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Exploring Multi-programming Applications in the NISQ Era

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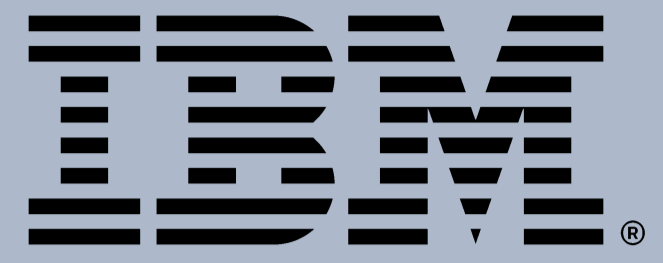
Exploring Multi-programming Applications in the NISQ Era



Siyuan Niu and Aida Todri-Sanial

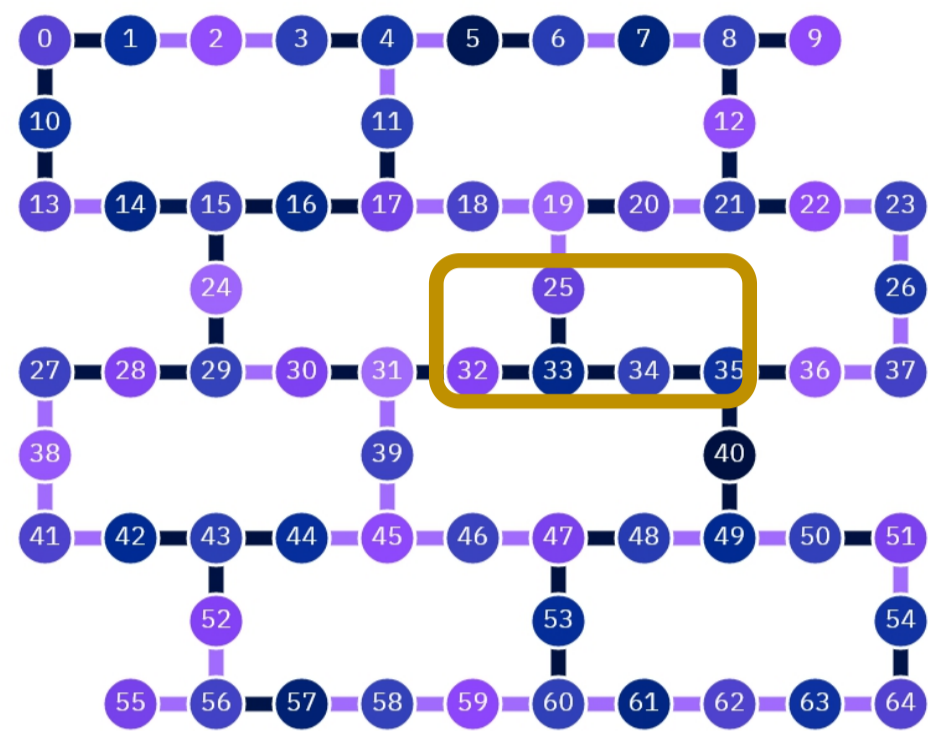
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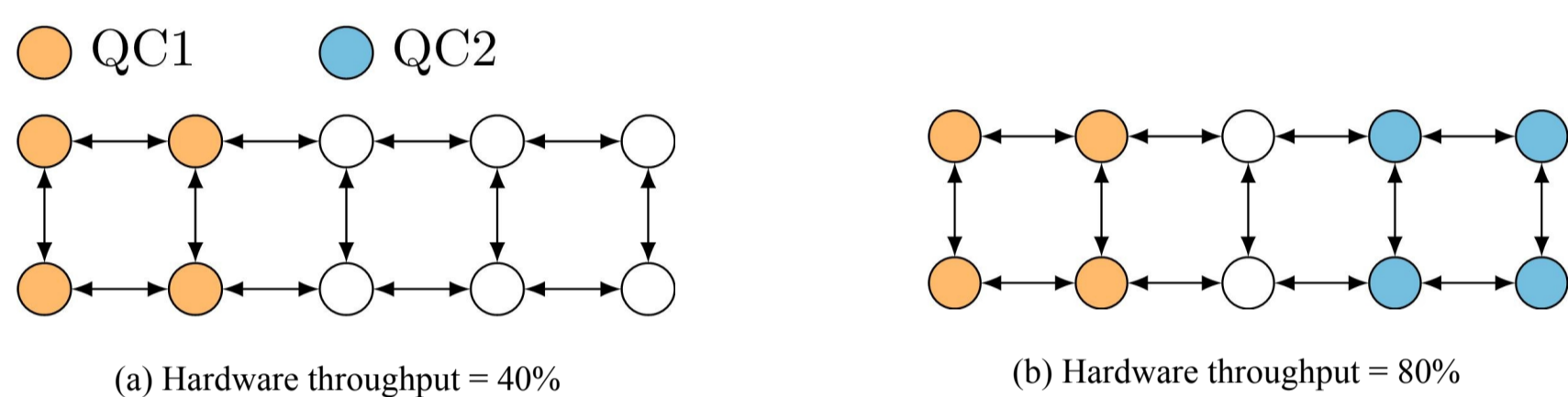
BQIT:22

Introduction



- **Limited** hardware connectivity
- Unavoidable **error** rates
- Only **small** circuits can obtain reliable results
- **Long** waiting time
- Hardware throughput: **8%**
- Total pending jobs: **1038**

Motivation



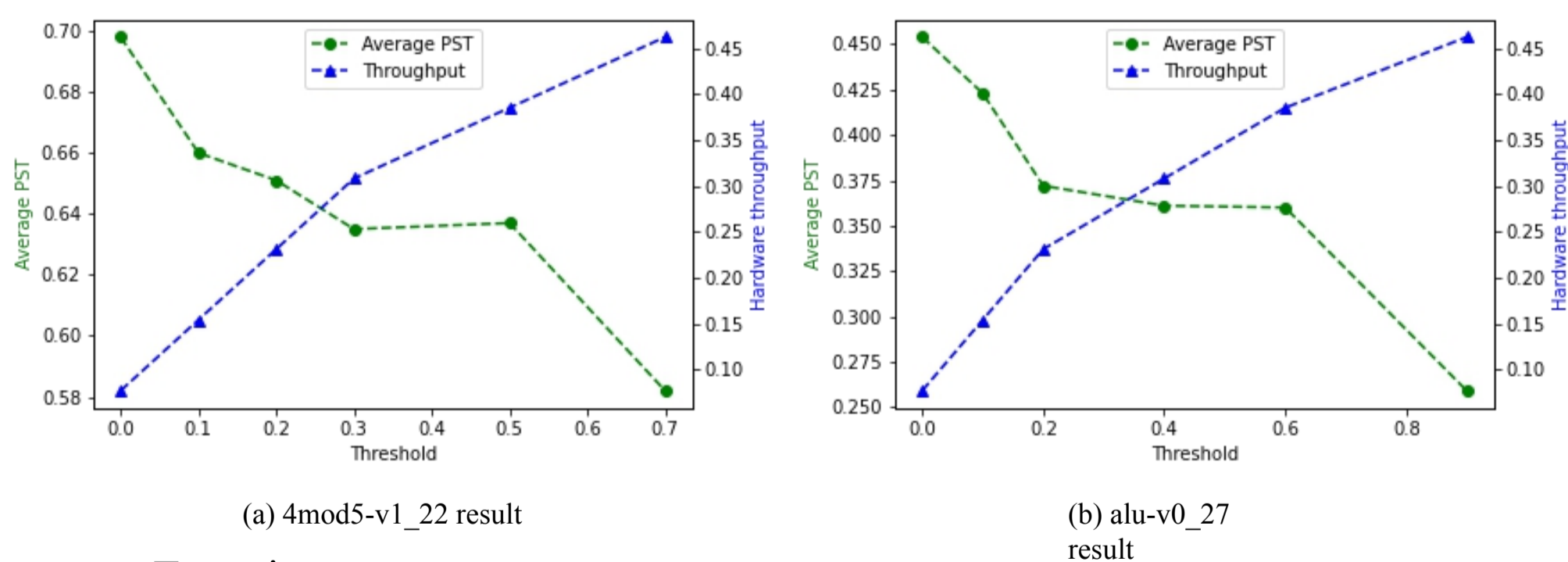
Key ideal: execute multiple circuits simultaneously to increase the hardware throughput and total runtime.

The multi-programming mechanism

Which factors should we consider to build a multi-programming technique?

- Crosstalk
- Partition qubits to reliable regions
- Qubit mapping (routing)
- Task scheduling
- Number of simultaneous circuits

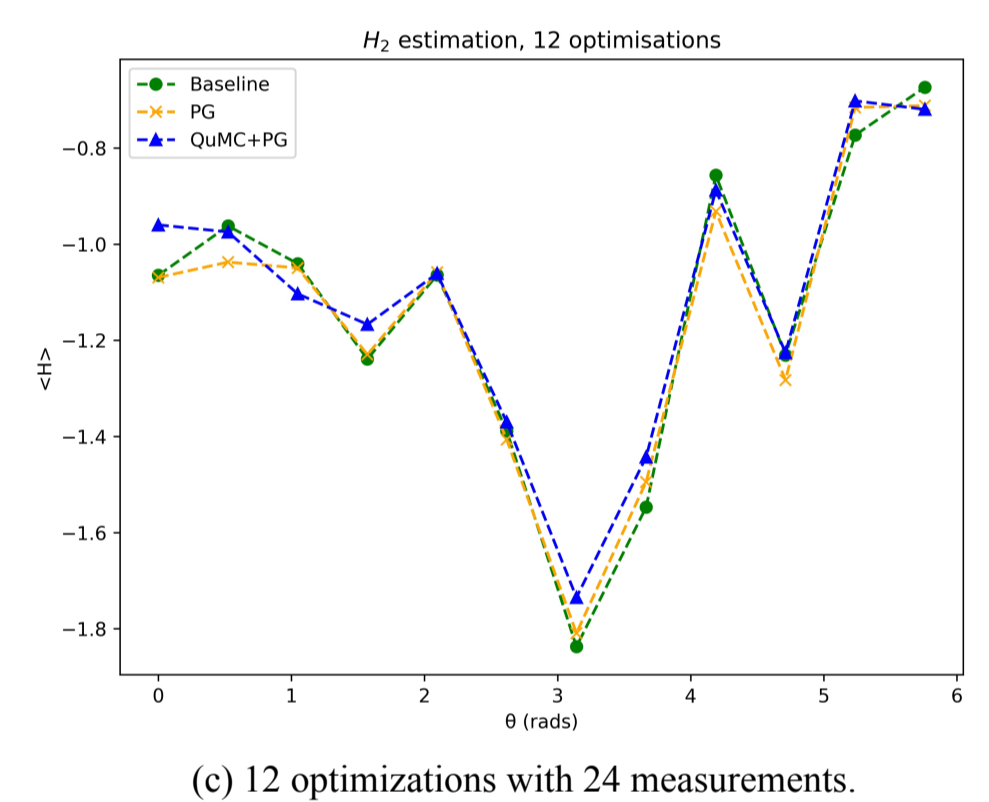
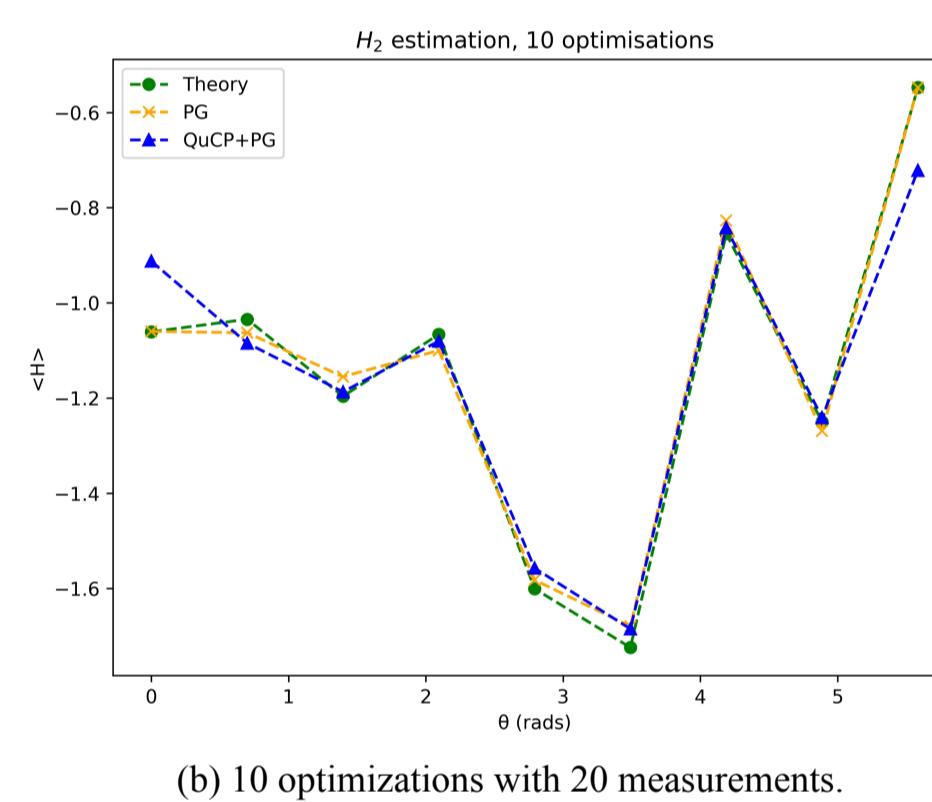
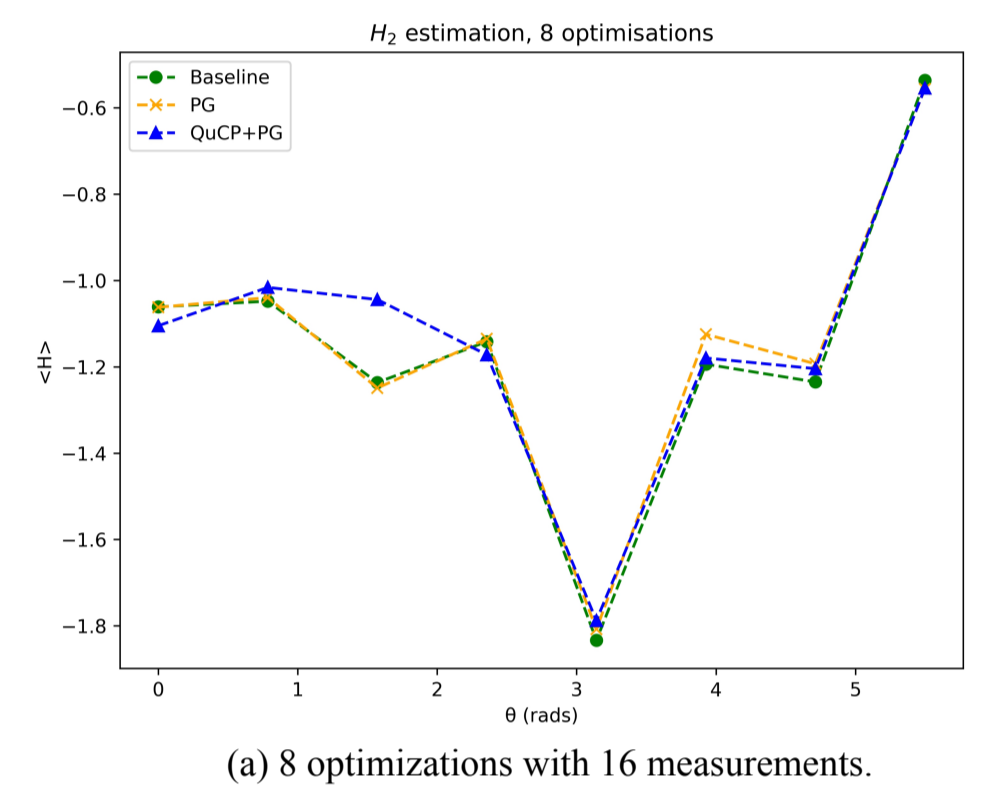
Hardware throughput vs Circuit fidelity



- Experiment setup
 - Execute different number of the same circuit on IBM Q 65 Manhattan.
 - Report the relation between hardware throughput and circuit fidelity.
- Results
 - # parallel circuit executions: one to six
 - Hardware throughput: 7.7% to 46.2%
 - Significant fidelity loss when hardware throughput is over **38%**.

Multiprogramming and VQE

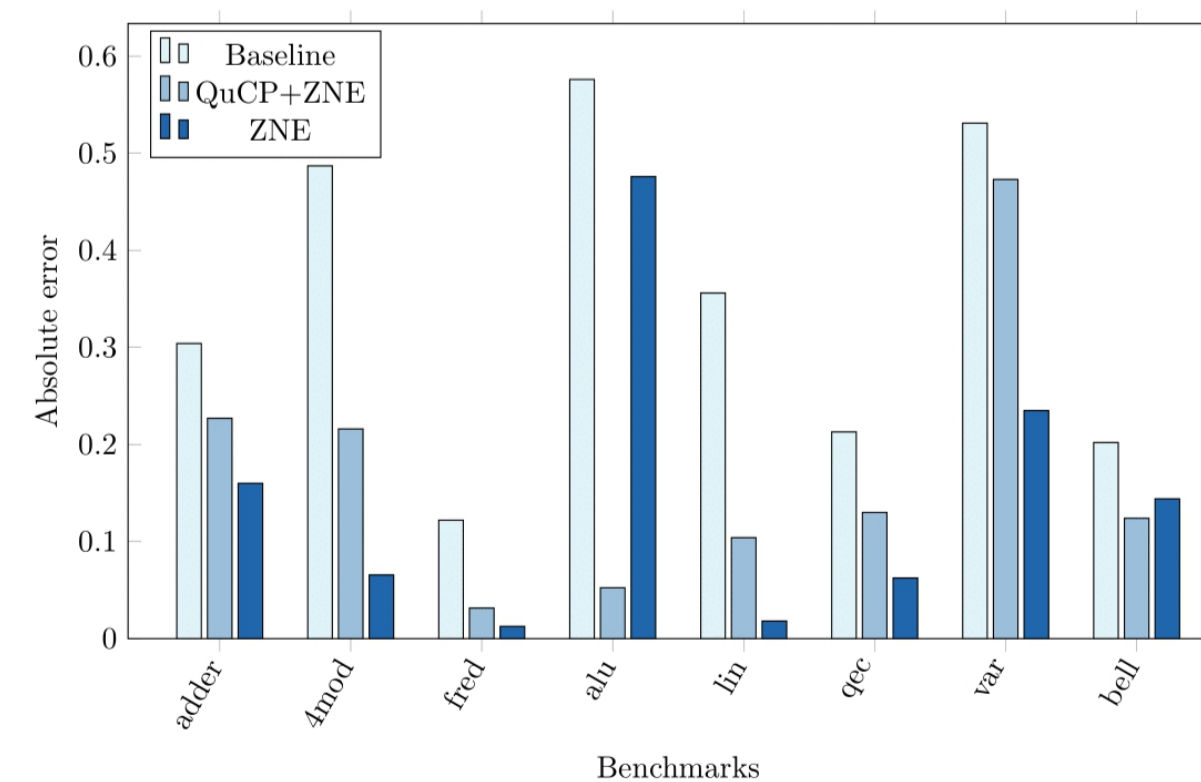
- VQE limitation
 - Split the computation into $O(N^2)$ sub-problems, introducing a large overhead of measurement circuits.
- Pauli grouping
 - Grouping commuting Pauli terms and measure them simultaneously.
- Idea
 - Apply multiprogramming to Pauli grouping
- Experiment setup
 - Estimate ground state energy of H_2
 - Hamiltonian: $\{II, IZ, ZI, ZZ, XX\}$
 - Heuristic ansatz state
 - Two repetitions
 - $RyRz$ on each qubit



- Results
 - Hardware throughput can be up to **73.8%** with an error rate of less than 10%.

Multiprogramming and ZNE

- Zero noise extrapolation (ZNE) error mitigation.
 - Noise-scaling
 - Extrapolation
 - Extra circuit overhead



- Results
 - The error rate is reduced by **2x** without any circuit overhead.

References

[1] [S.Niu et al. arxiv.2112.00387, 2021.](#)
 [2] [S.Niu et al. arxiv.2102.05321, 2021.](#)
 [3] [P.Gokhale et al. QCE 2020.](#)
 [4] [Y.Li et al. PRX 2017.](#)



Acknowledgment

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