Jessica Illiano

Quantum Communication Protocols for Quantum Security and Quantum Internet

Tutor: Prof.ssa Angela Sara Cacciapuoti

co-Tutor: Dr. Antonio Manzalini (TIM)

Cycle: XXXVI Year:First

My background

- MSc degree in Telecommunication Engineering
- Quantum Internet Research group

  http://www.quantuminternet.it

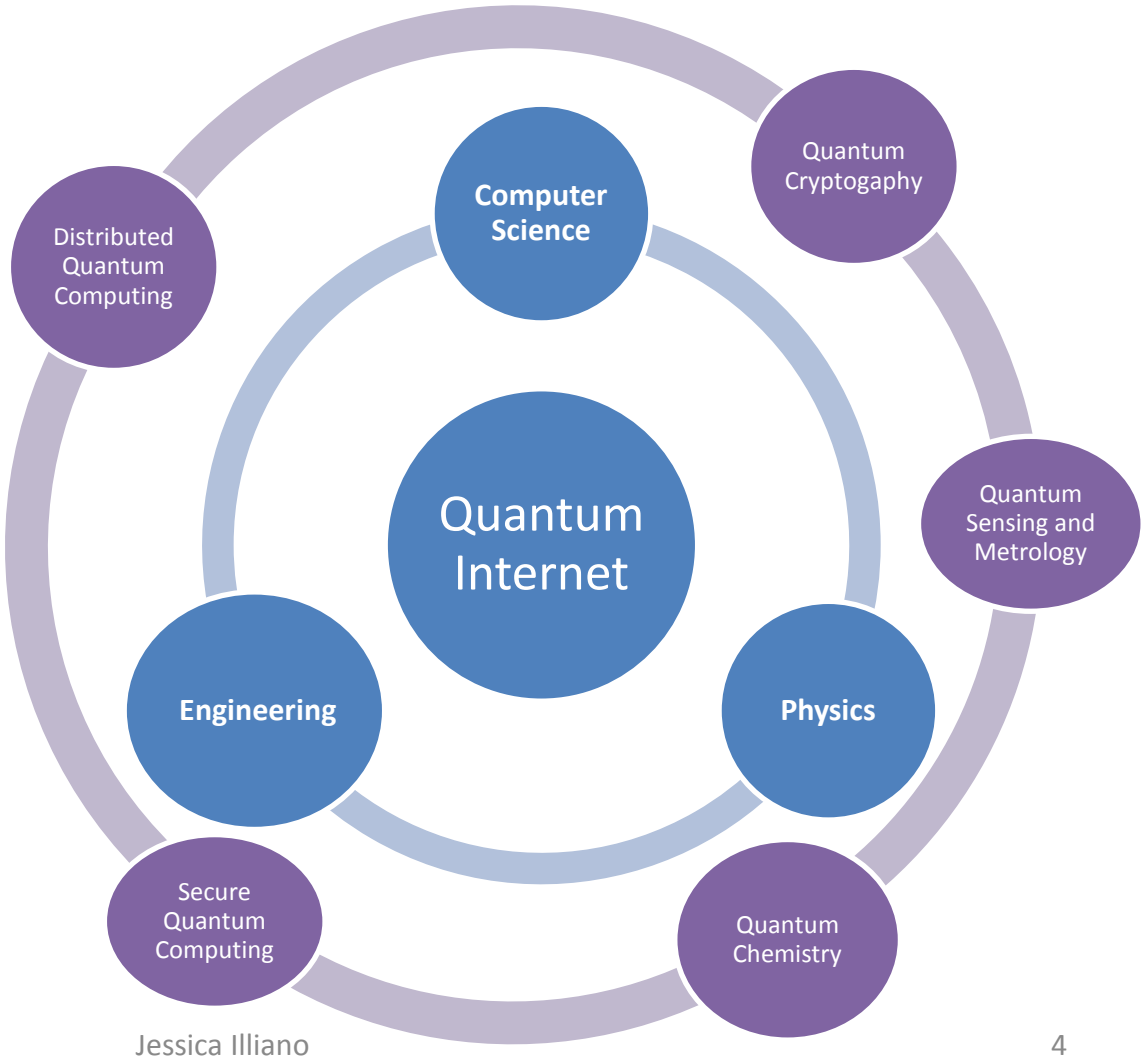
- PhD start date: 1/11/2020
- Company founded Scholarship
- Partner company: TIM S.p.A.

Research field of interest: Quantum Internet

Quantum Network

Collection of nodes that is able to exchange qubits and distribute entangled states amongst themselves.

- Qubits
- No Cloning Theorem
- Entanglement
- Quantum Teleportation process



Summary of study activities

- Courses borrowed from MSc curricula :
  - Quantum Information (6 CFU)
  - Nanotechnologies for Electrical Engineering (6 CFU)
  - Introduction to Quantum Circuits (9 CFU)

- Seminars (partial list) :
  - Quantum Simulators
  - Second Quantum Revolution: innovation trends and expected industrial impacts
  - TeamUp5g Workshop on Ethics and Inclusiveness for Telecommunications Engineers

- IEEE/DEI Summer Ph.D. School of Information Engineering “SilvanoPupolin”–SSIE2021
- PhD Summer School of Quantum Technologies
  - Student Presentation: On The Impact of the Quantum Data Plane on the Throughput
- Attended Conferences :
  - ACM NanoCom2021, 8th ACM International Conference on Nanoscale Computing and Communication Virtual Conference (Conference paper “On The Impact of the Quantum Data Plane on the Throughput “ presented)
- Side Activity :
  - TIM Remote Shadow Experience: soft skills

Research activity: Overview

- Problem:

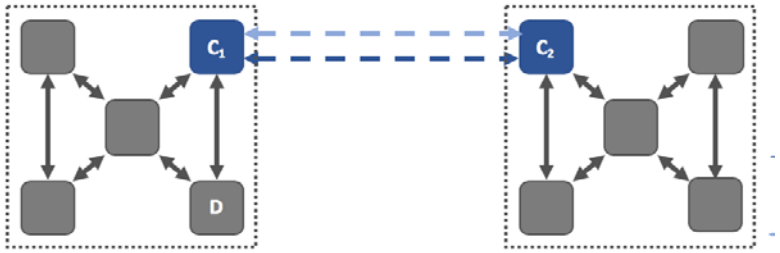
  The Quantum Internet is governed by the laws of quantum mechanics and it is based on phenomena with no counterpart in classical networks. This imposes new challenging constraints for network design. Specifically, classical network functionalities are based on the assumption that classical information can be safely read and copied. This assumption does not hold in the Quantum Internet. As a consequence, its design requires a major network-paradigm shift to harness the quantum mechanics specificities.

- Objective:
  - Interaction between classical network and quantum network
  - Network protocol stack for the Quantum Internet

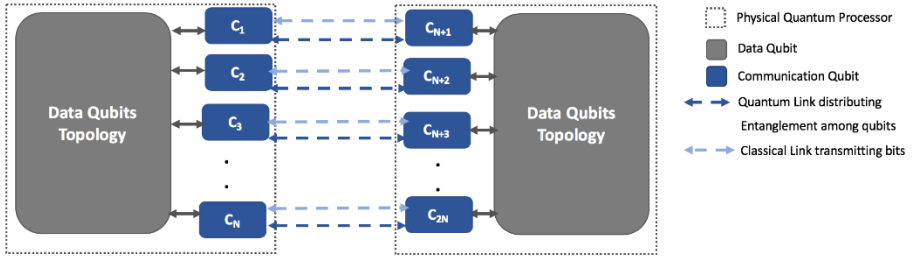
- Methodology:
  - Study of the characterizing phenomena
  - System Model
  - Mathematical Analysis
  - Numerical Simulations

Research activity: Interaction between classical network and Quantum Network

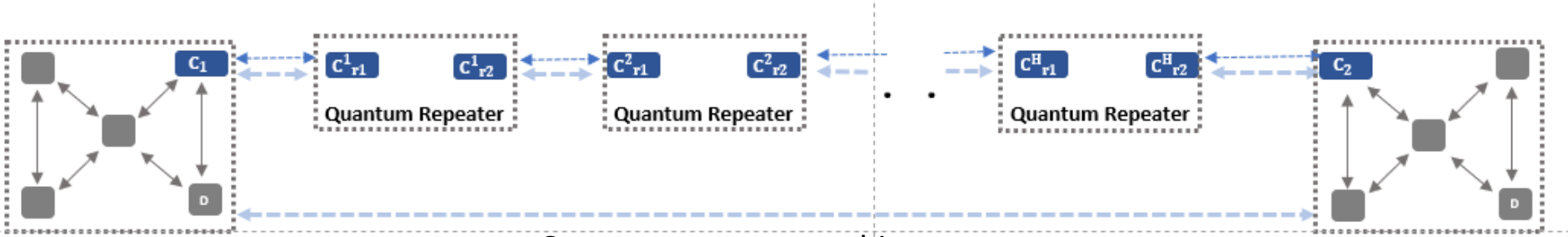
The Impact of the Quantum Data Plane Overhead on the Throughput



Single communication qubit



Multiple communication qubits

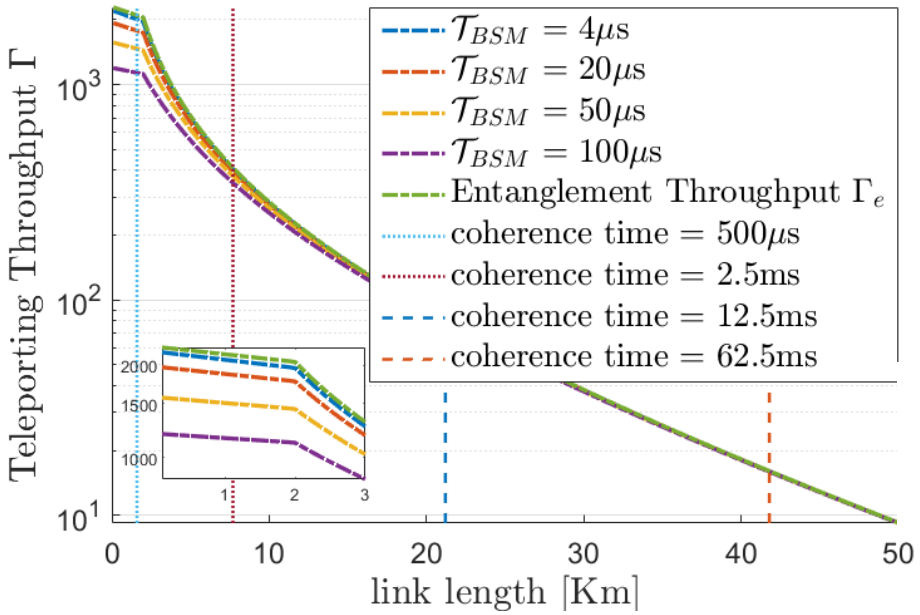


Quantum repeater architecture

Jessica Illiano, Angela Sara Cacciapuoti, Antonio Manzalini and Marcello Caleffi. "*The Impact of the Quantum Data Plane Overhead on the Throughput*". Proc. of The Eight Annual ACM International Conference on Nanoscale Computing and Communication (NANOCOM '21) September 7–9, 2021.

Interaction between classical network and Quantum Network

The teleporting throughput as a function of the link length.



Distance threshold

Entanglement Throughput

$$\Gamma_e \triangleq \frac{1}{\mathcal{T}_e}$$

Teleporting Throughput

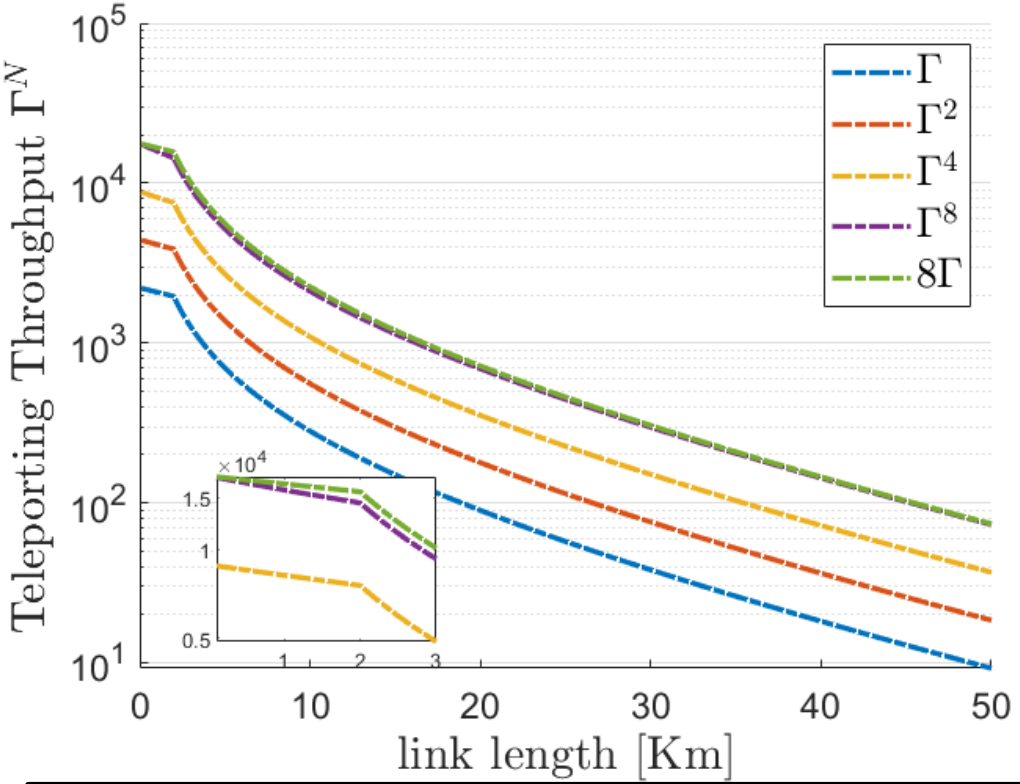
$$\Gamma = \frac{\mathcal{R}_b \Gamma_e}{2\Gamma_e + \mathcal{R}_b + \mathcal{R}_b \Gamma_e \left(\mathcal{T}_{SW} + \mathcal{T}_{BSM} + \mathcal{T}_c\right)}$$

Upper bounds

$$\Gamma < \frac{\mathcal{R}_b}{2} \qquad \Gamma < \Gamma_e$$

Interaction between classical network and Quantum Network

The teleporting throughput as a function of the link length.



Γ^N increases with N and it does not exceed $N\Gamma$

Teleporting Throughput

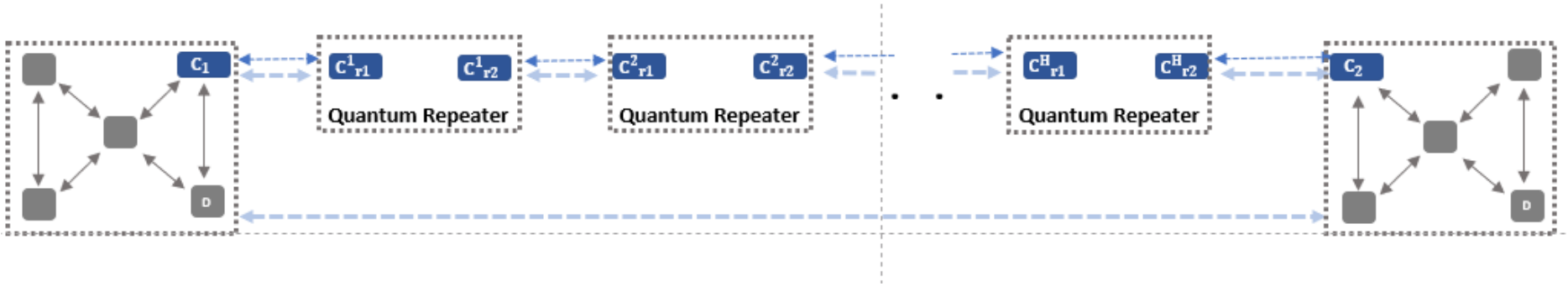
$$\Gamma^N = \frac{N\,\Gamma\,\mathcal{R}_b}{\mathcal{R}_b + 2(N-1)\Gamma}$$

Upper bounds

$$\Gamma^N < N\Gamma < \frac{N}{2}\mathcal{R}_b \qquad \boxed{\Gamma^N < N\Gamma} < N\Gamma_e$$

Interaction between classical network and Quantum Network

Quantum repeater architecture

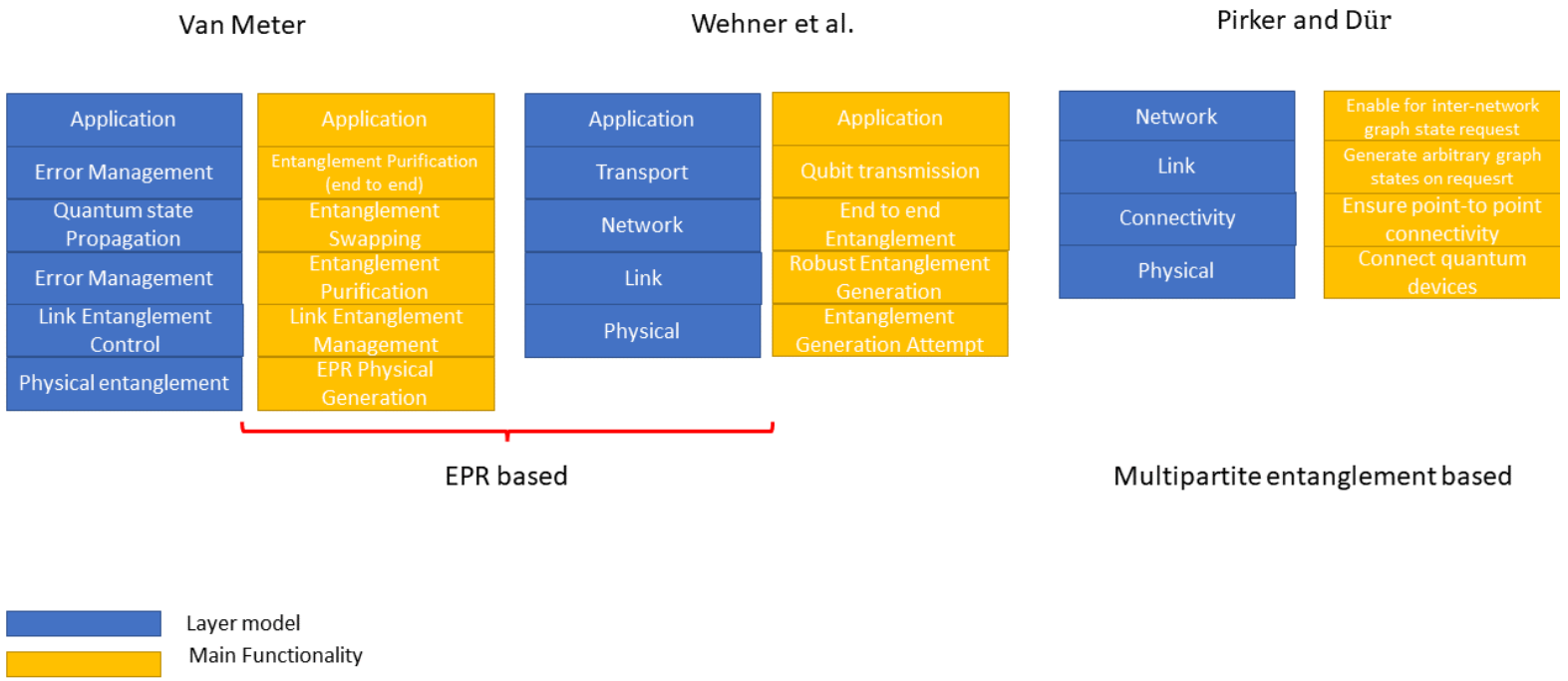


Teleporting Throughput

$$\Gamma_r = \frac{\min\limits_{i=0,..,H} \mathcal{R}_{b_i} \Gamma_{er}}{2\Gamma_{er} + \min\limits_{i=0,..,H} \mathcal{R}_{b_i} + \min\limits_{i=1,..,H} \mathcal{R}_{b_i} \Gamma_{er} \left[\mathcal{T}_{SW} + \mathcal{T}_{BSM} + \sum_{i=0}^{H} \mathcal{T}_{c_i}\right]}$$

On the Network Protocol Stack for the Quantum Internet

- Bipartite and Multipartite Entanglement
- The impact of entanglement on network connectivity
- Quantum Protocol Stack State-of-the-art



Next Year

- The Impact of the Quantum Data Plane Overhead on the Throughput
  - Quantum Repeater architecture: throughput upper bounds analysis
  - Insight on noise models for experimental evaluation

- On the Network Protocol Stack for the Quantum Internet:
  - Lower layers protocols

Products

[1]	Jessica Illiano, Angela Sara Cacciapuoti, Antonio Manzalini and Marcello Caleffi. "*The Impact of the Quantum Data Plane Overhead on the Throughput*". Proc. of The Eight Annual ACM International Conference on Nanoscale Computing and Communication (NANOCOM '21) September 7–9, 2021.
[2]	Jessica Illiano, Angela Sara Cacciapuoti, Antonio Manzalini and Marcello Caleffi. "*On the Network Protocol Stack for the Quantum Internet*" −invited paper−, to be submitted.