Depth-Driven Routing

A Novel Approach to the Qubit Routing Problem

Alessandro Annechini

alessandro.annechini@mail.polimi.it

Slides available here

Sala Conferenze Emilio Gatti, Via Giuseppe Ponzio, 34/5

Milano, 26 Luglio 2024

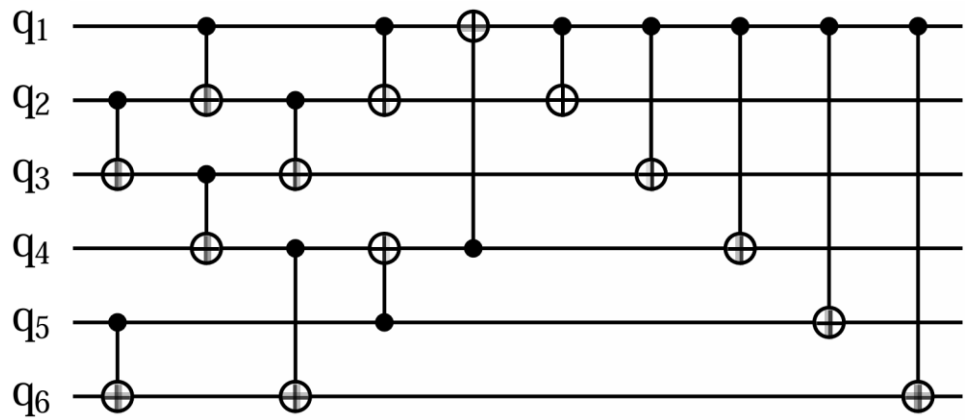
POLITECNICO MILANO 1863

POLITECNICO MILANO 1863 NECST laboratory

Qubits and quantum circuits

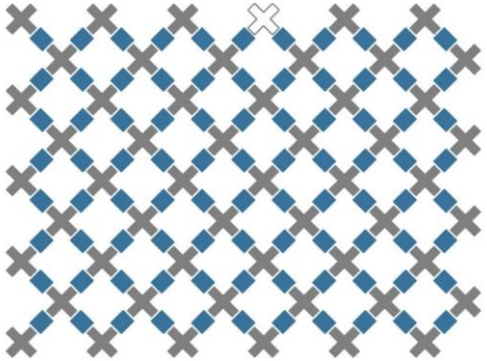
$$|q\rangle = \alpha|0\rangle + \beta|1\rangle$$

$$|\Psi\rangle = \sum_{i \in \{0,1\}^n} \alpha_i |i\rangle$$

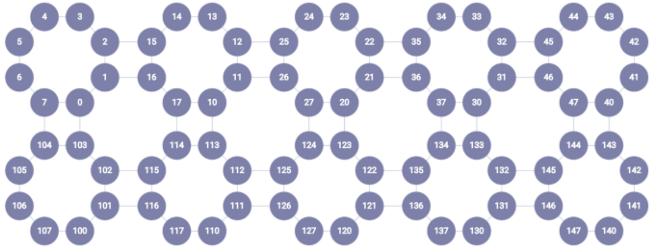


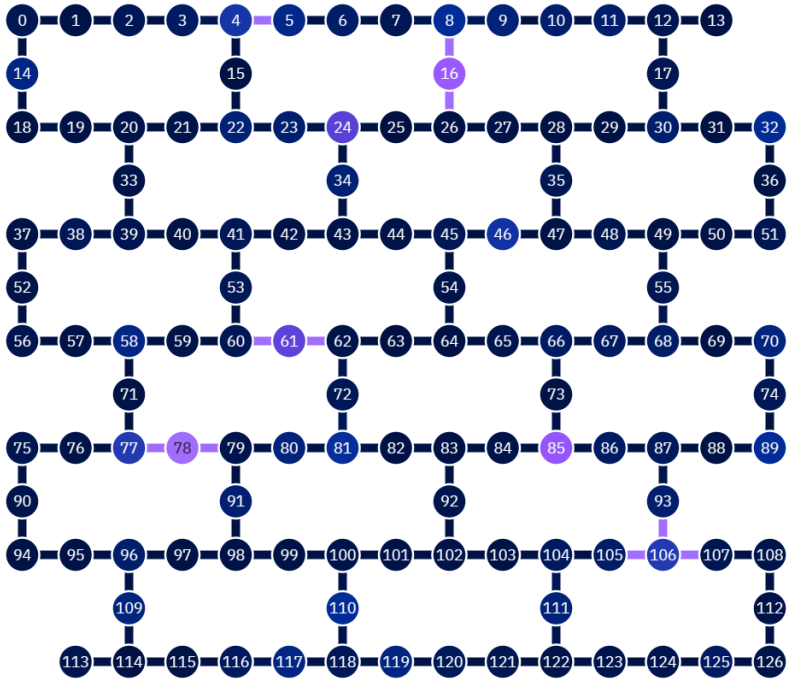
Quantum hardware

Google



rigetti

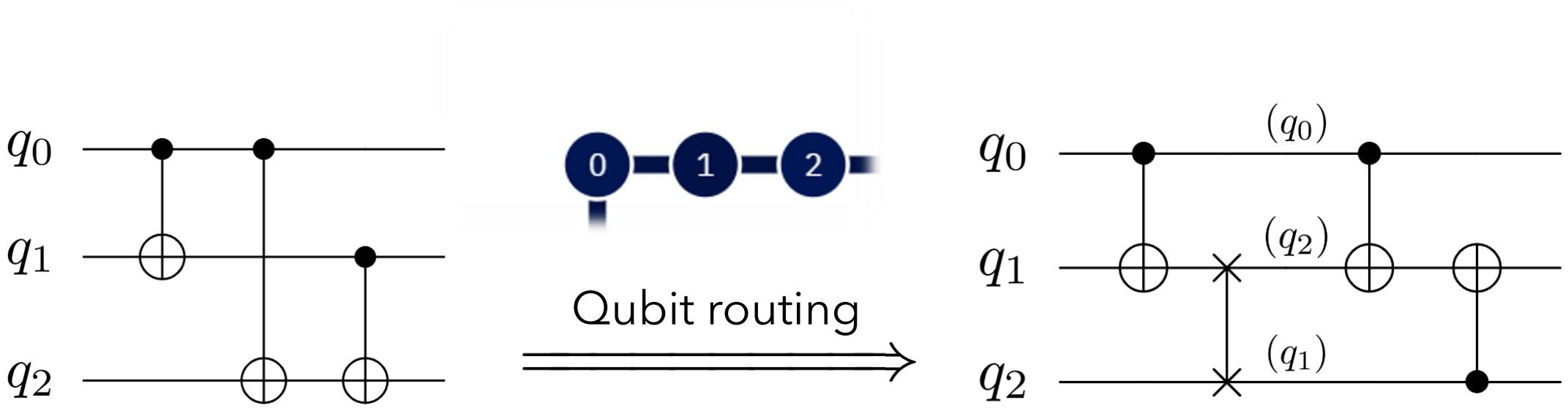




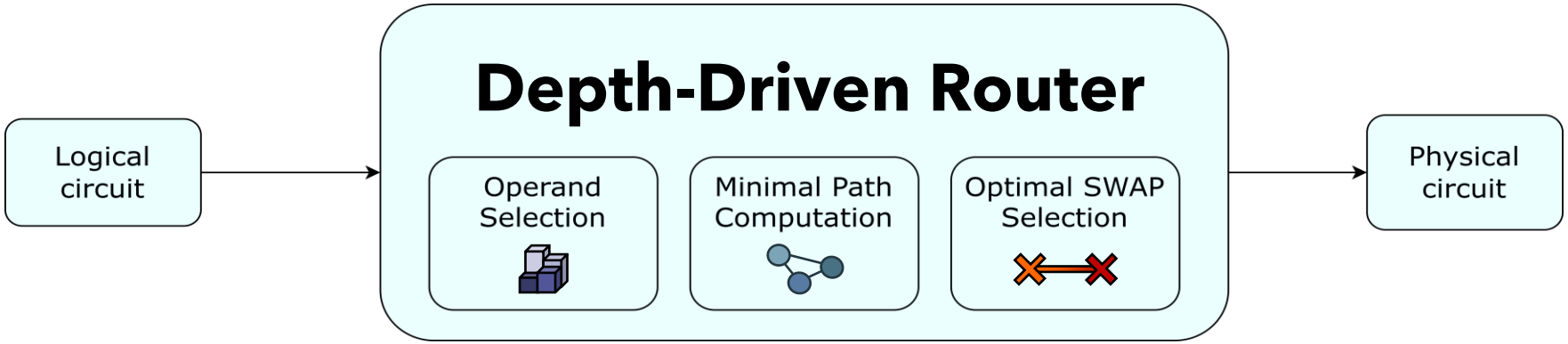
IBM

Google Sycamore: https://research.google/blog/quantum-supremacy-using-a-programmable-superconducting-processor/
Rigetti Aspen: https://investors.rigetti.com/news-releases/news-release-details/rigetti-computing-announces-commercial-availability-80-qubit
IBM Eagle: https://quantum.ibm.com/services/resources

Qubit routing



Depth-Driven Routing



Operand selection: selection of the pair of operands that need to be routed together

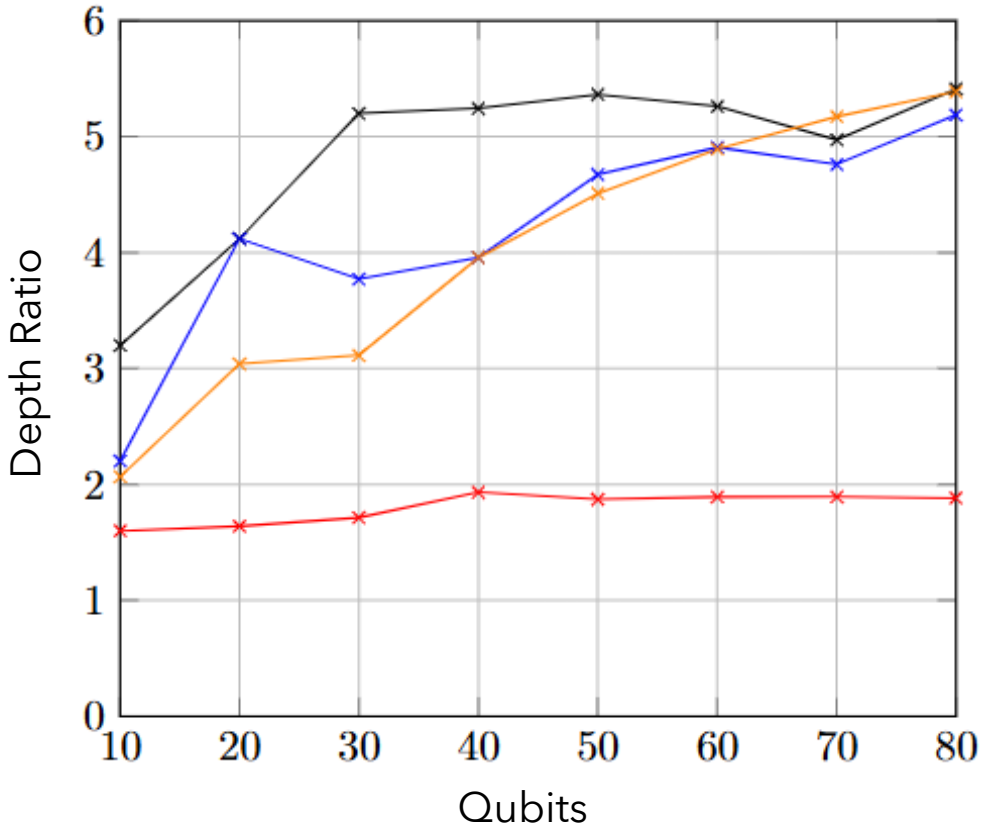
Minimal Path Computation: selection of the best path between the qubits with respect of:

- Execution time
- Number of required SWAP
- Lookahead

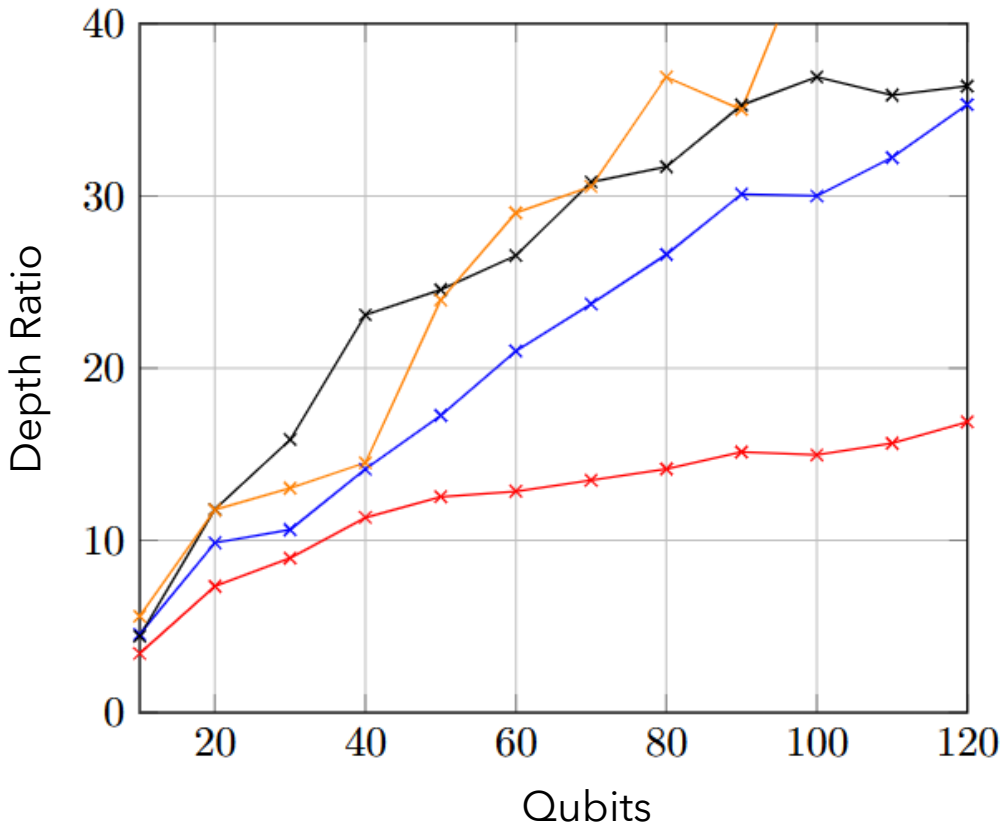
Optimal SWAP selection: the optimal SWAP is chosen and applied to the circuit

Results

$$\text{Depth Ratio} = \frac{\text{Final Depth}}{\text{Initial Depth}}$$



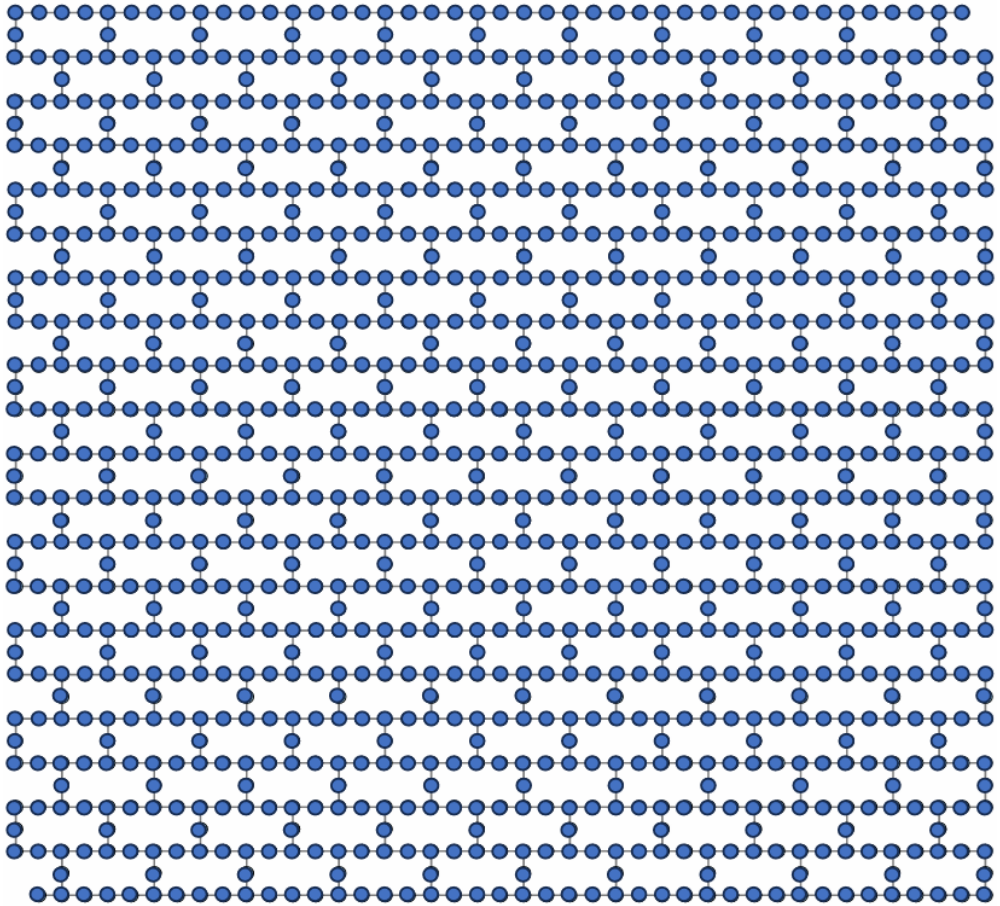
Topology: Rigetti Aspen (80 qubit)
Circuit: Deutsch-Jozsa



Topology: IBM Eagle (127 qubit)
Circuit: Two-Local Ansatz

Stochastic SABRE t|ket⟩ DDR

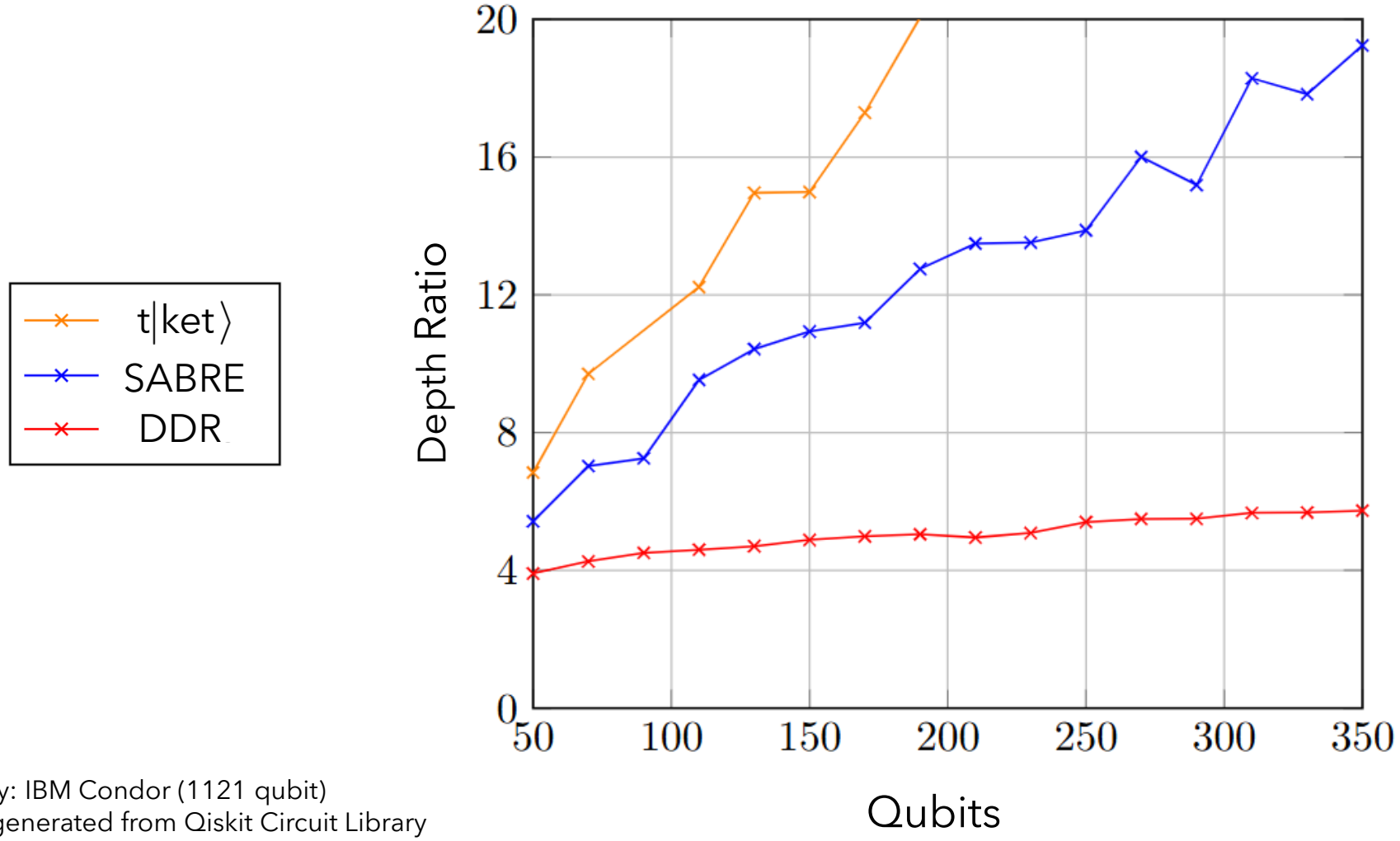
IBM Condor



IBM Condor: https://www.ibm.com/quantum/blog/quantum-roadmap-2033

Results

$$\text{Depth Ratio} = \frac{\text{Final Depth}}{\text{Initial Depth}}$$



Topology: IBM Condor (1121 qubit)
Circuit: generated from Qiskit Circuit Library

Conclusions

Contribution:

- We designed an algorithm for Qubit Routing aimed at minimizing the depth of hardware compliant circuits, which shows a depth reduction up to 70% with respect to state-of-the-art solutions

Future work:

- Perform more tests to validate and improve the quality of the algorithm
- Develop a full python library providing the routing functionalities to the most employed quantum computing frameworks

Thanks for the attention!

Alessandro Annechini

alessandro.annechini@mail.polimi.it

Sala Conferenze Emilio Gatti, Via Giuseppe Ponzio, 34/5

Milano, 26 Luglio 2024

POLITECNICO MILANO 1863

POLITECNICO MILANO 1863 NECST laboratory

https://www.linkedin.com/in/alessandro-annechini/