POLITECNICO DI MILANO

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

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	
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

	simulations through the integration of ray-based channel characterization into the well-established ns-3 framework. The specific objectives include: 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. 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. 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. 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. 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: 1. Literature review on Digital Network Twins (DNTs), ray-based channel modeling, and current network simulators for 6G networks. 2. Integration of ray-based channel modeling into ns-3 for enhancing simulation accuracy across multiple network layers and RATs. 3. Development of a modular framework to incorporate a deterministic, site-specific ray tracer for precise channel modeling.

	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. 2) Gain advanced skills in integrating ray-based channel modeling within network simulation frameworks like ns-3. 3) Enhance research skills by validating network simulation models through real-world field measurements. 4) Strengthen analytical abilities to evaluate the impact of high-accuracy physical-layer modeling on network performance. 5) Improve scientific communication through research dissemination in publications and presentations. 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 1 Associated Professors 2 Assistant Professors 10 PhD Students
Name of the research directors	Prof. Antonio Capone and Prof. Maurizio Magarini

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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.
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