15 PhD Positions in the EU H2020 Marie Curie ITN Project

MSCA-ETN
MINTS

European Training Network on
MIllimeter-wave NeTworking and Sensing for Beyond 5G

Applications are invited for 15 PhD positions ("Early Stage Researchers", ESRs) to be funded by the Marie-Sklodowska-Curie Innovative Training Network "MINTS – MIllimeter-wave NeTworking and Sensing for Beyond 5G" within the Horizon 2020 Programme of the European Commission.

MINTS provides a unique system-oriented training to 15 ESRs, nurturing a new generation of innovators thanks to internationally recognized researchers with broad experience in research, training, and participation in EU, national, and industry-sponsored projects. With the intensive involvement of industrial beneficiaries and partner organisations (Nokia, NEC, Sony, NI, IMEC, Proximus, Italtel), the ESRs will obtain in-depth knowledge and skills in mmWave networks and its key applications. This interdisciplinary and intersectoral training is an essential component of each ESR's PhD. The 15 ESRs are distributed over 7 beneficiaries in 6 countries: KU Leuven (Belgium), IMDEA Networks Institute (Spain), TU Darmstadt (Germany), NEC (Germany), University of Padua (Italy), Lund University (Sweden), and Nokia Bell Labs (Ireland). Additionally, the consortium is completed by 6 partner organisations: IMEC (Belgium), Proximus (Belgium), NI (Germany), Carlos III University of Madrid (Spain); Italy: Italtel (operator), Maynooth University (Ireland), and Sony (Sweden).

Each of the 15 ESRs will be working towards a PhD degree, supported by a carefully chosen supervisory team that maximizes both scientific excellence as well as interdisciplinary and intersectoral collaboration. The 15 MINTS ESRs will not only receive state-of-the-art science/technology training but will also benefit from a unique soft-skills training programme. The interdisciplinary and inter-domain training will make MINTS ESRs highly employable in various industries (such as the EU telecommunication vendors and operators Nokia, Eriksson, Deutsche Telekom, Telefonica, and Vodafone), academia, or public government bodies.

Key dates:

- July 21 2019: Launch of 15 ESR Positions
- **Oct 31 2019: Deadline for on-line application**
- Nov 30 2019: Circulation list "preselected candidates"
- Dec 2019: MINTS Recruitment Event (exact date to be decided)
- Dec 2019: Circulation list "recruited MINTS ESRs" (within one week after the Recruitment Event)
- March 1 2019: Targeted starting date for ESR contracts

Key Information Background

Number of positions available

15 PhD Positions

Research Fields

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

Keywords

mmWave – Beyond 5G – Sensing – Networking – Application – Beamforming – Software defined radio – Self-learning networks

Career State

Early Stage Researcher (ESR) or 0-4 yrs (Post Graduate)

Benefits and salary

The successful candidates will receive an attractive salary in accordance with the MSCA regulations for ESRs. **The fellowship will consist of a competitive salary of about € 46,440 (before taxes) per year**, with 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 origin). 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 www.b5g-mints.eu 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. ESR definition, mobility criteria, and English language proficiency). The deadline for the on-line registration is **Oct 31 2019**.

The MINTS Recruitment Committee selects between 20 and maximum of 30 candidates for the Recruitment Event which will take place in Leuven (Belgium) (**Dec 2019**). 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 ESR 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 (**Dec 2019**). The selected ESRs are to start their research as quickly as possible (target: March 1 2020).

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

Early-stage researchers (ESR) 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 (ESRs) 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 15 available PhD positions (see Figure 2 for interactions between ESRs/WPs)

ESR1: **Efficient channel estimation and beam training with (partial) channel state information**
Host: IMDEA Networks Institute, Madrid, Spain
Main supervisor: Prof. Joerg Widmer [IMDEA Networks]
Co-supervisors/mentors: Dr. Jesus O. Lacruz [IMDEA Networks]
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 design custom measurement beam patterns for phased antenna arrays to quickly acquire Channel State Information (CSI);
To investigate tradeoffs between link SNR maximization and interference minimization in order to balance fairness and efficiency throughout the network;
To investigate algorithms that acquire the full CSI when only partial information is available via efficient procedures, either involving prior measurements or by factoring in external information.

ESR2: Machine learning-enabled fast and hybrid mmWave beam tracking
Host: KU Leuven, Leuven, Belgium
Main supervisor: Prof. Guy Vandenbosch [KU Leuven]
Co-supervisors/mentors: Prof. Sofie Pollin and Dr. Evgenii Vinogradov [KU Leuven]; Prof. Fredrik Tufvesson [Lund University]
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 extract multidimensional (time, frequency, space) statistics from high-resolution channel measurements;

To design a low complexity mmWave hybrid beamforming antenna and a beam tracking algorithm for realistic channels using machine learning approaches.

ESR3: Fully digital massive MIMO mmWave communication for mission-critical applications
Host: Lund University, Lund, Sweden
Main supervisor: Prof. Fredrik Tufvesson [Lund University]
Co-supervisors/mentors: Prof. Sofie Pollin [KU Leuven], Dr. Harsh Tataria [Lund University]
Required profile: Electrical Engineering, Information and Communication Technology, Engineering Physics
Desirable skills, interests and background: Wireless communication, array processing, mathematical modelling, RF measurements, electromagnetics and antenna design, RF channel characterization and modelling (the applicant should be proficient in at least one or two of the skills)
Objectives:
To study the dynamic behaviour of mmWave massive MIMO systems in challenging scenarios with mission-critical constraints;
To harness the mmWave channel diversity via fully digital beamforming for ultra-reliable links in critical scenarios.

ESR4: Advanced localization and mapping techniques
Host: IMDEA Networks Institute, Madrid, Spain
Main supervisor: Dr. Paolo Casari [IMDEA Networks]
Co-supervisors/mentors: Dr. Amanda García [IMDEA Networks]
Required profile: Electrical engineering, telecommunications engineering or equivalent disciplines
Desirable skills/interests: Signal processing, array processing, 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 design location mechanisms adapted to different hardware capabilities, such as low-complexity algorithms for consumer-grade and constrained hardware for industrial applications;
To design localization algorithms with low-to-zero overhead by exploiting CSI;
To integrate simultaneous localization and mapping (SLAM) capabilities in mmWave location systems.

ESR5: Exploiting mmWave radios for indoor and outdoor environmental sensing
Host: University of Padua, Padua, Italy
Main supervisor: Prof. Michele Rossi [University of Padua]
Co-supervisors/mentors: Prof. Andrea Zanella [University of Padua]; Dr. Paolo Casari [IMDEA Networks]
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 develop algorithms for mmWave sensing in a wide range of different indoor environments;
To understand the limits of outdoor sensing at mmWave and to propose robust network architectures and procedures to enable reliable and high-precision outdoor sensing;
To investigate cooperative and infrastructure-less sensing via combining different views/sensor fusion.

ESR6: Fully digital massive MIMO mmWave positioning
Host: Lund University, Lund, Sweden
Main supervisor: Prof. Michael Lentmaier [Lund University]
Co-supervisors/mentors: Prof. Joerg Widmer [IMDEA Networks], Prof. Fredrik Tufvesson [Lund University]
Required profile: Electrical Engineering, Information and Communication Technology, Engineering Physics, Engineering Mathematics

Desirable skills, interests and background: Wireless communication and signal processing, mathematical modelling and analysis, RF measurements; electromagnetics and antenna design; RF channel characterization and modelling (the applicant should be proficient in at least one or two of the skills)

Objectives:

To investigate high-resolution parameter estimation for localisation enabled by mmWave massive MIMO systems;

To analyse the performance loss when high-resolution information is unavailable (e.g., in codebook-based or phased array-based systems);

To extend the proposed methods to achieve centimetre-level accuracy even in challenging and dynamic augmented reality applications.

ESR7: Efficient network control for large and highly dense mmWave deployments

Host: IMDEA Networks Institute, Madrid, Spain

Main supervisor: Prof. Arturo. Azcorra [IMDEA Networks]

Co-supervisors/mentors: Dr. Claudio Fiandrino [IMDEA Networks]

Required profile: Electrical Engineering, telecommunications engineering or equivalent disciplines

Desirable skills/interests: Wireless networking, wireless communications, mobile network architectures, network simulators, scalable networking algorithms and protocols, optimization, signal processing (the applicant should be proficient in at least one or two of the skills)

Objectives:

To design low-overhead and scalable schemes that take advantage of the sparseness of the mmWave multi-path channel for beam training;

To design algorithms that maximise data rates by including a small amount of additional beam training that enables the measurement of the full CSI;

To design efficient scheduling mechanisms that maximise spatial reuse in dense scenarios.

ESR8: Ultra-dense cell-free mmWave deployment

Host: KU Leuven, Leuven, Belgium

Main supervisor: Prof. Sofie Pollin [KU Leuven]

Co-supervisors/mentors: Dr. Qing Wang [KU Leuven]; Prof. Fredrik Tufvesson [Lund University]

Required profile: Telecommunications, Electrical Engineering, Computer Science

Desirable skills/interests: Wireless networking protocols, network architecture, optimization, machine learning (the applicant should be proficient in at least one or two of the skills)

Objectives:

To design an algorithm to assign users to mmWave hybrid antennas in ultra-dense cell-free networks;

To optimize the management overhead of optimal user/antenna allocation;

To improve the scalability of cell-free mmWave networking by leveraging available network information such as the clients' location.

ESR9: Resilient multi-RAT techniques to reduce link failure rate

Host: NEC, Heidelberg, Germany

Main supervisor: Dr. Andres Garcia Saavedra [NEC]

Co-supervisors/mentors: Dr. Xi Li [NEC]; Prof. Matthias Hollick [TU Darmstadt]; Dr. Arash Asadi [TU Darmstadt]

Required profile: Telecommunications, Electrical Engineering, Computer Science

Desirable skills/interests: 4G/5G network protocols, optimization, machine learning, signal processing, CPU scheduling (the applicant should be proficient in at least one or two of the skills)

Objectives:

To improve the resilience of 4G/5G communications systems for private networks by designing innovative multi-RAT architectures, exploiting both high- and low- frequency technologies, and multi-RAT opportunities to meet vertical industries needs;

To devise an efficient handover scheme through low-layer packet encapsulation or inter-stack tunnelling in MAC layer.

ESR10: Prediction-based mobility management for resilient mmWave networking
Host: University of Padua, Padua, Italy
Main supervisor: Prof. Michele Zorzi [University of Padua]
Co-supervisors/mentors: Prof. Andrea Zanella [University of Padua]; Dr. Arash Asadi [TU Darmstadt]
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 an efficient mobility management system for mmWave devices requiring low overhead;
To design prediction mechanisms for efficient beam management in order to improve the reactiveness and reduce initial access delay;
To design adaptive algorithms to improve the resiliency of mmWave connection in highly-mobile scenarios.

ESR11: MAC/Physical layer security of mmWave networks
Host: TU Darmstadt, Darmstadt, Germany
Main supervisor: Prof. Matthias Hollick [TU Darmstadt]
Co-supervisors/mentors: Dr. Arash Asadi [TU Darmstadt]; Dr. Dave Singelee [KU Leuven]
Required profile: Electrical Engineering, Computer Science
Desirable skills/interests: Physical layer security, SDR-based wireless prototyping, Strong mathematical background (the applicant should be proficient in at least one or two of the skills)
Objectives:
To develop mechanisms for enhancing the security of mmWave-specific procedures, including beamforming and beam tracking;
To protect control frames from attacks via low-overhead authentication schemes;
To design physical layer security mechanisms to prevent eavesdropping and associated attacks via randomization (beam hopping, side-lobe gain modulation, etc.).

ESR12: Interference-aware multi-connectivity for industry 4.0
Host: TU Darmstadt, Darmstadt, Germany
Main supervisor: Prof. Anja Klein [TU Darmstadt]
Co-supervisors/mentors: Dr. Gek Hong Sim [TU Darmstadt]
Required profile: Electrical Engineering, Computer science, Applied Mathematics
Desirable skills/interests: Applied machine learning techniques, Stochastic modeling, SDR-based wireless prototyping (the applicant should be proficient in at least one or two of the skills)
Objectives:
To identify the number of simultaneous connections required in order to meet the desired level of reliability;
To develop algorithms that decide upon the number of connections adaptively based on the current failure rate of the links and the received interference;
To design algorithms for reducing the interference caused by the multi-connectivity.

ESR13: Delay jitter bounding through inter-layer coordination and multi-path for industry 4.0
Host: Nokia Bell Lab, Dublin, Ireland
Main supervisor: Dr. Stepan Kucera [Nokia Bell Lab]
Co-supervisors/mentors: Prof. Ronan Farrell [Maynooth University]; Prof. Michele Rossi [University of Padua]; Dr. Arash Asadi [TU Darmstadt]
Required profile: Electrical Engineering, Wireless Engineering

Desirable skills/interests: Signal processing, network protocols, optimization, programming & implementation skills, machine learning (the applicant should be proficient in at least one or two of the skills)
Objectives:
To achieve bounded end-to-end delay jitter by coordinating the beam selection dynamics at the physical layer with the rate-control dynamics at the transport layer;
To propose scheduling methods to optimize multi-path routing and the amount of traffic along each path;
To develop multi-path packet aggregation approaches at the MAC, network, and transport layers.

ESR14: Context- and content-awareness in V2X communication
Host: TU Darmstadt, Darmstadt, Germany
Main supervisor: Prof. Ralf Steinmetz [TU Darmstadt]
Co-supervisors/mentors: Prof. Matthias Hollick [TU Darmstadt]; Prof. Sofie Pollin [KU Leuven]
Required profile: Electrical Engineering, Computer Science, Applied Mathematics
Desirable skills/interests: Applied machine learning techniques, Stochastic modeling, Physical layer multicast (the applicant should be proficient in at least one or two of the skills)
Objectives:
To facilitate the transmission of large volumes of data in vehicular networks under high-speed mobility;
To devise proactive mechanisms that leverage on board sensors to trigger handover or beam alignment procedures;
To design physical layer multicasting approaches where a multi-lobe beam pattern is formed to communicate with several vehicles simultaneously.

ESR15: Real-time high-throughput AR
Host: KU Leuven, Leuven, Belgium
Main supervisor: Prof. Liesbet Van der Perre [KU Leuven]
Co-supervisors/mentors: Prof. Lieven De Strycker [KU Leuven]
Required profile: Electrical Engineering, telecommunications
Desirable skills/interests: Wireless communications, experimental electronics, embedded systems, sensor systems (the applicant should be proficient in at least one or two of the skills)
Objectives:
To devise methods that reduce the communication latency using spatial diversity and the multi-RAT capabilities of AR devices;
To enable GPS-less localization and positioning for AR devices using low-cost sensors in indoor scenarios;
To enhance the energy efficiency of AR hardware through energy-aware activation of sensors and RATs.

ETN MINTS project abstract and key project information

The global telecommunications market has become tremendously competitive due to the emergence of new Asian players and saturation of traditional products (e.g., mobile broadband), which has decelerated the growth of the EU's telecommunications market. Thus, without dramatic innovation to open up new markets, EU's telecommunications industry is at risk. However, new markets such as industry 4.0 and autonomous driving demands extremely high data rates which can only be provided at mmWave frequencies. To successfully overcome mmWave challenges, a closely integrated, skilled and multi-disciplinary team is needed to co-create innovative technology and applications. The ETN for MIllimeter-wave NeTworking and Sensing for Beyond 5G (MINTS) offers the first training program on mmWave networks that covers the full stack from physical layer to application. MINTS is an inter-sectoral and interdisciplinary cluster of excellence formed by electrical engineers and computer scientists aiming at innovative solutions for future mmWave networks and has pooled leading members of large EU initiatives (5G PPP), EU projects (ERC, H2020), and major telecommunications manufacturers (NOKIA, Sony, NEC), operators (e.g., Italtel, Proximus) and prototype providers (NI). MINTS lays the foundation for resilient mmWave networks by enhancing physical-layer robustness via dynamic

multi-beamforming techniques (WP1) and leveraging the directionality and broad communication bandwidth of mmWave systems for accurate environmental sensing (WP2). MINTS addresses the networking issues of dense mmWave systems through advanced interference control and secure algorithms (WP3) and devises application-specific solutions for emerging application of mmWave communications, including industry 4.0, V2X and augmented reality (WP4). The 15 ESRs in MINTS benefits from a comprehensive soft-skills training (WP5) and a tailored dissemination and exploitation strate-gy (WP6) which will boost their careers.

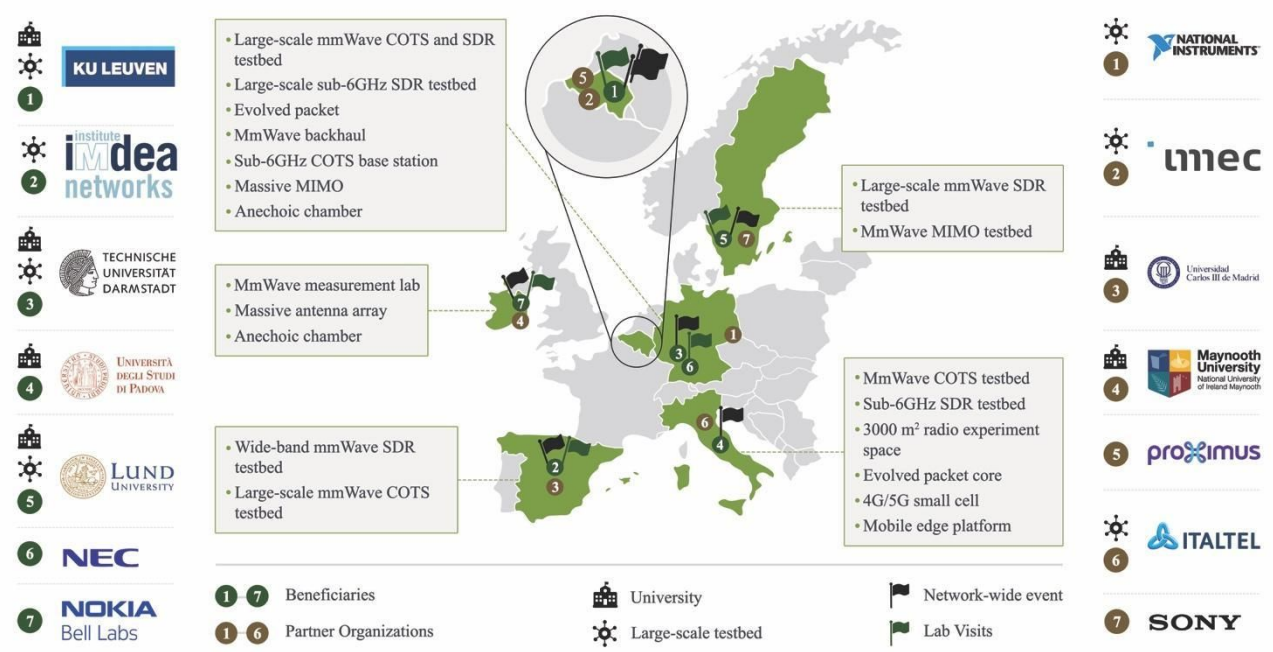

Figure 1. *MINTS Consortium*

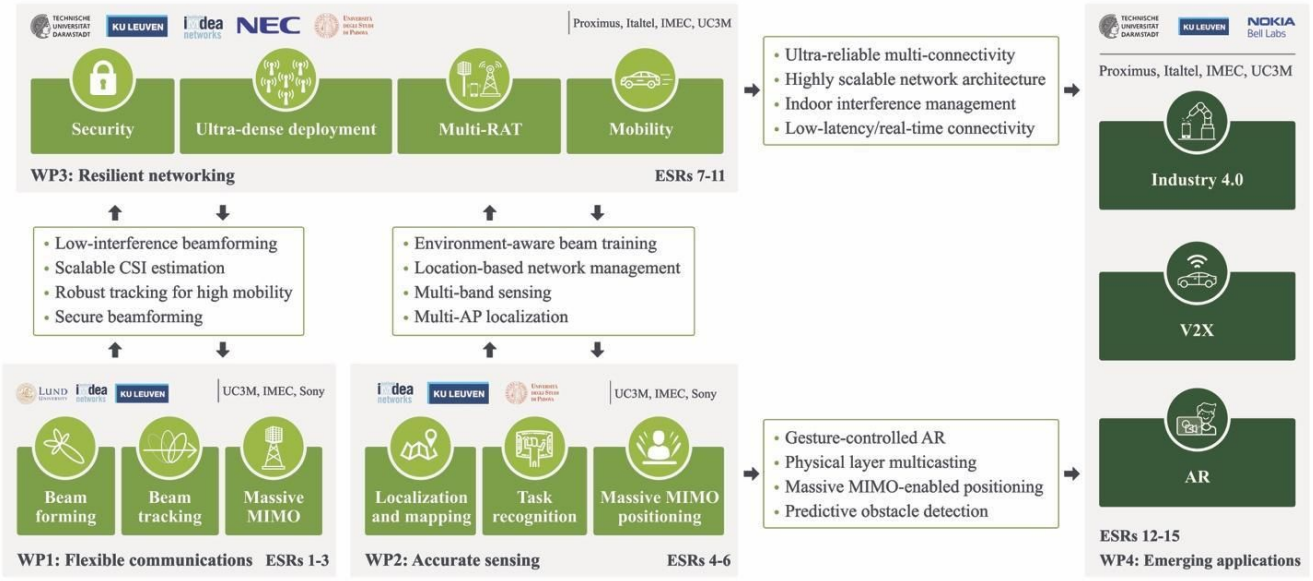

Figure 2. *MINTS WPs and ESRs*

MINTS 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: Flexible communications

Worldwide trials have shown the feasibility of such efficient mmWave communications in static point-to-point use cases, such as fixed wireless access. However, the low accuracy of the current beamforming techniques and the high overhead of antenna alignment lead to scalability issues and intermittent interference, specifically in dense deployments and dynamic scenarios. WP1 thus focuses on a more flexible physical layer design which accommodates such highly dynamic and dense scenarios. The three ESRs in WP1 will develop integrated techniques to enhance the accuracy of beamforming, while ensuring low beam maintenance overhead in order to increase the scalability of the proposed approaches. High mobility such as that of vehicles requires even more advanced approaches that take advantage of machine learning in order to reduce beam training latency and overhead. In particular, **ESR1** will develop customized beam patterns tailored for low-overhead channel estimation and efficient channel state information (CSI) measurement. Concurrently, **ESR2** will design hybrid multi-beam beamforming techniques to improve directivity, resilience and reduce unwanted interference from side lobes. **ESR3** will investigate fully digital, massive MIMO and distributed MIMO techniques to achieve ultra-resilient mmWave communications in highly varying environments.

WP2: Accurate sensing

RF signals of sub-6GHz wireless systems (e.g., WiFi) have been widely used for localization and recognition tasks. The rich multi-path and the ability to penetrate through obstacles enable human presence detection, movement tracking, and gesture recognition (even through walls). Moreover, characteristics of the received signal such as time of flight and angle of arrival can be analysed to estimate distances and identify obstacles, enabling both device localisation and environment mapping. However, the accuracy of sensing algorithms at sub-6GHz frequencies is limited due to interference from other devices, the low bandwidth and multi-path reflections. While the propagation characteristics of mmWave signals limit the sensing range, they enable much higher sensing accuracy due to the use of directional antennas, the short wavelength, the large bandwidth and reduced fading. The three ESRs in this WP will augment mmWave communication devices with high accuracy localization and sensing capabilities. Sensing techniques that jointly use both sub-6GHz and mmWave bands with their complementary propagation characteristics can further enhance sensing/localization range and coverage, while maintaining high accuracy. **ESR4** will design a high-accuracy mmWave location system based on angle, range and Doppler information. **ESR5** will study methods to recognize different movement patterns (e.g., walking, falling, robot versus person) by tracking the changes in the channel state of mmWave signals. **ESR6** will extend these approaches to fully digital massive MIMO transceivers, for parallel multi-channel estimation and tracking of multipath components. **ESRs 4-6** jointly work towards exploiting different frequency bands by using high-resolution channel information from both mmWave and long-range, low-penetration loss sub-6GHz signals.

WP3: Resilient networking

Accommodating the characteristics of mmWave frequencies not only triggered major modifications to the physical layer but also requires to adapt higher layers to implement important supporting functionalities. Since the majority of prior mmWave research focused on solving communication issues, networking challenges have largely remained unexplored. In particular, the rate requirements together with the high directionality of mmWave connections call for new approaches to enable ultra-dense and cell-free deployments; the susceptibility to blockage requires mechanisms to enhance the network resilience through multi-Radio Access Technology (RAT) designs, network support for fast handover and beam training mechanisms that can quickly recover from outages; finally, it is important to ensure the security of such new mmWave network functionalities.

MmWave signals face high penetration loss, as most construction and furnishing materials are opaque to mmWaves. This may induce frequent blockage and link outage in typical mmWave deployments. Ubiquitous mmWave coverage thus requires a very dense deployment of base stations, which gives rise to high interference, requiring advanced network management and control techniques. At the same time, ultra-dense

deployments are essential to limit the number of users per base station to achieve high per-user data rates. Therefore, **ESR7** will work towards devising methods to mitigate the impact of interference by leveraging location information for more accurate beamforming and scheduling techniques, which reduce the overall interference footprint and enhance spectral efficiency through high spatial reuse. **ESR8** will facilitate ultra-dense cell-free deployments with large numbers of low-cost and distributed hybrid antennas. This requires efficient allocation of users to antennas, as well as highly scalable scheduling and resource allocation schemes.

While mmWave systems provide short to medium communication ranges, high susceptibility to blockage and high throughput, sub-6GHz systems provide long range, comparatively lower throughput, and lower susceptibility to blockage. Hence, developing efficient systems that exploit these complementary frequency bands is key to highly resilient overall network designs. **ESR9** will investigate multi-RAT capabilities to leverage the sub-6GHz interface when a mmWave link is not available or Gbps data rates are not needed. In addition, low-overhead multi-RAT methods are designed to improve the resilience of wireless connectivity by seamlessly maintaining simultaneous connections to several RATs. MmWave connections in urban and mobile environments are particularly prone to interruptions, both because of blocking obstacles and because beam alignment may fail due to mobility. However, the structured nature of these obstacles (e.g., buildings, walls) and their order of appearance can be predicted. **ESR10** will study data-driven and machine learning-based techniques to enhance resilience through network support for efficient beam management and base station selection to proactively predict and counteract future link interruptions.

In terms of the security of mmWave systems, early studies argued that directionality eliminates the common security threats such as eavesdropping and man-in-the-middle attacks, since the attacker cannot overhear the transmission between the receiver and the transmitter without blocking the path between them. However, these studies overlooked both the presence of mmWave signals reflected by nearby obstacles and the large side-lobes caused by imperfect beamforming. This exposes the mmWave networks to attacks targeting not only the data plane but also the control plane, by manipulating beam alignment and beam tracking procedures. **ESR11** will devise security mechanisms which eliminate such attacks at the MAC layer via low-overhead control message authentication, and at the physical layer via channel and beam hopping techniques.

WP4: Emerging applications

MmWave communication will be the key enabler for the emerging disruptive technologies that not only demand very high QoS requirements in terms of data rate (Gbps), latency (< 5ms) and reliability (10^{-8} failure rate) but also operate in challenging environments with high mobility and ultra-dense deployments. This WP develops solutions to meet the requirements of three key applications, namely, industry 4.0, autonomous driving, and Augmented Reality (AR). The key premise of industry 4.0 is the use of high-performance wireless connectivity for the reliable exchange of information between sensory, monitoring, and control devices. The main reason that keeps industry from using wireless technologies is attributed to the lack of fiber-like reliability. While initial trials demonstrated that mmWave can provide the same data rates as fiber optics, the technology is far from providing fiber-like reliability. Autonomous vehicles and the vast amounts of sensor data they generate are the main drivers behind mmWave communication in V2X scenarios. While existing sub-6GHz standard (802.11p and LTE-V) can already accommodate a portion of V2X needs, their limited data rate cannot meet throughput requirements of autonomous driving for exchanging high-definition 3D maps, LIDAR, and other high-volume sensor information. However, maintaining highly directional mmWave links at vehicular speeds is a challenging task. Also AR is rapidly gaining importance in industry applications, training, remote assistance, etc. It critically relies on the high throughput of mmWave communications in order to offer interactive and real-time experiences whereby the real-world is augmented with information provided in real time by the cloud, or generated in the digital environment. However, the quality of this augmentation tightly depends on the timely delivery of information and on the precise knowledge of the device's location. Unfortunately, there is no one-size-fits-all solution for these applications, since their operating environment (e.g., mobility, density) and QoS requirements are very diverse. **ESRs 12-13** will contribute to the improvement of communication reliability for industry 4.0 applications. **ESR12** will devise multi-access techniques to increase resilience by eliminating a single-point-of-failure configuration and by allowing each device to maintain several mmWave

connections simultaneously. **ESR13** will design coordination schemes between the physical and the transport layers in order to bound the end-to-end jitter. This will ensure that the rate control mechanisms of such protocols as TCP are not affected by the high rate variability of mmWave links. Furthermore, **ESRs 12-13** will jointly investigate resilient multi-beam selection techniques for industrial environments . **ESR14** will devise fast handover and beam training techniques which exploit the multi-RAT capability of vehicles for low-overhead coordination, and will factor in the vehicle's sensing capabilities to improve context-aware beam training. **ESR14** will also develop mmWave V2V beam alignment methods within platoons, in order to maximise spatial reuse and reduce the load on the infrastructure. **ESR15** will study methods to minimize latencies and provide latency guarantees for AR applications. Also, mmWave localization techniques and the sensors integrated on AR headsets will be used for precise location and movement tracking required for AR applications in indoor and outdoor scenarios.

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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 MINTS 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 ESRs 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 ESR 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 ESRs (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 ESRs 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 ESRs 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 15 ESRs 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 MINTS Network Wide Events (M8) in order to deliver specific action plans to target specific networks relevant for the vacant ESR positions.

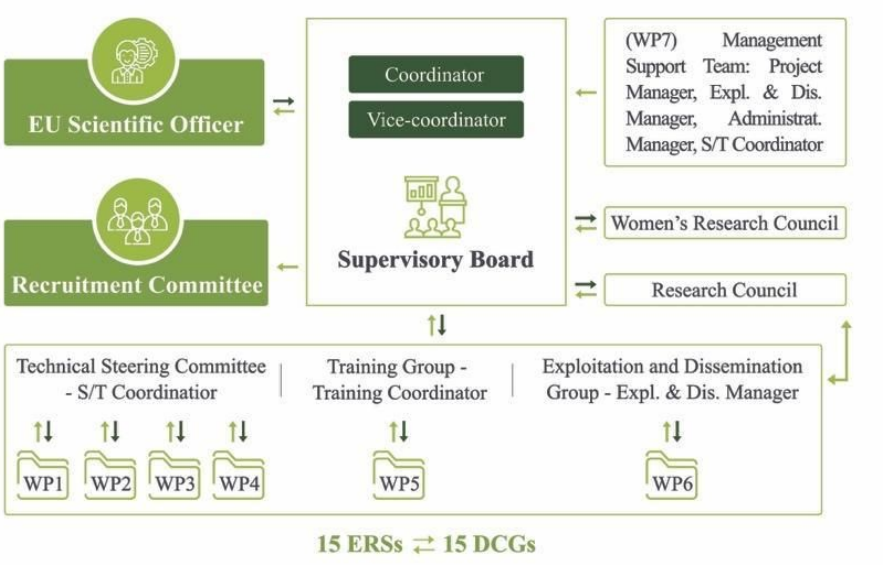

Figure 3. *MINTS Management Structure*

Recruitment Committee: This committee involves the General Coordinator, the Scientific Coordinator, and one representative from each beneficiary. The recruitment committee oversees the recruitment of15 ESRs during the collective recruitment event.