

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

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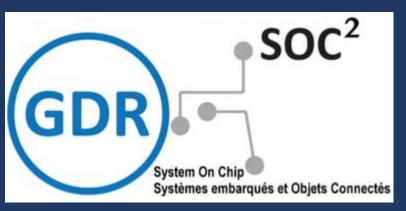
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A Hardware-aware Heuristic for the Qubit Mapping Problem in the NISQ Era



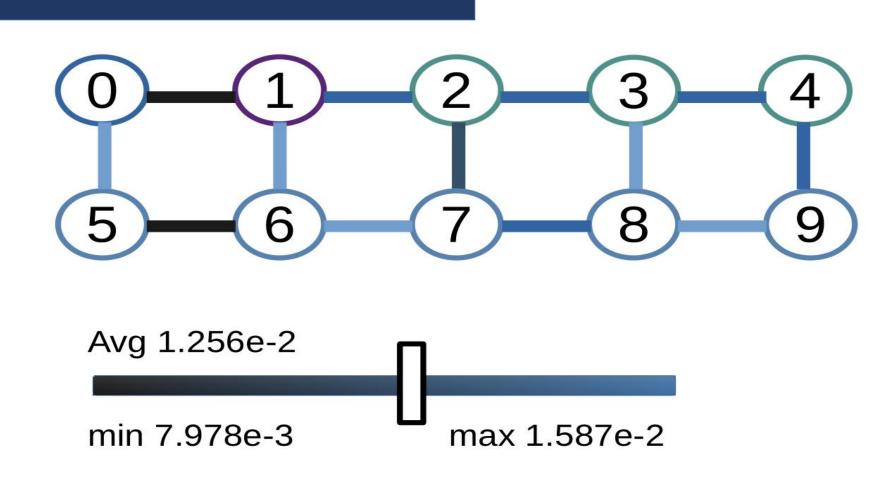
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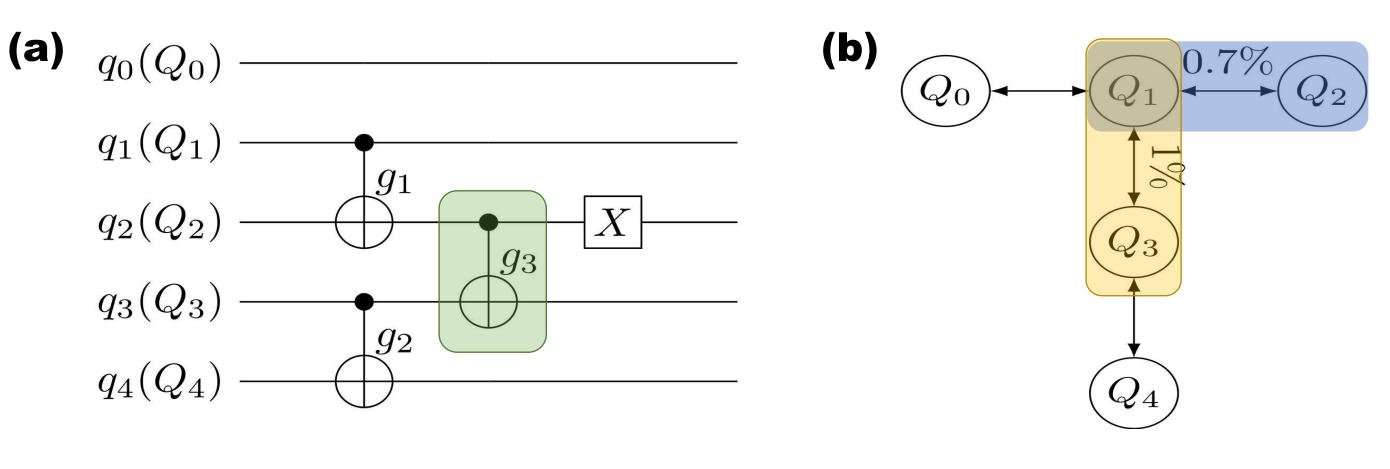


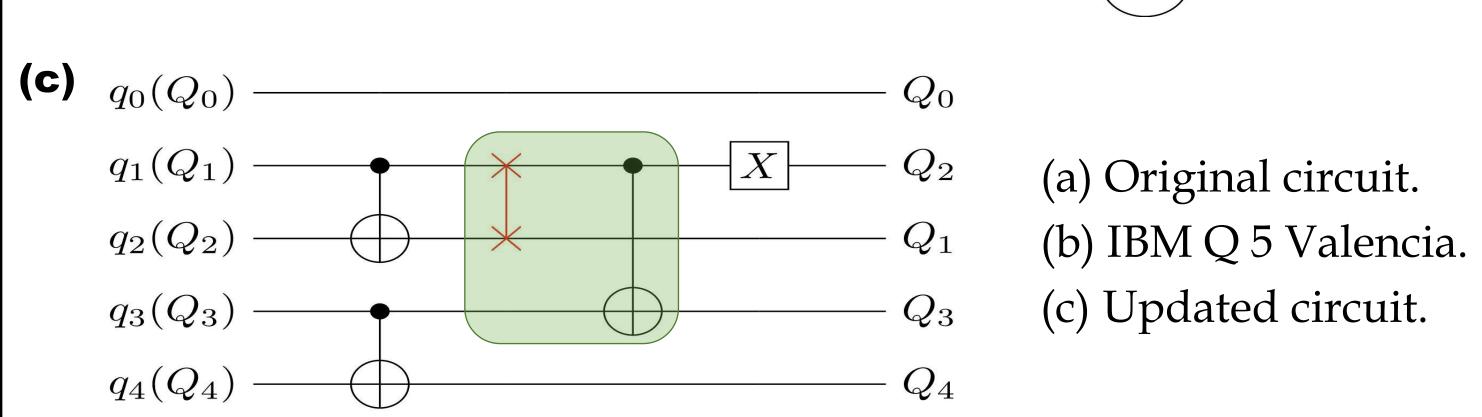
Introduction



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

Motivation





- Initial mapping
- $\{q_0 \to Q_0, q_1 \to Q_1, q_2 \to Q_2, q_3 \to Q_3, q_4 \to Q_4\}$
- •SWAP candidates:
- $\{q_1, q_2\}$ and $\{q_1, q_3\}$
- Choose $\{q_1, q_2\}$ because of the lower error rate.
- Final mapping
- $\{q_0 \to Q_0, q_1 \to Q_2, q_2 \to Q_1, q_3 \to Q_3, q_4 \to Q_4\}$

Methods

- Hardware-Aware (HA) mapping transition algorithm.
 - Cost function

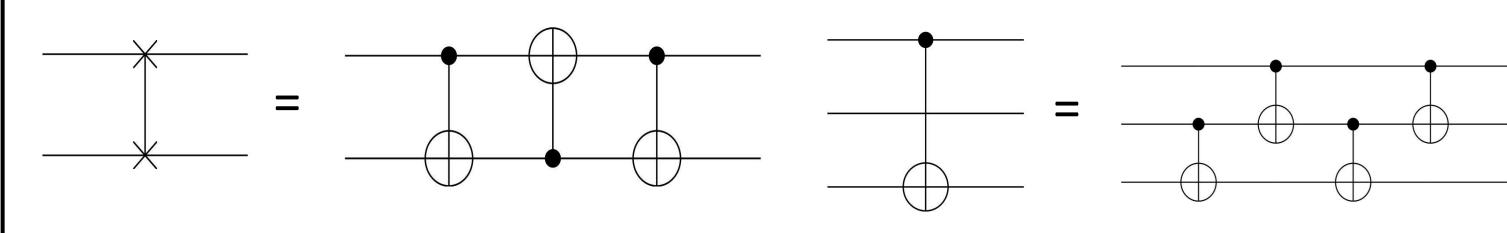
$$H = \frac{1}{|F|} \sum_{g \in F} D[\pi(g, q_1)][\pi(g, q_2)] + W \times \frac{1}{|E|} \sum_{g \in E} D[\pi(g, q_1)][\pi(g, q_2)]$$

Distance matrix

$$D = \alpha_1 \times S + \alpha_2 \times \varepsilon + \alpha_3 \times T$$

• S: SWAP matrix, ε : SWAP error matrix, T: SWAP execution time matrix

• Selection between SWAP and Bridge gate.



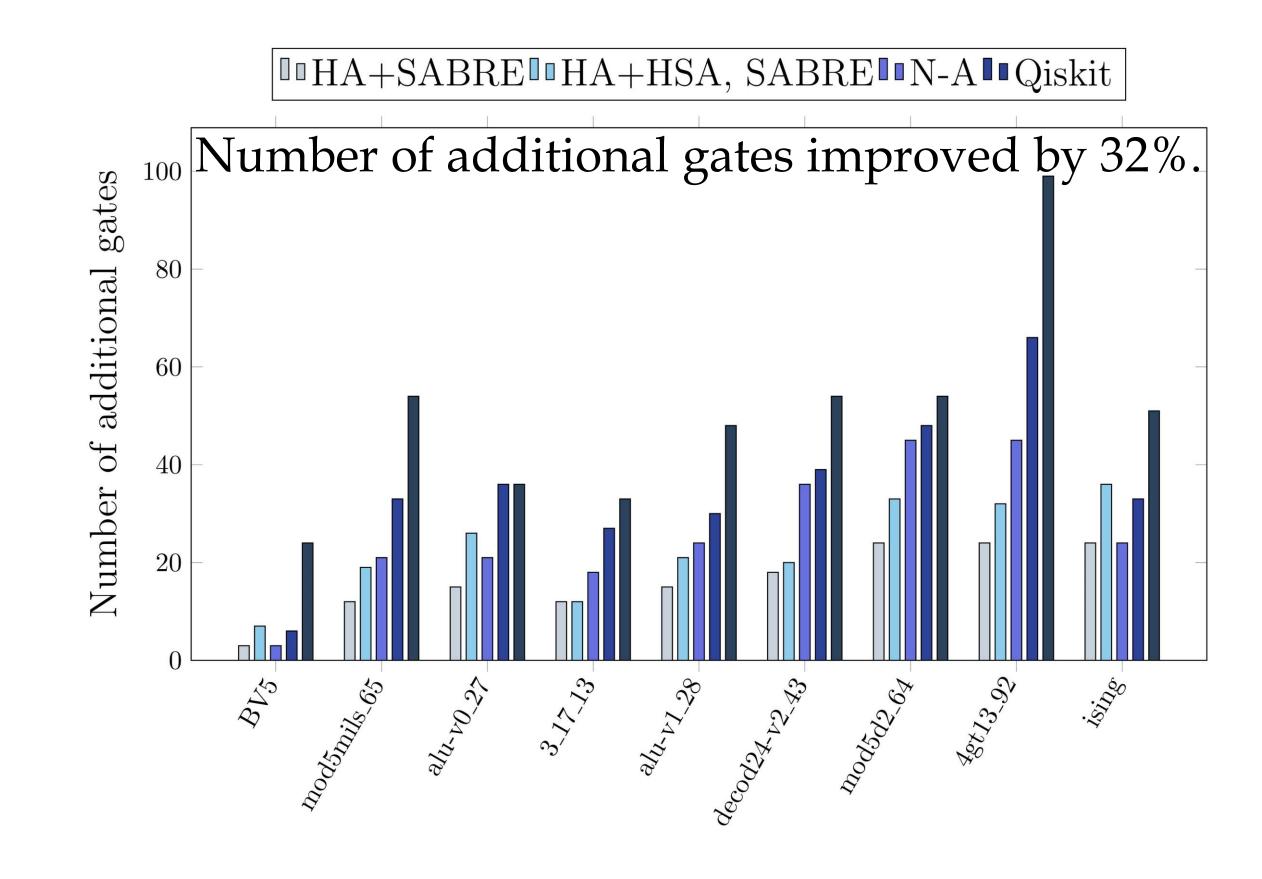
SWAP gate

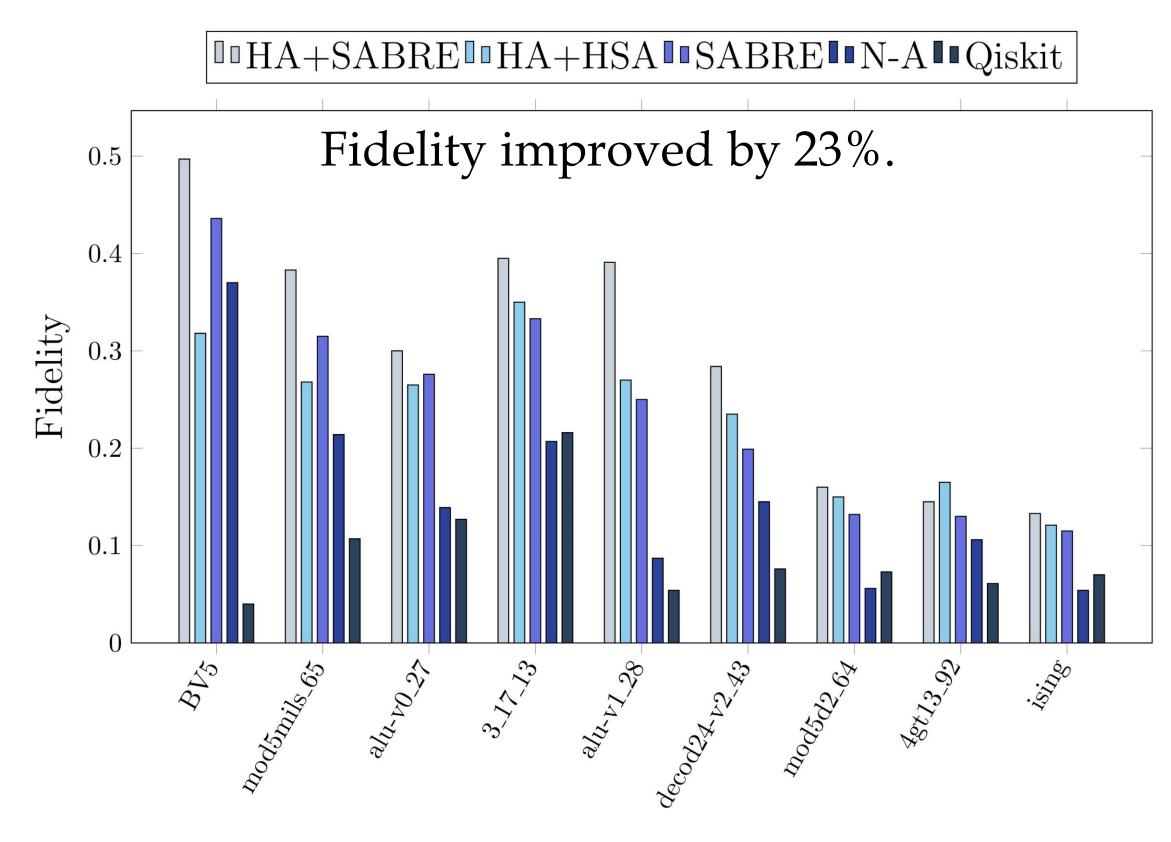
Bridge gate

- Hardware-aware Simulated Annealing (HSA) initial mapping.
 - Hardware-aware **get_neighbor** method.

Results

• Comparison of number of additional gates and fidelity on IBM Q 20 Almaden.





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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