POLITECNICO DI MILANO

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

Research Area n. 4 - Telecommunications

THEMATIC Research Field: CLASSICAL AND QUANTUM ERROR CORRECTION FOR DISTRIBUTED QUANTUM COMPUTING

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	Quantum Computing promises exponential speed-ups in solving complex computational problems, such as prime factorization (Shor's algorithm [16]), search in an unstructured database (Grover's algorithm [13]), approximate algorithms for the max-cut problem (Quantum Approximate Optimization Algorithm [12]), and many others. Current and future quantum computers are based on different qubit technologies [1-6], each with their advantages and disadvantages, but in any case the quantum information is highly fragile due to decoherence and noise [15]. This means that quantum computers are not yet fault-tolerant, making Quantum Error Correction (QEC) a crucial area of study for future advancements [9]. To enhance the scalability of qubit numbers – and consequently, computational power – Distributed Quantum Computing (DQC) is recognized as the most promising approach [10]. In this context, new paradigms, protocols, and algorithms will need to be developed, requiring tailored techniques for both classical and quantum error correction in order to efficiently distribute computation. This research aims to explore and develop advanced quantum error correction techniques specifically designed

	for distributed quantum computing architectures. Traditional QEC codes, such as the surface code and stabilizer codes, have been extensively studied for standalone quantum processors or quantum memories [17]. However, their direct application to DQC is non-trivial due to factors like network-induced errors, detector inefficiencies or channel loss [7]. Additionally, classical error correction may play a significant role in quantum networking, since the architecture of DQC is still undefined. The research activity of the PhD will be carried out in the framework of the project “High-resolution” (GORU-IEIIT) at CNR-IEIIT and will significantly contribute to the advancements in the field. The main objectives of the research will be: •Investigate the interplay between classical and quantum error correction in DQC, since the majority of QEC codes are based on existent classical codes, such as Low-Density Parity-Check (LDPC) codes. •Develop novel quantum error correction (QEC) codes optimized for quantum networks. •Explore fault-tolerant protocols that minimize resource overhead while maintaining error resilience.
Methods and techniques that will be developed and used to carry out the research	Theoretical Analysis: Study the limitations of existing QEC codes and classical error correction methods in DQC scenarios. Assert potential architectures for DQC, identifying bottlenecks within the technological stack and determining areas for improvement. Algorithm Development: Formulate novel efficient DQC algorithms and QEC schemes optimized for distributed quantum systems, leveraging techniques such as tensor networks, LDPC codes, and machine learning approaches. Simulation and Benchmarking: Implement the developed techniques using quantum simulators (e.g., Qiskit, Cirq, PennyLane) and benchmark their performance against state-of-the-art error correction methods. Potential Experimental Validation: Collaborate with experimental

	quantum computing groups to test proposed schemes on physical quantum networks.
Educational objectives	Train of the PhD student in quantum physics, channel coding and information theory.
Job opportunities	Classical channel coding and error correction techniques are adopted in any communication link (wireless, optical, wired) and information storage system (DRAM memories, NAND flash, SSD). Many companies are investing in research in the context of quantum technologies.
Composition of the research group	0 Full Professors 1 Associated Professors 2 Assistant Professors 1 PhD Students
Name of the research directors	Prof. Luca Barletta, Dr. Marco Ferrari (CNR)

Contacts
luca.barletta@polimi.it marcopietro.ferrari@cnr.it

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

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