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A Hardware-aware Heuristic for the Qubit Mapping Problem in the NISQ Era

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Motivation

- NISQ devices.
- Connectivity constraint: Nearest-neighbor connections.
- Different physical qubits: various calibration data.
- Qubit mapping problem: Adapting a quantum program to given hardware connectivity.

Introduction

- Hardware-Aware (HA) mapping transition algorithm.
- Cost function
  \[ H = \frac{1}{|F|} \sum_{g \in F} \sum_{q \in Q} D[\rho(q_0.q_1)|\rho(q_0.q_2)] + W \times \frac{1}{|E|} \sum_{g \in E} D[\rho(q_0.q_1)|\rho(q_0.q_2)] \]
- Distance matrix
  \[ D = a_1 \times S + a_2 \times \varepsilon + a_3 \times T \]
  - S: SWAP matrix, \varepsilon: SWAP error matrix, T: SWAP execution time matrix
- Selection between SWAP and Bridge gate.

Methods

- Hardware-Aware (HA) mapping transition algorithm.
- Cost function
- Distance matrix
- Selection between SWAP and Bridge gate.

Results

- Comparison of number of additional gates on IBM Q 20 Almaden (large benchmarks).
- Comparison of number of additional gates and fidelity on IBM Q 20 Almaden (small benchmarks).

Conclusion

- Map the most used qubit of the mapped circuit to the most connected physical qubit.
- Apply CNOT gates on qubits that are directly connected and with reliable interconnects.
- If a CNOT cannot be applied on two neighbor qubits, apply on two qubits whose distance is two.

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