CROSS-VALIDATING QUANTUM NETWORK SIMULATORS[1]

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Background

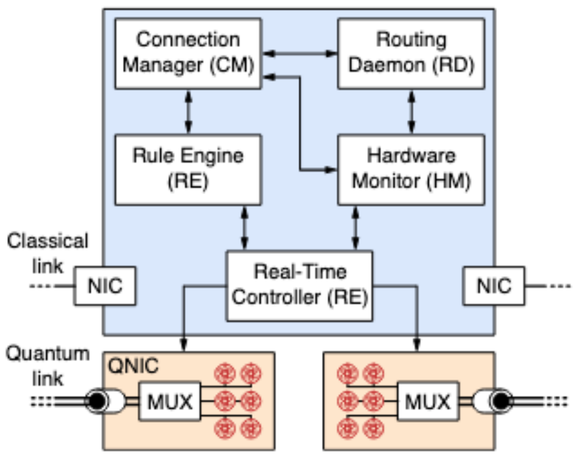
- There are many different simulators with overlapping goals, assumptions architectures, and designs.
- Regardless of differences between simulators, the results should agree.
- We aim to analyze the real difference between simulator network architecture design choices.
- QuISP Goal: To simulate large scale quantum network and inter-networks with minimal resources.
- SeQUeNCe Goal: To simulate photon quantum networks, while providing high level of customizability.
- We focus on the performance differences between the QuISP and SeQUeNCe architectures.

Architecture Comparison

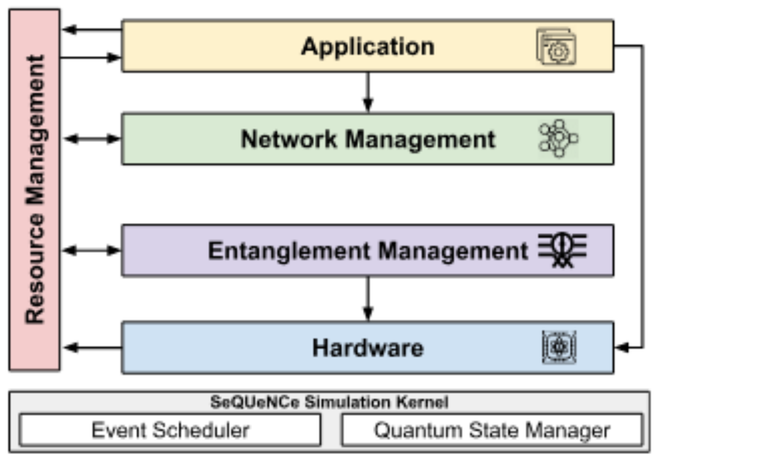
- QuISP follows the Quantum Router Software Architecture (QRSA).
- QUisp's stack includes: Connection Manager, Routing Daemon, Rule Engine, Hardware Monitor, and RT controller.
- SeQUeNCe uses a modular framework based on a simulation kernel. It includes: application, resource management, network management, entanglement management, and the hardware.

Network Protocol Comparison

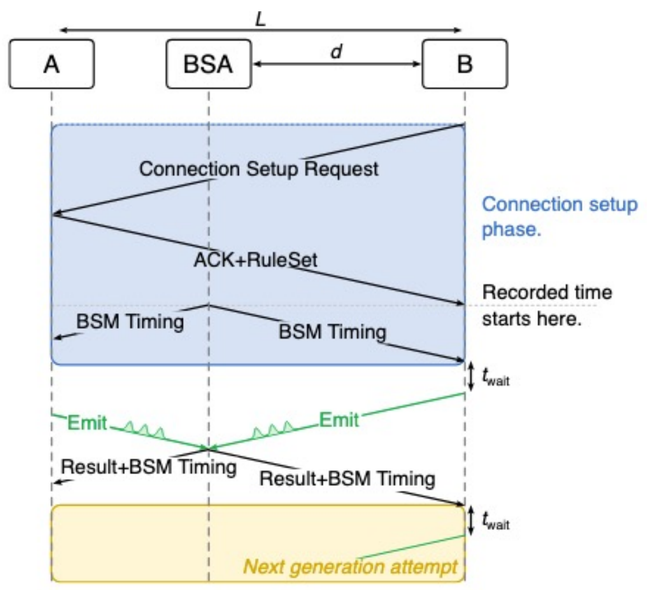
- SeQUeNCe uses a three-way handshake for every entanglement generation attempt to allow for continuous generation of bell pairs.
- QuISP utilizes a conn. setup phase, the can continuously generate entanglement without repeating the handshake protocol.



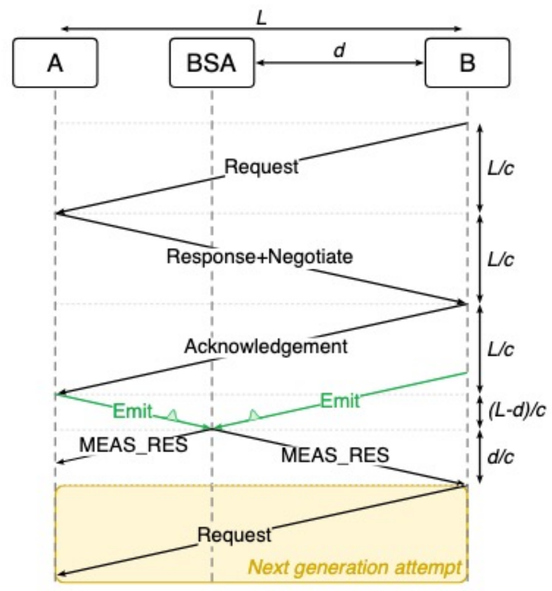
Quantum Internet Simulation Package (QuISP) [3]



Simulator of Quantum Network Communication (SeQUeNCe) [2]



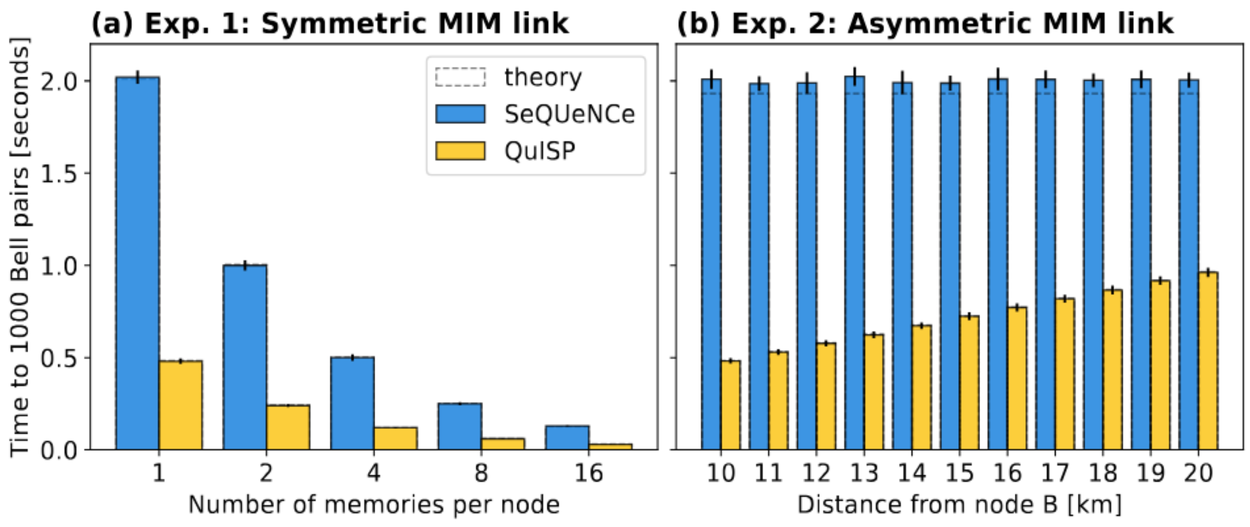
QuISP Network Flow Diagram



SeQUeNCe Network Flow Diagram

Anti-/Symmetric Memory-Interference-Memory (MIM)

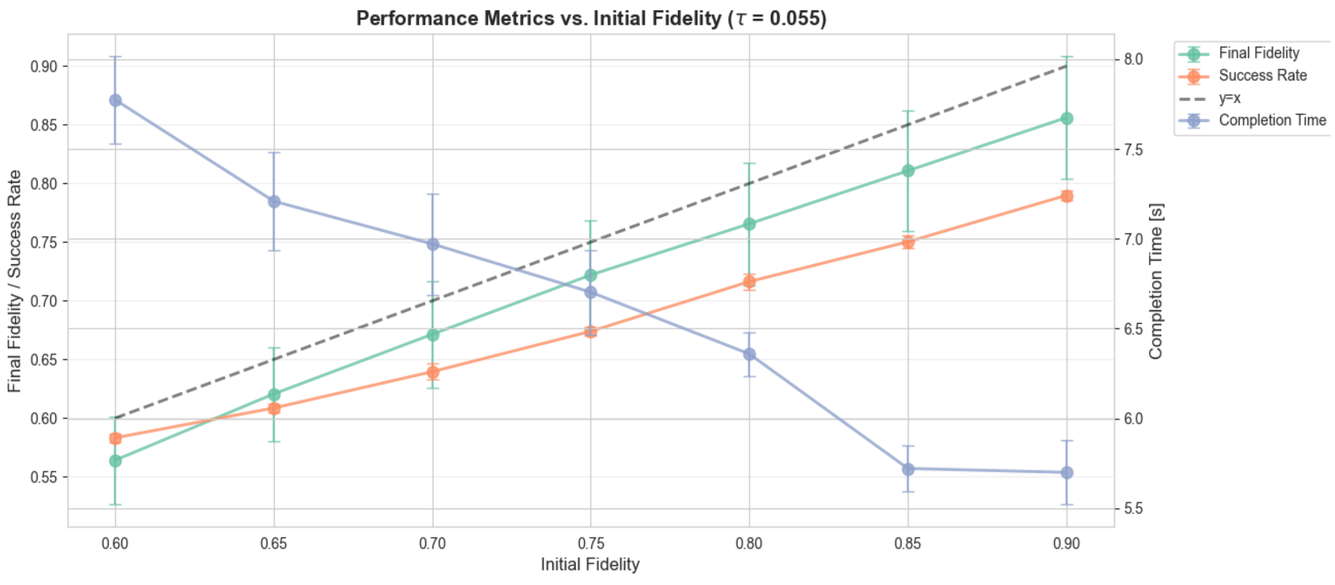
- 2 Nodes are positioned 20km away from each other, with a BSM in the middle.
- For anti-symmetric the distance from the BSM to the first end node is swept from 10-20 km, while the number of memories is fixed at 1
- All memories will have unity fidelity and infinite coherence time.
- Sweep the number of memories in each node.
- ***Evaluate:*** The time to generate 1000 successive bell pairs



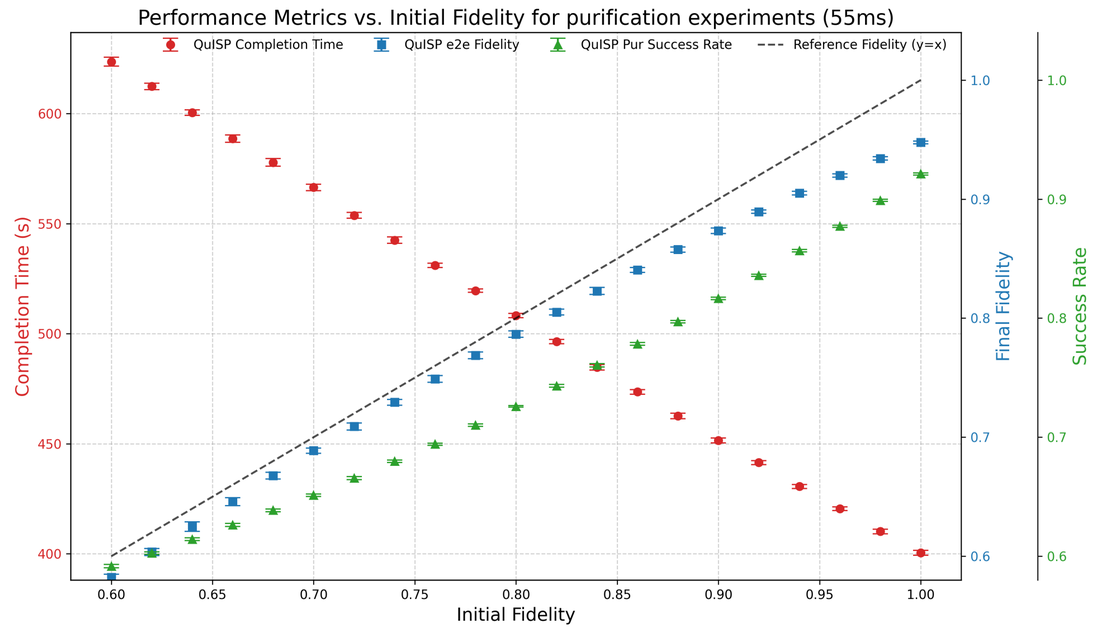
Comparison of theory, SeQUeNCe, and QuISP for entanglement generation experiments

Symmetric (MIM) with Purification (Preliminary)

- 2 Nodes are positioned 40 km away from each other, with a BSM in the middle.
- All memories will have unity fidelity and infinite coherence time.
- Sweep the number of memories in each node.
- ***Evaluate:*** The purified fidelity and success rate of the purified pairs.



SeQueNCe Purification Metrics for 55ms coherence time for 500 pairs



QUisp Purification Metrics for 55ms coherence time for 100k pairs

[1] J. Chung et al., "Cross-Validating Quantum Network Simulators," in IEEE INFOCOM 2025 - IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), May 2025, pp. 1–6. doi: 10.1109/INFOCOMWKSHPS65812.2025.11152951.
[2] X. Wu et al., "SeQUeNCe: a Customizable Discrete-Event Simulator of Quantum Networks," Quantum Sci. Technol., vol. 6, no. 4, p. 045027, Sept. 2021, doi: 10.1088/2058-9565/ac22f6.
[3] R. Satoh et al., "QuISP: a Quantum Internet Simulation Package," in 2022 IEEE International Conference on Quantum Computing and Engineering (QCE), Sept. 2022, pp. 353–364. doi: 10.1109/QCE53715.2022.00056.

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