

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

**DOTTORATO DI RICERCA / PhD PROGRAM IN  
INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING**

## **Activities and Publications Report**

**PhD Student: Jessica Illiano**

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**Student ID: DR995140**

**PhD Cycle: XXXVI**

**PhD Cycle Chairman: Prof. Stefano Russo**

**PhD program student's start date: 01/11/2020**

**PhD program student's end date: 31/10/2023**

**Supervisor: Angela Sara Cacciapuoti**

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**Co-supervisor: Antonio Manzalini**

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**PhD scholarship funding entity:**

**TIM S.p.A.**

## General information

In 2020 Jessica Illiano received the Master Science degree in Telecommunication Engineering from the University of Napoli Federico II. She attended a curriculum in Telecommunication Engineering within the PhD program in Information Technology and Electrical Engineering. She received a grant from Tim S.p.A. .

## Study activities

### Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organization
1	Quantum Information	MSc course	6	Prof.ssa Angela Sara Cacciapuoti	University of Naples Federico II
1	Nanotechnologies for Electrical Engineering	MSc course	6	Prof. Carlo Forestiere	University of Naples Federico II
1	Introduzione ai circuiti quantistici	MSc course	9	Prof. Giovanni Miano	University of Naples Federico II
2	Quantum Photonic Technologies	Ad hoc course	4	Prof. Marco Bellini (CNR - INO, Florence)	University of Naples Federico II
3	-	-	-	-	-

### Attended PhD Schools

Year	School title	Location	Credits	Dates	Organization
1 <sup>st</sup>	IEEE/DEISummer Ph.D. School of Information Engineering “SilvanoPupolin”– SSIE2021	Online	5	12-16/07/2021	Università degli Studi di Padova
1 <sup>st</sup>	Quantum Technologies PhD Summer School	Online	4,6	13-17/09/2021	UNINA Department of Physics
2 <sup>nd</sup>	SQMS/GGI Summer School on Quantum Simulation of Field Theories	Online	4.5	25-29/07/2022	Galileo Galilei Institute

### Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organization
1 <sup>st</sup>	Quantum Simulators	0.2	Prof. Rosario Fazio	University of Naples Federico II	Department of Physics
1	Robot manipulation and control	0.5	Prof. Bruno Siciliano	University of Naples Federico II	Scuola Superiore Sant’Anna
1	How to get published with IEEE	0.3	Rachel Berrington	IEEE	IEEE

## Activities and Publications – Final Report

UNINA PhD in Information Technology and Electrical Engineering – XXXVI Cycle

PhD candidate: Jessica Illiano

1	GDPR basics for computer scientists	0.3	Dr. Rigo Wenning	European Research Consortium for Informatics and Mathematics	UNINA DIETI
1	Advances in Machine Learning for Modelling and Understanding in Earth Sciences	0.3	Prof. Gustau Camps-Valls	Dept. Electrical Engineering - Universitat de València	University of Napoli Federico II
1	Dai mainframe all'IoT	0.4	Prof. Antonio Mazzeo	University of Napoli Federico II	University of Napoli Federico II
1	IEEE Authorship and OA symposium	0.3	Rachel Berrington	IEEE	IEEE
1	Second Quantum Revolution: innovation trends and expected industrial impacts	0.4	Prof. Angela Sara Cacciapuoti	Unina Dieti	University of Napoli Federico II
1	Artificial Intelligence and 5G combined with holographic technology: a new perspective for remote health monitoring	0.4	Dr. Pietro Ferraro, Dr. Pasquale Memmolo	ISASI	University of Napoli Federico II
1	TeamUp5G Workshop on Ethics and Inclusiveness for Telecommunications Engineers	2	Prof. Ana García Armada	University Carlos III of Madrid, Spain	University Carlos III of Madrid, Spain
2 <sup>nd</sup>	Entanglement transitions in the quantum Ising chain: A comparison between different unravelings of the same Lindbladian	0.1	Dr. Angelo Russomanno	Scuola Superiore Meridionale, Napoli	University of Napoli Federico II
2	Seeqc: the digital quantum computing company	0.2	Dr. Marco Arzeo	Seeqc-EU srl	University of Napoli Federico II
2	Cavity magnonics in strong coupling regime – from magnon-polariton hybrid states to perspectives for quantum sensing	0.2	Prof. Giuseppe Maruccio	Università del Salento	University of Napoli Federico II
2	The Quantum Internet: the quest for a network paradigm shift	0.1	Prof.ssa Angela Sara Cacciapuoti	UNINA DIETI	University of Napoli Federico II
3 <sup>rd</sup>	Game Theory for Information Engineering	0.6	Prof. Leonardo Badia	University of Padua, ITALY	University of Napoli Federico II

3 <sup>rd</sup>	Unleash the impact of your research with video and graphical abstracts	0.2	Dr. Tulio Rossi	Director at Animate Your Science	DIETI
3	Quantum communications with continuous variables of light	0.3	Dr. Cosmo Lupo	Politecnico di Bari	University of Naples Federico II
3	Corso di Formazione progettazione europea modulo 1, fondi europei e programmazione 2021/2027	0.4	Tommaso Foglia	MUR	University of Naples Federico II
3	Corso di Formazione progettazione europea modulo 2, Panoramica delle opportunità di finanziamento	0.6	Tommaso Foglia	MUR	University of Naples Federico II
3	Corso di Formazione progettazione europea modulo 3, tecniche e metodi per la redazione dei progetti	0.6	Tommaso Foglia	MUR	University of Naples Federico II
3	APRE Autumn School	4.6	Matilde De Bonis	APRE	APRE

### Research activities

During her PhD program, Jessica Illiano investigated the challenges arising from the design of the Quantum Internet protocol stack. Specifically, she examined in depth the impact of *entanglement* on such a design. Entanglement plays a pivotal role for the Quantum Internet, serving not only as a key communication resource but also as an enabler for quantum network functionalities. Stemming from such a deep analysis, she focused on different network functionalities, including the *entanglement access*. Specifically, she designed and analyzed the protocol named Entanglement Access Control Protocol (EAC) that exploits two multipartite entangled states for solving the entanglement access. Then, she modelled the noisy entanglement distribution with a discrete Markov chain. The theoretical framework developed for the EAC performance analysis gave birth to an additional open problem, namely, the optimization of the number of attempts required to finalize the distribution process. Indeed, there exists a trade-off between the average time interval employed for the distribution and the number of nodes that access to the entangled resource. Jessica Illiano tackled the optimization of this trade-off through a Markov decision. Her research activities on the impact of entanglement on the design of the Quantum Internet protocol stack continued by investigating the facets of the *classical-quantum interface*, namely, an interface enabling a bi-directional interplay between the classical Internet and the Quantum Internet.

The analysis of the impact of entanglement on the design of the Quantum Internet have been further discussed by Jessica Illiano with an application-oriented perspective with respect to the

Distributed Quantum Computing. Finally, she participated in the investigation on an additional functionality for the Quantum Internet, namely, the quantum addressing.

### Tutoring and supplementary teaching activities

Preparation and participation to the event “Porte Aperte Ingegneria 2023”.

#### Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1 <sup>st</sup>	21	9,7	30,5	0
2 <sup>nd</sup>	9	6,5	56,6	0
3 <sup>rd</sup>	0	7,3	55,8	0,3

### Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
1 <sup>st</sup>	Nu Quantum L.t.d	Carmen Palacios Berraquero, CEO		<input type="checkbox"/> Research on entanglement scheduler for ion-based computing platform <input type="checkbox"/> Joint scientific contribution preparation for QCTiP23.

### PhD Thesis

In the PhD Thesis, Jessica Illiano discussed the challenges arising from the design of the Quantum Internet protocol stack. The Quantum Internet, namely, the global communication network interconnecting heterogeneous quantum networks, is governed by the laws of quantum mechanics which impose constraints with no counterpart in the classical networks. Indeed, the communication primitives underlying the classical Internet are challenged in the Quantum Internet. Her thesis delves into the design of the Quantum Internet by deeply investigating the impact of quantum phenomena on communication protocols and network functionalities. Specifically, the thesis examines the impact of the most distinctive feature of quantum mechanics, namely, the phenomenon of *quantum entanglement*, on the Quantum Internet protocol stack design. Entanglement plays a pivotal role for the Quantum Internet, serving not only as a key communication resource but also as an enabler for quantum network functionalities. Indeed, it enables a new concept of connectivity referred to as *entanglement-based connectivity*, which profoundly impacts on the design of the Quantum Internet protocol stack. Stemming from such a deep analysis, the focus has been on different network functionalities, including the *entanglement access*. Specifically, the *entanglement access* is examined with the design and the analysis of a genuinely quantum protocol, i.e., the *Entanglement Access Control* (EAC) protocol, able to deterministically solve the contention of a shared resource. The impact of entanglement on the

Quantum Internet protocol stack design is further analyzed by investigating the facets of the *classical-quantum interface*, namely, an interface enabling a bi-directional interplay between the classical Internet and the Quantum Internet. Indeed, the Quantum Internet cannot operate independently nor autonomously from the classical Internet as quantum network functionalities, such as the entanglement distribution, demand for a tight cross-layered interplay with the classical Internet protocol stack.

## Publications

Research results appear in 6 papers published/or under review in international journals, 6 contributions to international conferences, 1 published book chapter.

## List of scientific publications

### International journal papers

- J. Illiano, M. Caleffi, A. Manzalini, A. S. Cacciapuoti  
Quantum Internet Protocol Stack: a Comprehensive Survey,  
*Computer Networks*,  
vol. 213, August 2022, 109092,  
doi: 10.1016/j.comnet.2022.109092
- A. S. Cacciapuoti, J. Illiano, S. Koudia, K. Simonov, M. Caleffi,  
The Quantum Internet: enhancing Classical Internet Services one Qubit at a Time,  
*IEEE Network*,  
vol.36,no.5,pp 6-12, September/October2022.  
doi: 10.1109/MNET.001.2200162.
- A. S. Cacciapuoti, J. Illiano, M. Caleffi,  
Quantum Internet Addressing,  
*to appear on IEEE Network, 2023.*
- A. S. Cacciapuoti, M. Viscardi, J. Illiano, M. Caleffi,  
Entanglement Distribution in The Quantum Internet: Knowing when to Stop!,  
arXiv:2307.05123, July 2023, *under review*
- J. Illiano, M. Caleffi, M. Viscardi, A. S. Cacciapuoti,  
Design and Analysis of Genuine Entanglement Access Control for the Quantum Internet,  
arXiv:2305.01276, May 2023, *under review*
- M. Caleffi, M. Amoretti, D. Ferrari, D. Cuomo, J. Illiano, A. Manzalini, A. S. Cacciapuoti,  
Distributed Quantum Computing: a survey,  
arXiv:2212. 10609, December 2022, *under review*



## International conference papers

- L. D'Avossa, M. Caleffi, C. Wang, J. Illiano, S. Zorzetti, A.S. Cacciapuoti,  
Towards the Quantum Internet: entanglement rate analysis of high-efficiency electro-optic transducer, *to appear on Proc. of IEEE International Conference on Quantum Computing (QCE23)*, Sep 17–22, 2023 Bellevue, Washington, Hyatt Regency Bellevue on Seattle's Eastside.
- M. Viscardi, J. Illiano, A.S. Cacciapuoti, M. Caleffi  
Entanglement Distribution in the Quantum Internet: an optimal decision problem formulation, *to appear on Proc. of IEEE International Conference on Quantum Computing (QCE23)*, Sep 17–22, 2023.
- A.S. Cacciapuoti, J. Illiano, M. Viscardi, M. Caleffi,  
Quantum Internet: the Dawn of the Quantum Paths, *Invited Paper, Proc. of ACM International Conference on Nanoscale Computing and Communication (ACM NANOCOM '22)*, October 5–7, 2022,  
doi:10.1145/3558583.3558860.
- J. Illiano, M. Viscardi, S. Koudia, M. Caleffi, A.S. Cacciapuoti.  
Quantum Internet: from Medium Access Control to Entanglement Access Control, *Proc. of IEEE Globecom 2022*, pp. 1329-1334,  
doi: 10.1109/GCWkshps56602.2022.10008516.
- M. Caleffi, J. Illiano, S. Koudia. A.S. Cacciapuoti.  
The Quantum Internet: a Communication Engineering Perspective, *Proc. of IEEE International Conference on Quantum Computing and Engineering (QCE)*, 2021, pp. 365-365,  
doi: 10.1109/QCE52317.2021.00054.
- J. Illiano, A. S. Cacciapuoti, A. Manzalini, M. Caleffi,  
The Impact of the Quantum Data Plane Overhead on the Throughput, *Proc. of ACM International Conference on Nanoscale Computing and Communication (ACM NANOCOM'21)*, September 2021, Pages 1–6,  
doi:10.1145/3477206.3477448.

## Published Book Chapter

J. Illiano, A. S. Cacciapuoti,  
On the Entanglement Role for the Quantum Internet.  
In: M.S. Greco, D. Cassioli, S.L. Ullo, M. J. Lyons, (eds) *Women in Telecommunications. Women in Engineering and Science.*  
*Springer*, Cham. DOI:10.1007/978-3-031-21975-7\_13

Date 20/10/2023

PhD student signature

Jessica Illiano

Supervisor signature

Angela Sore Cacciapuoti