Harnessing the Power of Long-Range Entanglement for Clifford Synthesis

IBM **Quantum**
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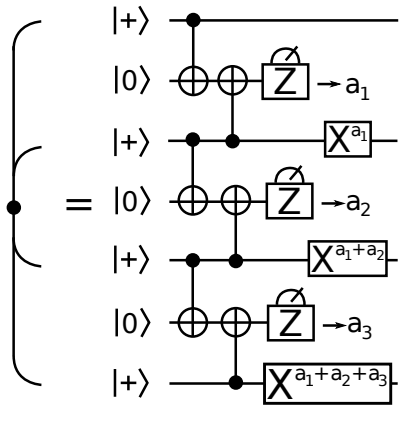
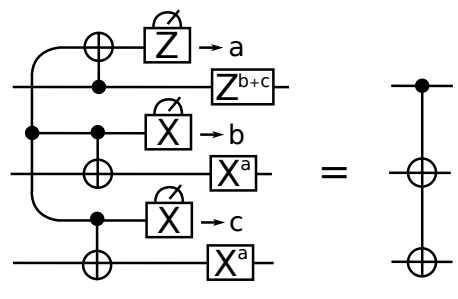
Main Result: A quantum architecture and compilation algorithm for fast Clifford synthesis.

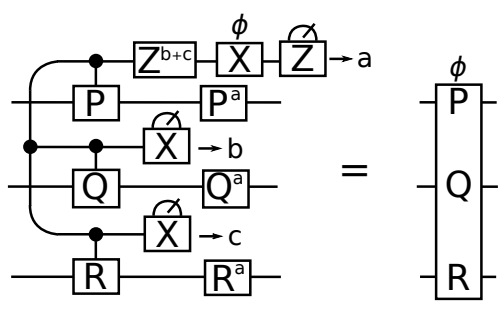
I. Motivation: harnessing the power of long-range entanglement for circuit synthesis.



Constant depth circuit for GHZ state synthesis.



CNOT Fan Out

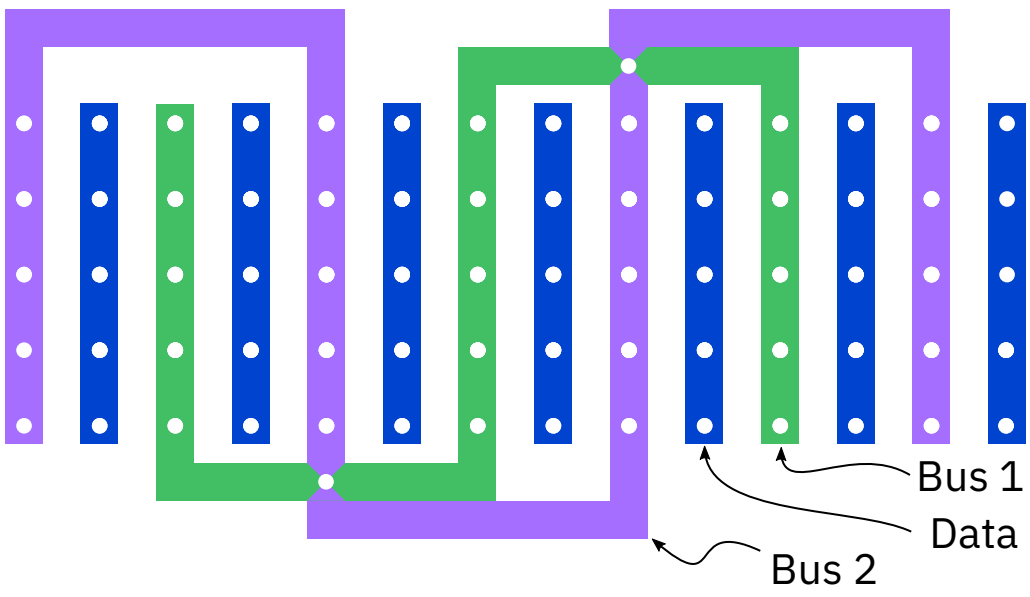


Pauli Rotation

GHZ states as a resource for *n* qubit gates.

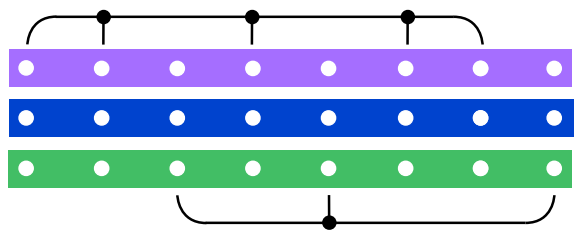
II. Architecture Proposal: "Dual Snake"

Two entanglement buses with linear shape.

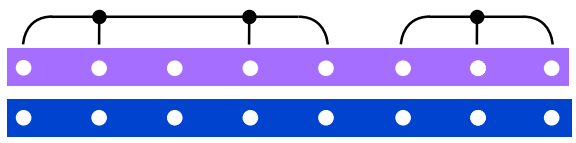


Parallelization features:

Two buses allow parallel injection of disjoint states

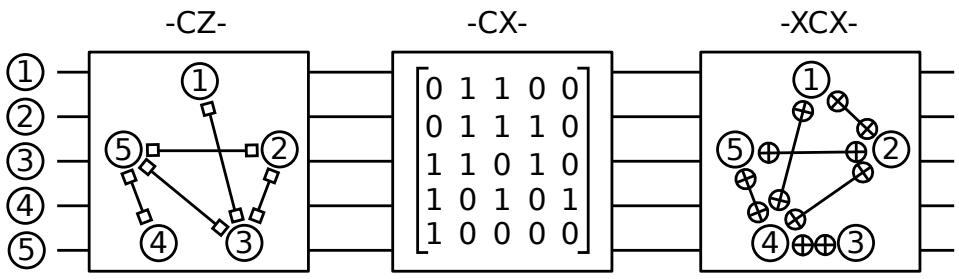


Linear shape allows parallel injection within one bus



Grid layout: permutation of qubits in $O(\sqrt{n})$

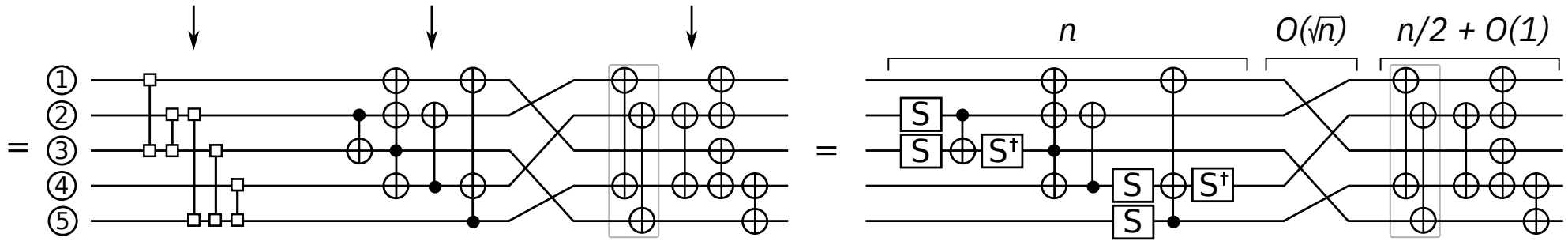
III. Clifford Synthesis Algorithm



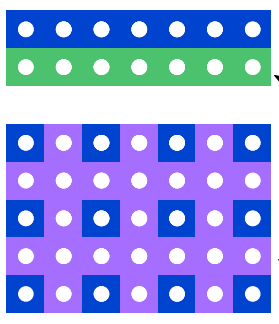
1. Compute the -CZ-CX-XCX- decomposition
2. Synthesize XCX and CX circuits using:

$\lceil n/2 \rceil + O(1)$ $\quad$ $n + O(\sqrt{n})$

3. Merge the CZ into the CX circuit



IV. Results



Architecture	Best Known Depth for n qubit Clifford Circuits			
Linear Nearest Neighbor	$7n - 4$		Maslov, Yang	arXiv:2210.16195
All to All	$2n + O(\log^2 n)$		Maslov, Zindorf	arXiv:2201.05215
Single Entanglement Bus	$2n + 1$		Pllaha et al.	arXiv:2102.11380
Padded Grid	Using teleportation only: $O(n^{3/2})$		Beverland et al.	arXiv:2110.11493
Dual Snake	$\left\lceil \frac{3}{2} n \right\rceil + O(\sqrt{n})$		This work	