POLITECNICO DI MILANO

# PhD in INGEGNERIA DELL'INFORMAZIONE / INFORMATION TECHNOLOGY - 41st cycle

### Research Area n. 4 - Telecommunications

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| **Number of scholarship offered** | 3 |
| **Department** | DIPARTIMENTO DI ELETTRONICA, INFORMAZIONE E BIOINGEGNERIA |

**Description of the Research Area**

The research in the Telecommunications Area of the Ph.D. Programme in Information Technology at the Department of Electronics, Information and Bioengineering (DEIB) is organized along these lines:

•**Communications:** the main research topics are Applied Electromagnetics with particular attention to Innovative techniques for microwave circuits design, and numerical methods for electromagnetics; Information Transmission and Radio Communications with principal attention to modulation, detection theory, channel estimation and equalization, synchronization, information theory, block codes and algebraic decoding, and turbo-like codes with iterative decoding; Optical Communications, including Quantum Key Distribution, both from the system and component point of views; Wireless and Space Telecommunications (terrestrial and space telecommunications using centimeter, millimeter and optical wavelengths, identification and modeling of the radio-channel properties, design of advanced satellite-based telecommunication and broadcasting systems at centimeter and millimeter waves).

•**Networks**: the research topics focus on 5G/6G Radio Access Networks, Internet of Things, autonomic and sustainable optical and microwave networks, network softwarization (SDN, NFV), network programmability (P4), security and cryptography, Artificial Intelligence for network management, and novel network platforms for a wide range of rising applications as smart cities, sustainable mobility, disaster resiliency, e-health, etc.

•**Sensors**: the research topics focus on Remote Sensing and Signal Processing for Multimedia and Telecommunications. The activities in Remote Sensing focus on the design of innovative systems, applications and processing methods, based on imaging Synthetic Aperture RADAR (automotive, drones and cubesat/spaceborne MIMO swarms), on the study and implementation of methods and systems for assessing and tracking the integrity of pipelines transportation

assets (detection of leaks, corrosion, threats, pumps failure), and on the imaging and multidomain inversion of the properties of the subsurface for hydrocarbons exploration.

See https://www.deib.polimi.it/eng/telecommunications and the personal web pages of the faculty members involved in the Telecommunications Area for more information on the current research activities.

All the research activities carried out within the Telecommunication Area are characterized by a high level of interdisciplinary ranging from mathematics, physics, computer science, digital mono/multi-dimensional signal processing and obviously topics traditionally connected to telecommunications and remote sensing.

The Telecommunications area is characterized by strong connections with Universities and Research Centers in Europe and outside Europe, but also by a strict cooperation with leading-edge companies active in the Telecommunication/Remote-Sensing/Multimedia markets and also outside these areas offering to PhDs effective possibilities to found excellent job opportunities in high-tech companies.

Further information:
- Research at the DEIB Department: https://www.deib.polimi.it/eng/
- PhD Programme in Information Technology (IT PhD): https://dottoratoit.deib.polimi.it/
- Telecommunications Section at DEIB: https://www.deib.polimi.it/eng/telecommunications

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## Research Area n. 4 - Telecommunications

**THEMATIC Research Field: ENHANCING THE SIMULATION ACCURACY OF 6G NETWORKS THROUGH REAL-TIME GEOMETRIC CHANNEL MODELING IN DIGITAL NETWORK TWINS**

| Monthly net income of PhDscholarship (max 36 months) |
|---|
| € 1400.0 |
| In case of a change of the welfare rates during the three-year period, the amount could be modified. |

| Context of the research activity | |
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| **Motivation and objectives of the research in this field** | The growing complexity of 6G networks demands more accurate tools for simulation, management, and optimization. As 6G networks evolve, traditional methods for network simulation face limitations in terms of accuracy, flexibility, and scalability. These challenges are intensified by the need to support multiple Radio Access Technologies (RATs) and the diverse environmental conditions that affect wireless communication. The emerging concept of Digital Network Twins (DNTs) represents a promising solution, providing a virtual representation of physical networks that can be used for experimentation, analysis, and validation before real-world deployment. While network simulators have been widely used, they are often based on deep abstractions that fail to fully capture the intricacies of network behavior. The need for more accurate, dynamic, and multi-layered simulations has driven the integration of advanced channel modeling techniques, such as ray-based link-level simulators, into network simulators like Network Simulator 3 (ns-3). This integration has the potential to significantly improve simulation accuracy and provide a more realistic approach to managing 6G networks. The primary objective of this research is to develop an open-source, full-stack DNT capable of supporting multiple RATs, with a focus on improving the accuracy of network |

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| | simulations through the integration of ray-based channel characterization into the well-established ns-3 framework. The specific objectives include: <br> 1. Designing and developing a modular framework to implement a flexible, scalable integration of a ray-based channel model within ns-3, enabling high-accuracy simulations across different network layers. <br> 2. Enhancing the accuracy of wireless network simulations by incorporating a deterministic, site-specific ray tracer for precise channel modeling, addressing the limitations of traditional stochastic models. <br> 3. Validating the proposed approach by conducting field measurements in both rural and urban environments, ensuring the ray tracer accurately replicates real-world propagation conditions. <br> 4. Evaluating performance to assess how improved physical-layer modeling impacts higher network layers, with a focus on comparing discrepancies between traditional stochastic models and ray-tracing enhanced simulations. <br> 5. Addressing the limitations of stochastic models by quantifying the inaccuracies they introduce in network simulations, using different metrics like Packet Reception Ratio (PRR) and Packet Reception Disagreement Ratio (PRDR). |
| **Methods and techniques that will be developed and used to carry out the research** | The research methodology will include: <br> 1. Literature review on Digital Network Twins (DNTs), ray-based channel modeling, and current network simulators for 6G networks. <br> 2. Integration of ray-based channel modeling into ns-3 for enhancing simulation accuracy across multiple network layers and RATs. <br> 3. Development of a modular framework to incorporate a deterministic, site-specific ray tracer for precise channel modeling. |

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| | 4. Performance evaluation of developed simulation framework and its validation through real-world measurements in urban and rural environments to ensure accurate replication of propagation conditions |
| **Educational objectives** | 1) Develop expertise in Digital Network Twins (DNTs) and their application in 6G network simulations.<br>2) Gain advanced skills in integrating ray-based channel modeling within network simulation frameworks like ns-3.<br>3) Enhance research skills by validating network simulation models through real-world field measurements.<br>4) Strengthen analytical abilities to evaluate the impact of high-accuracy physical-layer modeling on network performance.<br>5) Improve scientific communication through research dissemination in publications and presentations.<br> 6) develop team working skills through the collaboration with the research groups on both theoretical and practical topics; and develop skills for life-long learning and professional development |
| **Job opportunities** | For the ambitious and disruptive objectives of the research, as well as for the reputation of the involved research groups, it is expected that after completion of the PhD program the candidate will be ready for being part of any research team in public and private institutions and centers, universities, and industry. |
| **Composition of the research group** | 1 Full Professors<br>1 Associated Professors<br>2 Assistant Professors<br>10 PhD Students |
| **Name of the research directors** | Prof. Antonio Capone and Prof. Maurizio Magarini |

| **Contacts** |
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| antonio.capone@polimi.it<br>maurizio.magarini@polimi.it |

| **Additional support - Financial aid per PhD student per year (gross amount)** |
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**POLITECNICO DI MILANO**

| Housing - Foreign Students | -- |
|---|---|
| Housing - Out-of-town residents | -- |

| Scholarship Increase for a period abroad | |
|---|---|
| Amount monthly | 700.0 € |
| By number of months | 6 |

| Stage and period abroad | |
|---|---|
| Institution or company where the candidate will spend the period abroad (name and brief description) | |
| By number of months abroad | 0 |

| Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information |
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EDUCATIONAL ACTIVITIES (purchase of study books and material, including computers, funding for participation in courses, summer schools, workshops and conferences).

TEACHING ASSISTANTSHIP: availability of funding in recognition of supporting teaching activities by the PhD student.
There are various forms of financial aid for activities of support to the teaching practice.
The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.

COMPUTER AVAILABILITY:
1st year: Yes
2nd year: Yes
3rd year: Yes

DESK AVAILABILITY:
1st year: Yes
2nd year: Yes
3rd year: Yes

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## Research Area n. 4 - Telecommunications

### OPEN SUBJECT Research Field: TELECOMMUNICATIONS

| Monthly net income of PhDscholarship (max 36 months) |
|---|
| **€ 1400.0**<br>In case of a change of the welfare rates during the three-year period, the amount could be modified. |

| Context of the research activity | |
|---|---|
| **Motivation and objectives of the research in this field** | The research field Telecommunications is focused on the design and implementation of devices, systems, networks (Internet, wireless networks, optical networks), services, and applications for the transmission and the processing of any type of signals (including audio, video, RADAR) and multimedia information. Particular attention is given to advanced networks and transmission systems for mobile and fixed users and to remote sensing applications aiming at earth observation and sub-soil exploration. The strong connection with leading companies (within and outside the telecommunication market) makes the mix between theory and application one of the strengths of the Telecommunications research field at Politecnico di Milano.<br><br>http://www.deib.polimi.it/eng/telecommunications |
| **Methods and techniques that will be developed and used to carry out the research** | The research is carried out with the support of a supervisor and of his research group. Seminars and courses are offered to encourage an interdisciplinary approach to the research. Computer simulation and/or laboratory activities are always required to finalize the research. |
| **Educational objectives** | The doctoral program offers advanced training in the hot topics explored by the scientific community and industry. |

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| | A period of study within one among the worldwide most recognized research institutions is supported by the doctoral school and the supervisor.<br><br>http://dottoratoit.deib.polimi.it/ |
| **Job opportunities** | Careers in the leading telecommunication, remote sensing, multimedia companies are facilitated by the strong connection between the academic and industrial research. Post doc positions in the university are frequently offered. |
| **Composition of the research group** | 11 Full Professors<br>20 Associated Professors<br>11 Assistant Professors<br>57 PhD Students |
| **Name of the research directors** | Any faculty member can act as research advisor |

| Contacts |
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| Prof. Massimo Tornatore<br>Coordinator of the Telecommunications area<br>E-mail: massimo.tornatore@polimi.it<br>Phone: +39 02 2399 3683<br>Web: https://www.deib.polimi.it/eng/people/details/339682<br><br>Prof. Luigi Piroddi<br>Coordinator of the Ph.D. IT Programme<br>E-mail: luigi.piroddi@polimi.it<br>Phone: +39 02 2399 3556<br>Web: https://www.deib.polimi.it/eng/people/details/318548 |

| Additional support - Financial aid per PhD student per year (gross amount) | |
|---|---|
| **Housing - Foreign Students** | -- |
| **Housing - Out-of-town residents** | -- |

| Scholarship Increase for a period abroad | |
|---|---|
| **Amount monthly** | 700.0 € |
| **By number of months** | 6 |

| Stage and period abroad |
|---|

| Institution or company where the candidate will spend the period abroad (name and brief description) | |
|---|---|
| By number of months abroad | 0 |

**Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information**

EDUCATIONAL ACTIVITIES (purchase of study books and material, including computers, funding for participation in courses, summer schools, workshops and conferences).

TEACHING ASSISTANTSHIP: availability of funding in recognition of supporting teaching activities by the PhD student.
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The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.

COMPUTER AVAILABILITY:
1st year: Yes
2nd year: Yes
3rd year: Yes

DESK AVAILABILITY:
1st year: Yes
2nd year: Yes
3rd year: Yes