Entanglement distribution effect on coordination protocols

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Description

Quantum networks (QN) provide communication services whose capabilities extend beyond classical networks, improving scalability of distributed quantum applications, enabling quantum cryptography and coordination primitives that surpass their classical counterparts. For instance for synchronous consensus problem against full information adaptive adversary, quantum solutions are known to reach $O(1)$ expected round complexity [1], while the best classical solutions had lower bounds of $\Omega(n/\log(n))$. The limitation of the result is that the network model assumes *unbounded*, *uniform*, and *error-free* quantum channels. That assumption is not faithful to near-term QNs, where quantum information is transmitted via "quantum teleportation" over distributed *Bell pairs*—pairs of maximally *entangled qubits* with each qubit located at a separate node. Due to the noisy nature of quantum devices, the cost of quantum links, and the fast rate of state degradation, the Bell pairs passed from network to the consensus algorithms will have bounded rate, be topology-dependent, and imperfect.

To maximize the rate and quality of Bell pair generation under extremely constrained and error-prone quantum hardware resources, there is a variety of entanglement distribution protocols [2]. The choice of the protocol will inevitably affect the performance of the coordination protocols.

Goal

The goal of this project is to evaluate the effect of the choice of entanglement generation protocols on the expected termination time of quantum consensus protocols. Especially interesting to study how the performance of the consensus algorithm over a given entanglement generation protocol changes as a function of the topology, the quality of local quantum links, and the amount of resources available in the network.

Objectives

- Understand the basics of QNs (EPR-pairs, swapping; see [3])
- Familiarize oneself with the NetSquid network simulator (register to get access)
- Check-out the NetSquid implementation of protocols analyzed in [4]
- Use `TeleportationWithDemand` application to run the coin algorithm of [1]
- Research the typical parameters used in the evaluation of QN protocols
- Evaluate the coin's fairness under simulation regimes used in the literature

Expected results: A report with performance plots of quantum coordination speed as a function of entanglement distribution protocols and the network

Prerequisites

- Python
- Basics of TCP/IP protocol stack and network router operation

References

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