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A Test Suite for Quantum Networks

Assessing an application's effectiveness as a benchmark for quantum networks

Quantum Networks

In recent years, quantum technology has undergone massive developments. Quantum networks are among these rapidly developing technologies: A communication network made up of multiple quantum nodes connected by quantum links. Where classical networks use classical bits, quantum networks use quantum bits, or qubits, to store and transmit data. A quantum network could provide numerous advantages over classical networks, such as more secure communication, distributed quantum computing and more [1].

Aim of the project

This project aims to contribute to the development of a benchmarking suite for quantum networks. We will assess the effectiveness of a certain application for benchmarking the system.

We do this by running the application on a simulated system, and varying system parameters to discover how much they affect the results of the application. Examples of parameters we will test for are:

- Link entanglement fidelity
- Quality of quantum operations
- Memory lifetimes

Blind Quantum Computation (BQC)

The application we will be testing is Blind Quantum Computation (BQC). BQC is a quantum network algorithm that allows a server to perform a quantum computation on behalf of a client, without knowing exactly what it is calculating. Figure 1 shows the effective calculation that the server performs. The calculation is the same for every iteration of the algorithm, but the parameters α and β are chosen by the client every time the algorithm is run.

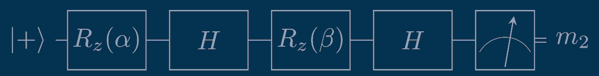

Figure 1: Effective computation that the client wants the server to perform.

[1] Simon, C. Towards a global quantum network. Nature Photon 11, 678–680 (2017). https://doi.org/10.1038/s41566-017-0032-0

Methodology

When executing experiments with BQC, we calculate the average accuracy of the results and use this as our performance metric. To calculate this, we first determine manually for the input parameters what the end state of the measured qubit will be. We use this to determine the expected amount of times the application returns 0. We then compare this to the actual amount of times the application returns 0 to get the accuracy of one batch. We execute 10 batches for every experiment, and take the average of this as our performance metric.

Additionally, we execute every experiment with different input parameters α and β to see if certain varied system properties affect the application differently for different input parameters.

Results

Figure 2 plots the results of one of the executed experiments. The experiment was executed with two GenericQDevices connected by a DepolariseLink. In this configuration we vary the fidelity of EPR pairs generated by the DepolariseLink. This plot shows the relation between the average accuracy of the application and the fidelity of EPR pairs generated by the link. Every line is a different combination of α and β.

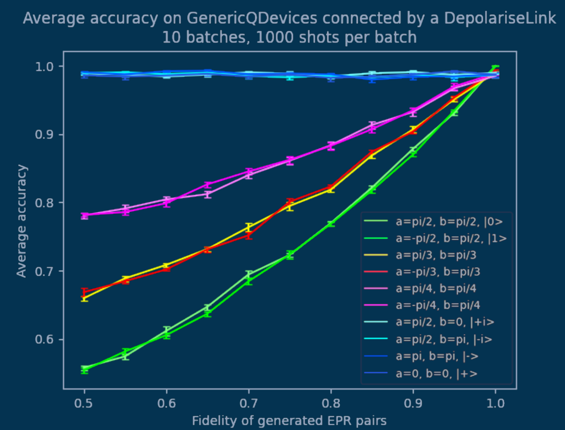

Figure 2: Accuracy of the application for a changing link entanglement fidelity.

Discussion

Table 1 shows for what parameters BQC can detect imperfections. What we see from these results is that it is sensitive to almost all parameters. This would mean that it is a good full-system benchmark, but not a good benchmark to test individual components of a network. BQC could work well in combination with other applications that are more focused towards individual parameters. We could draw the parallel to software testing by seeing those applications as unit testing, and BQC as integration testing.

DepolariseLink parameters	Detectable
Fidelity of EPR pairs	Yes
Success probability of generating entanglement	No
Time taken for an entanglement generation attempt	No
GenericQDevice parameters	**Detectable**
Decoherence times	Yes
Single qubit gate depolarisation probability	Yes
Two qubit gate depolarisation probability	Yes
HeraldedLink parameters	**Detectable**
Length	Yes
Attenuation coefficient	Yes
Probability of photons being lost when entering the connection	Yes
Dark count probability	Yes
Detector efficiency	Yes
Hong-Ou-Mandel visibility	Yes
NVQDevice parameters	**Detectable**
Depolarisation probability during initialisation of the electron qubit	No
Depolarisation probability of single qubit gate applied to the electron qubit	Yes
Depolarisation probability during initialisation of a carbon qubit	Yes
Depolarisation probability of single qubit gate applied to a carbon qubit	Yes
Depolarisation probability of two qubit gate applied to a carbon qubit and the electron qubit	Yes
Probability of measuring a 1 instead of 0 in an electron measurement	Yes
Probability of measuring a 0 instead of 1 in an electron measurement	Yes
Decoherence times of the electron qubit	Yes
Decoherence times of the carbon qubits	Yes

Table 1: A table showing whether the application can detect errors when these system parameters are imperfect in a network.

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