Quantum

Design and Implementation of Modern Quantum Repeaters for Future Quantum Communication Technology and Teleportation

Computing

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Introduction

- Quantum communication leverages the principles of quantum mechanics to transmit qubits between remote locations
- Long-range quantum communication e.g. quantum internet requires quantum repeaters.
- Quantum repeater devices: the communication channels get fragmented into small segments composed of nodes or relay stations, where each segment has a quantum repeater which plays its role in extending entanglement to its adjacent nodes.
- Quantum Repeaters rely on entanglement as a resource, entanglement purification to maintain high fidelity qubits
- Protocols implemented in quantum repeaters: generation/distribution protocol, entanglement swapping, entanglement purification

Main Objective

To design and implement a modern quantum repeater infrastructure for future quantum communication technologies and applications

Specific Objectives

- Design and implement a complete quantum circuit of a quantum repeater
- Explore various purification strategies to determine the optimum strategy
- Study the effects of various purification protocols on the overall purification optimization scheme

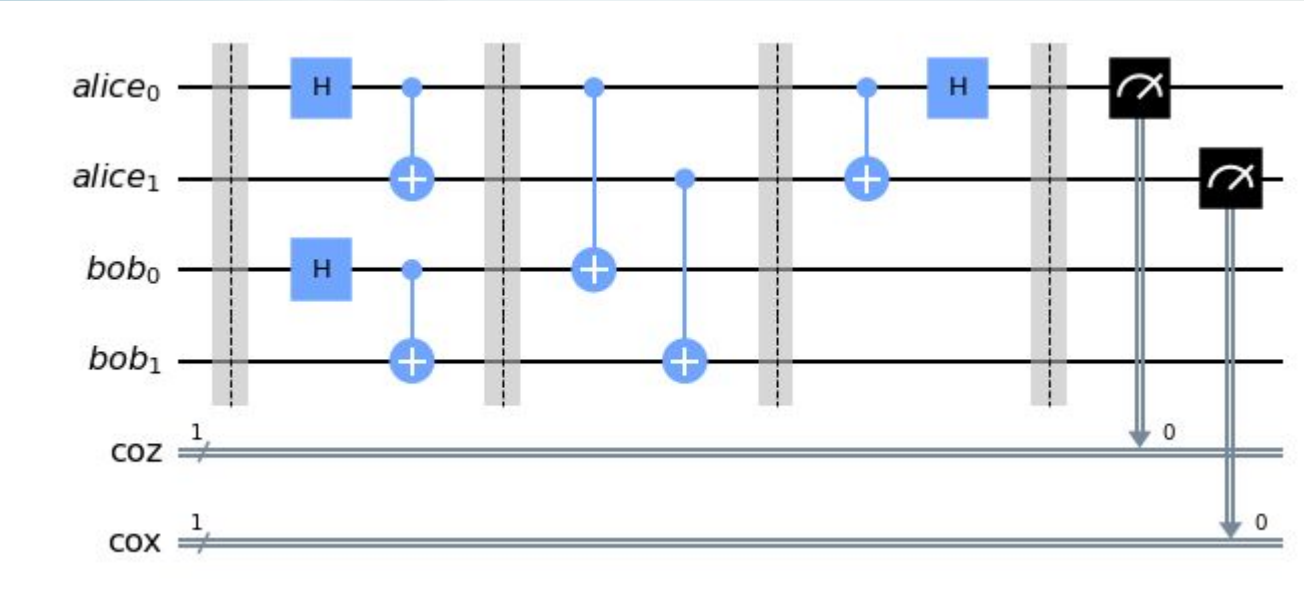
Experimental Setup

Research Approach

- IBM Quantum Computers and IBM Qiskit QASM Native Simulator
- Emulate Noise using ‘NoiseModel’ Qiskit Module based on a real Quantum device
- Entanglement Purification - Bennett’s and Deutsch’s Protocols
- Distribution of Bell-Pairs emulated using Swap gates
- Implementation of quantum memory

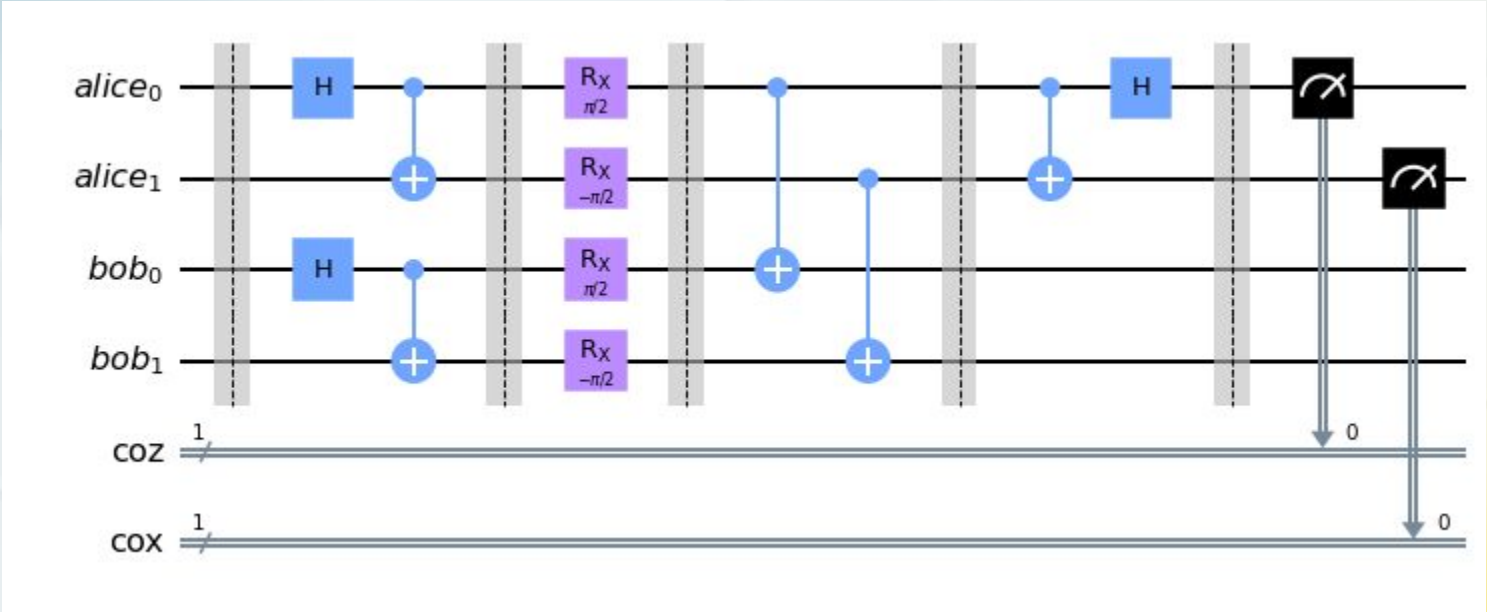
Quantum Entanglement Purification

Implementation of Bennett's Purification Protocol

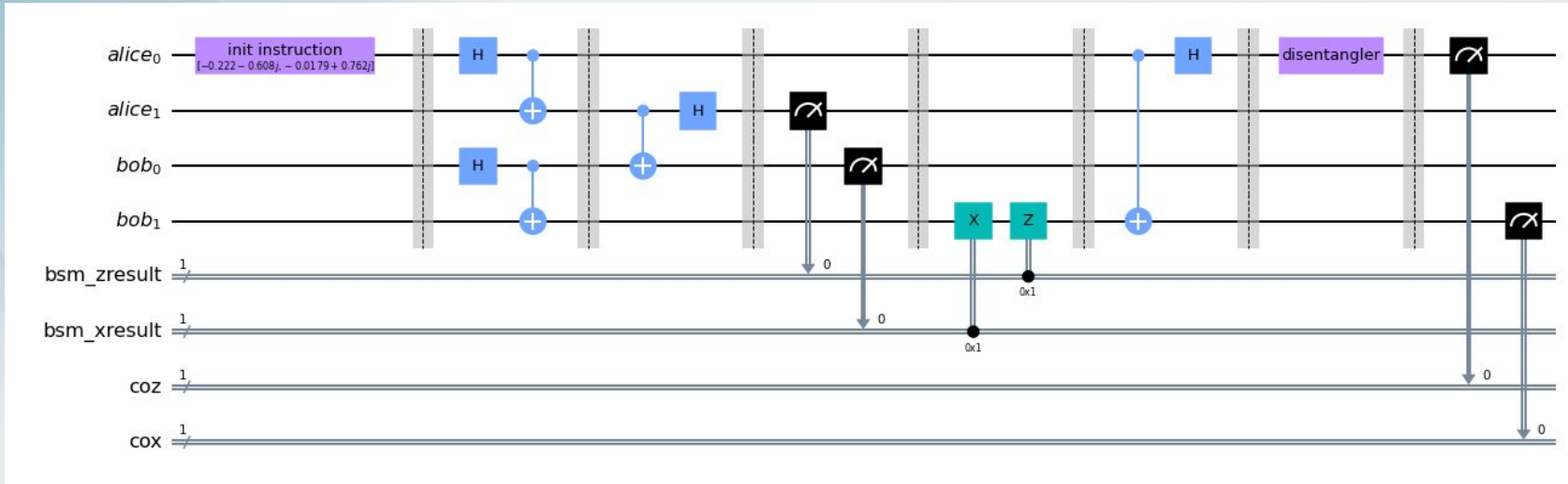


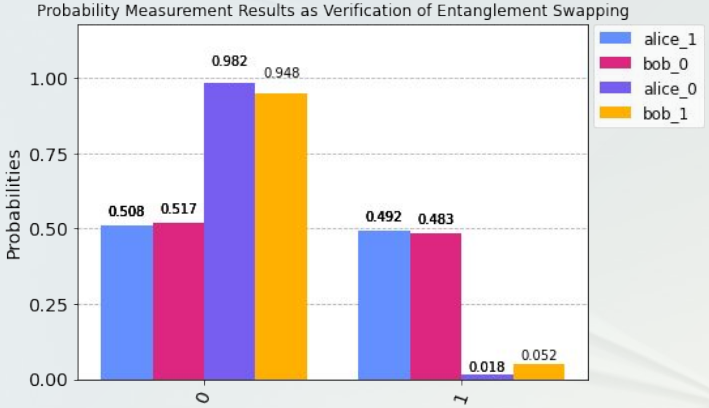
Quantum Entanglement Purification

Implementation of Deutsch's Purification Protocol



Quantum Entanglement Swapping





Results and Discussions

Complete Quantum Repeater Architecture

A Near-term quantum repeater (heralded) device operating in the Noisy-Intermediate Scale Quantum Computing era

Heralding

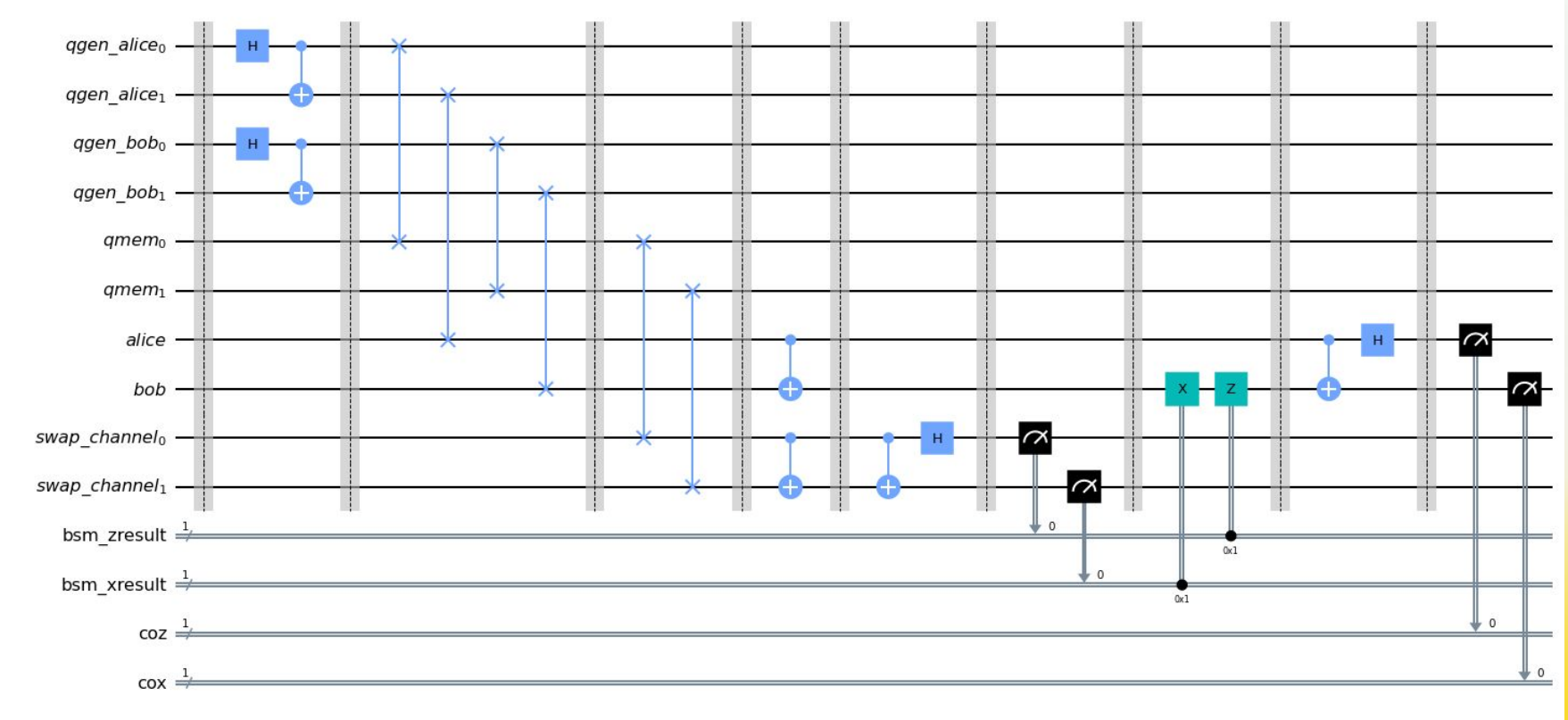
- Lower Bandwidth
- Uses entanglement purification to mitigate for errors

Operation Quality

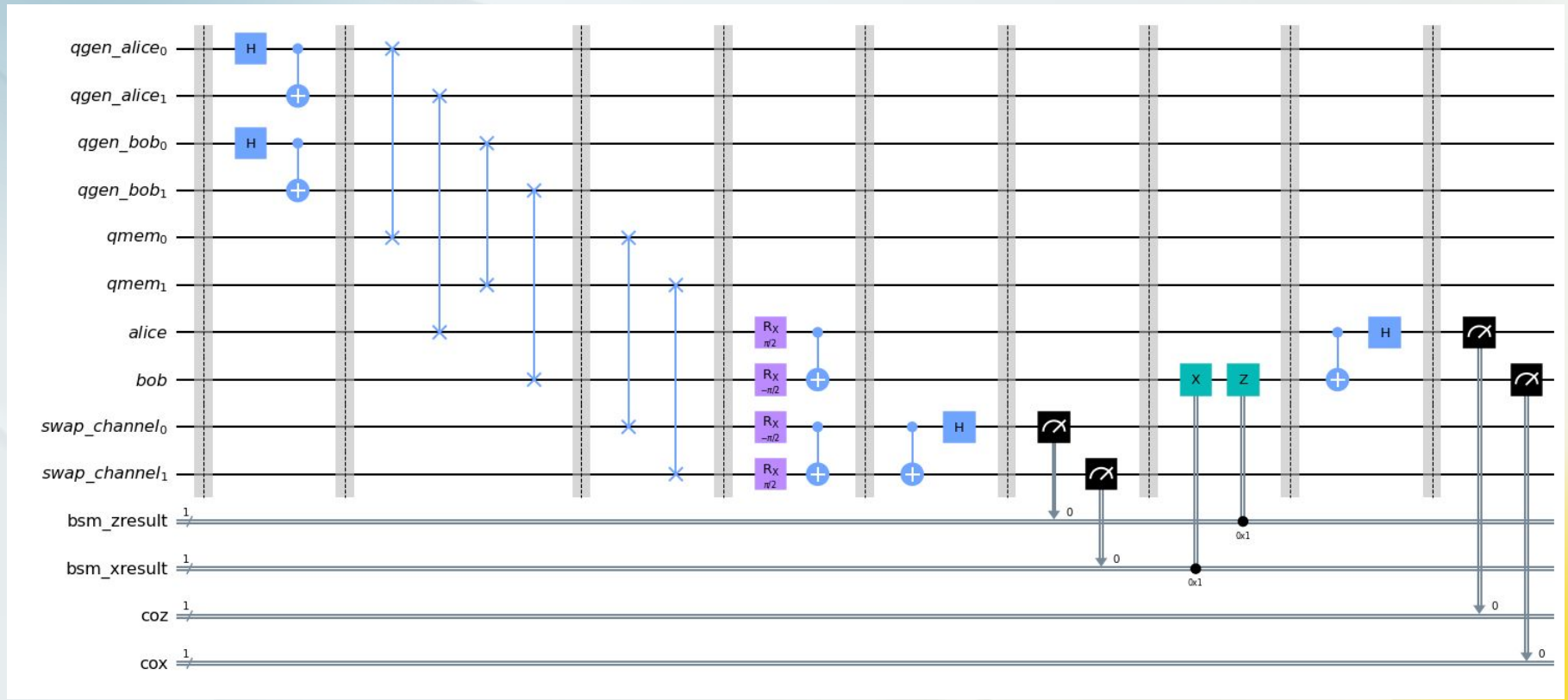
- Gate fidelity
- Qubit fidelity
- Readout Fidelity

Quantum Algorithms have to work within the limitations of the current hardware

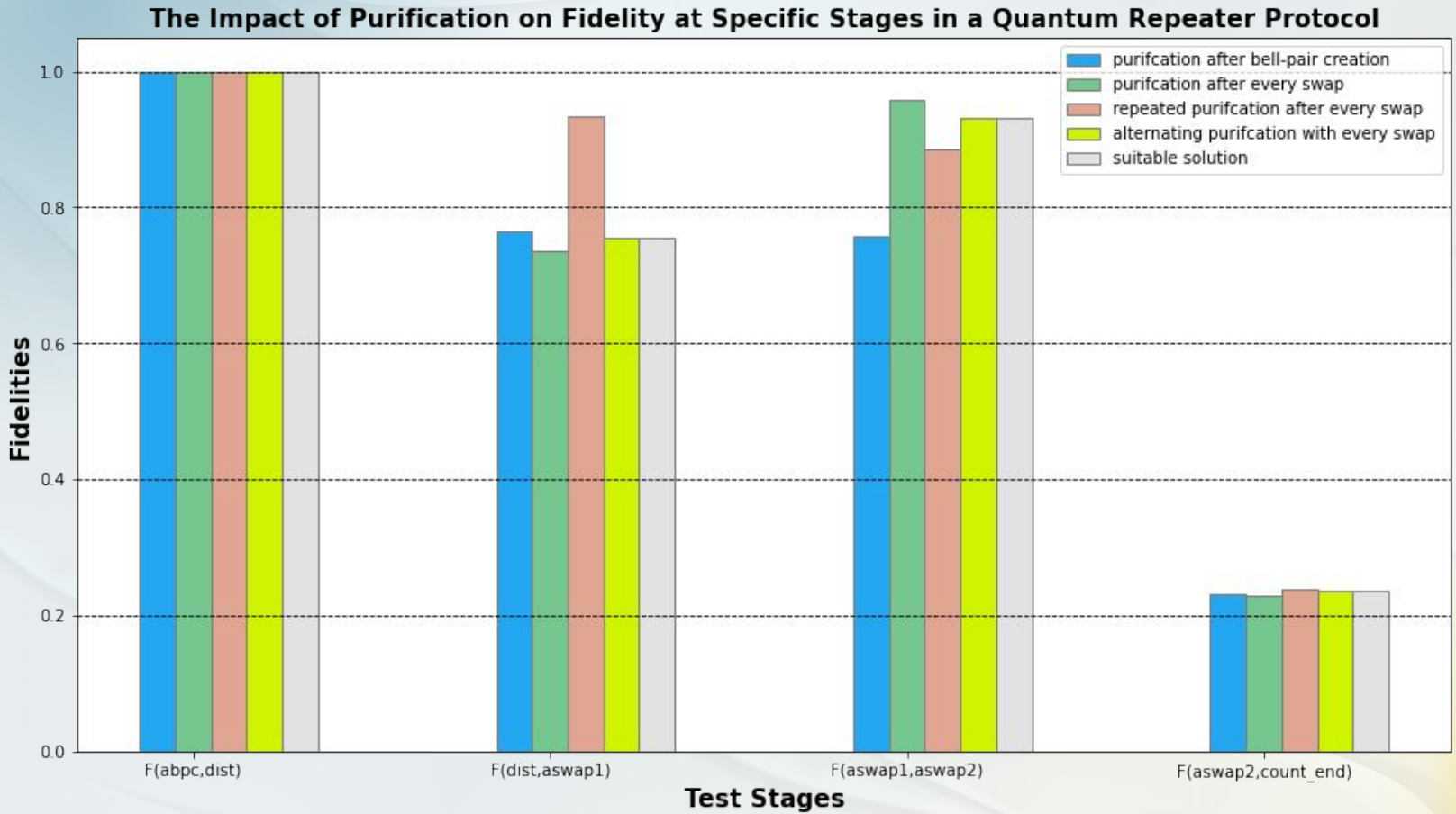
Quantum Repeater Architecture Implementing Bennett's Purification Protocol



Quantum Repeater Architecture Implementing Deutsch's Purification Protocol

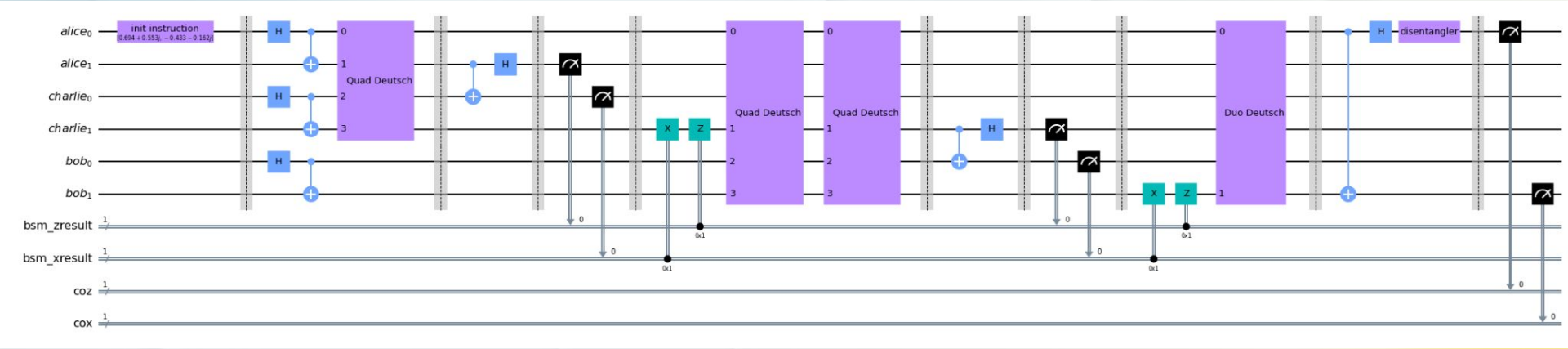


Purification Strategy

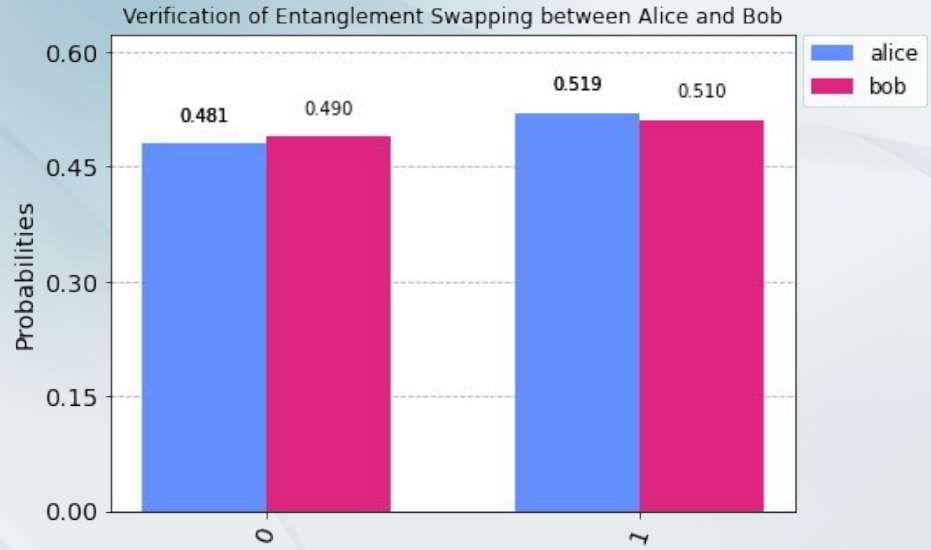


Purification Strategy

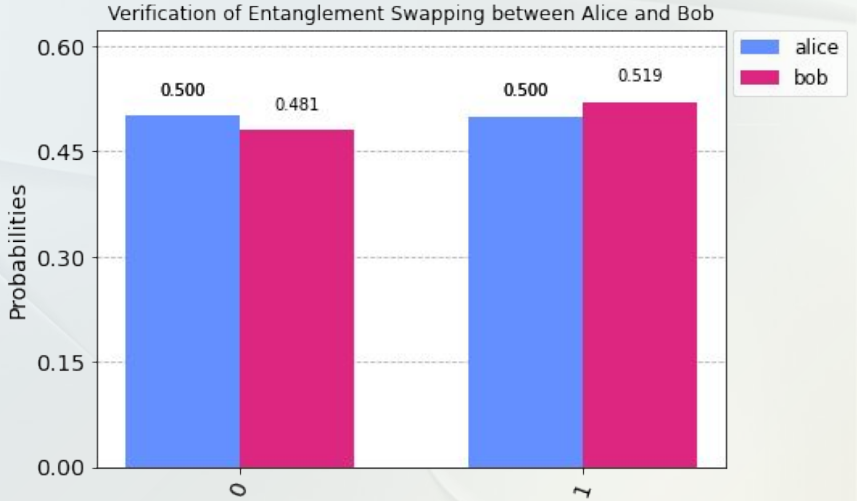
Optimized Quantum Repeater Circuit for the Alternating Purification strategy implementing Deutsch's purification protocol



Purification Strategy



Verification results for the alternating purification strategy



Verification results for the repeated purification strategy

Conclusion

- Noise is the biggest challenge causing errors in the quantum repeater protocol
- The purification strategy is optimum when tailored to the quantum network and quantum repeaters used
- More research needed to refine quantitative results on entanglement purification protocol strategies.

Thank you!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computing
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dynamics
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slide
displacement
heads
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encode
arrow
number
times
field
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coins
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