Recruitment problems are also, if still needed, discussed during the first 6thSense Network Wide Events (M8) in order to deliver specific action plans to target specific networks relevant for the vacant DC positions.

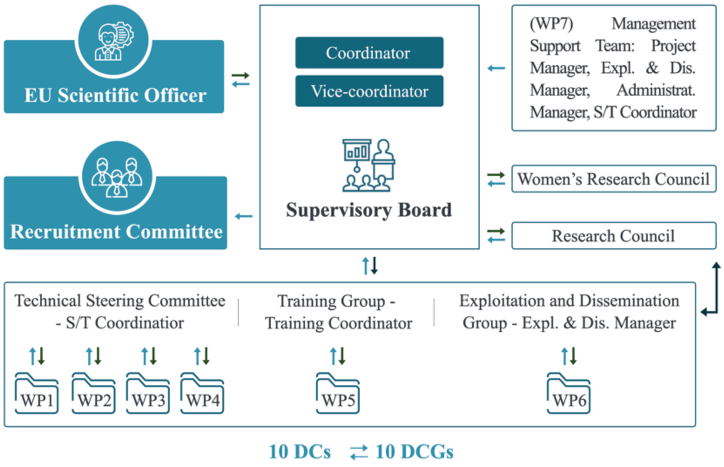

Figure 3. *6thSense Management Structure*

Recruitment Committee: This committee involves the General Coordinator, the Scientific Coordinator, and one representative from each beneficiary. The recruitment committee oversees the recruitment of10 DCs during the collective recruitment event.