Brown Quantum Initiative

iQuHACK 2024

Overview

- Problem: Determine an inexpensive probe for the IonQ noise profile
- Considered noise-probes as edge-colorings on complete graphs
- QFT vs. deep-Cnot benchmarking

Fidelity Extraction

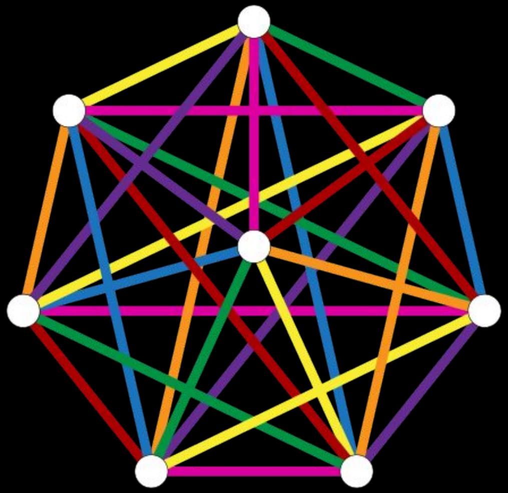
- Prepare Bell's states by applying Hadamard + CNot gates on the i, j state.
- Cycle i, j based on graph-coloring
- Count the numbers of 00, 01, 10 and 11 hits at locations i, j (let Pij give the count fraction)
- Define the fidelity function by F = min(P00,P11)/max(P00,P11) x (P00+P11)/total_shots
- F near 1 for excellent two-qubit gate (assumed symmetric)

Fidelity Extraction

- Assumed the major source of noise comes from the two-qubit gate
- To avoid further noise, we only apply two-qubit gates on each qubit once in a single circuit and feed in two-qubit gates as many as possible

Graph coloring

- Test circuits of n qubits: edge-coloring problem in n complete graph
- Vizing's theorem: every simple undirected graph may be edge colored using a number of colors that is at most one larger than the maximum degree Δ of the graph, but at least Δ colors.
- In n = 11 complete graph, we need 11 colors.



AWS's Challenge

Linear Programming

- Label physical graph from 0 to n - 1. Permutation a maps physical graphs to a logical graph.
- Collect statistical information of physical graph and logical graph (two-qubit fidelities, degrees of vertices)
- Goal is to maximize utility function V = sum_ij (W_ij n_ij), with
  - W_ij the fidelity of gates on the i. j qubits and,
  - n_ij the counts of 2-qubit gates on the i, j qubits
- Potential drawback: early test circuits typically very shallow

Benchmarking

- QFT + iQFT circuit ~ **44 qubit depth** vs deep-CNOT circuit ~ **100 qubit depth**
- Shallow vs. deep construction: more utility gained for re-wiring in deep circuit (avoiding compounded error)

Thank you!