Performance of Quantum Algorithms on the IBM Quantum Computers

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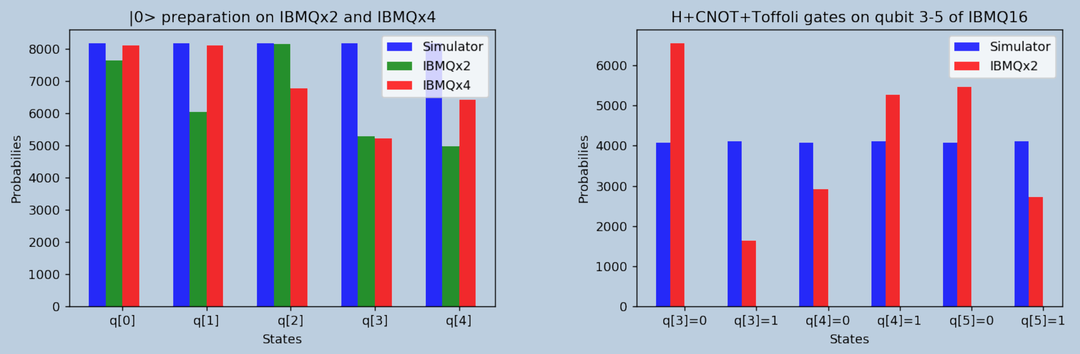
Abstract

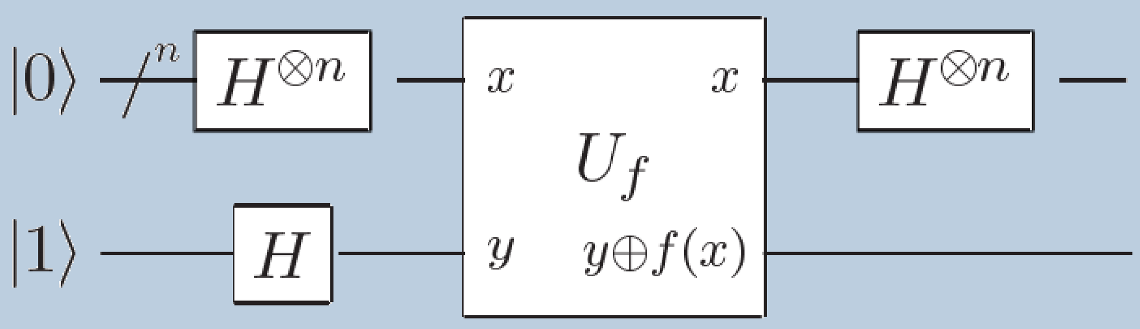
Quantum computation is an emerging technology with the prospect to outperform classical computation in many classes of problem, and Shor's and Grover's algorithm are its prominent examples. In 2016, IBM released the Quantum Experience, an online platform for public users to execute quantum algorithms. In this work, we execute Shor's and Grover's on the IBM Q quantum computers to test its ability and to assess the current progress of quantum computing.

Accuracy of the IBMQ



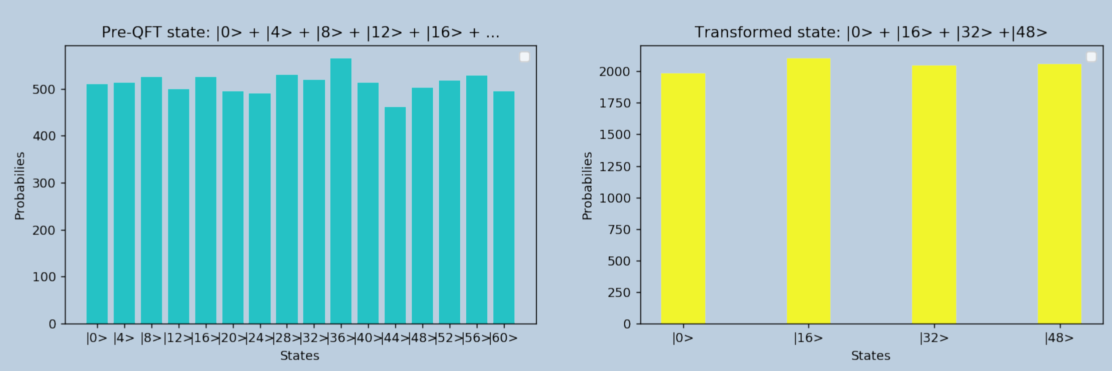
The simulated results, shown in blue, are the ideal data. The IBMQ computers yield noticable error rate even for simple tasks like $|0\rangle$ preparation or applying basic gates. Major improvements in quantum error correcting are needed.

Quantum parallelism



Crudely speaking, quantum parallelism allows us to evaluate the value of $f(x)$ for many values of x simultaneously. By normal measurements we only gather the value of $f(x)$ for one value of x every time, but by smart state preparation and picking the right $f(x)$, we can process the final state $|f(x)\rangle$ to regain some of its crucial properties and solve staunching problems. [2]

Quantum Fourier Transform



One of such imperative property is, for example, the period of $f(x)$. Like the classical Fourier transform, which is utilized usually to expose the period of a function, the quantum one can give us the "period" of $f(x)$ by manipulating a superposition of state using interference.

References

[1] Monz, T. et al. *"Realization Of A Scalable Shor Algorithm"*. Science, vol 351, no. 6277, 2016, pp. 1068-1070. American Association For The Advancement Of Science (AAAS), doi:10.1126/science.aad9480. Accessed 29 July 2019.

[2] Nielsen, Michael A, and Isaac L Chuang. *Quantum Computation And Quantum Information*. Cambridge University Press, 2019.

[3] Patrick J. Coles. et al. *Quantum Algorithm Implementations for Beginners*. arXiv:1804.03719 [cs.ET]

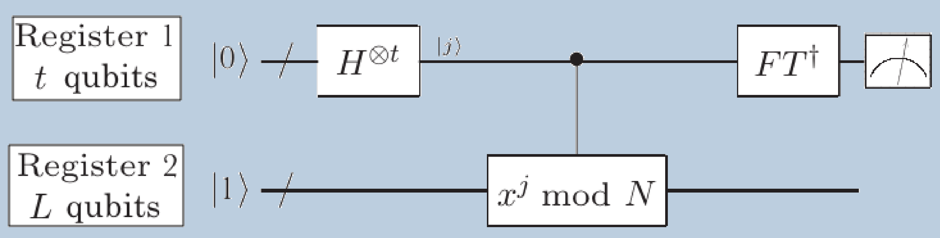
GitHub link

https://github.com/mx73/VCTP44

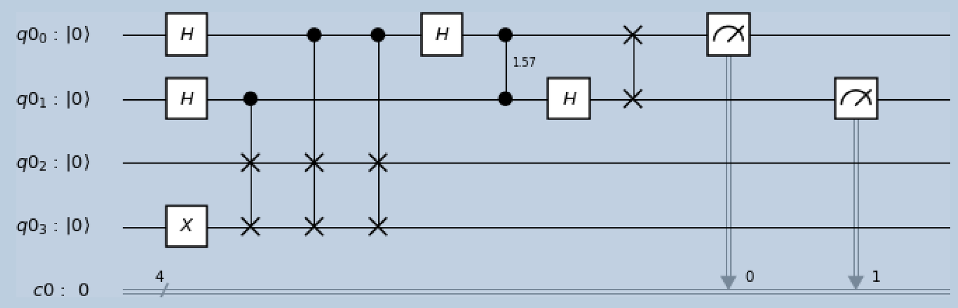
Shor's algorithm on the IBMQ

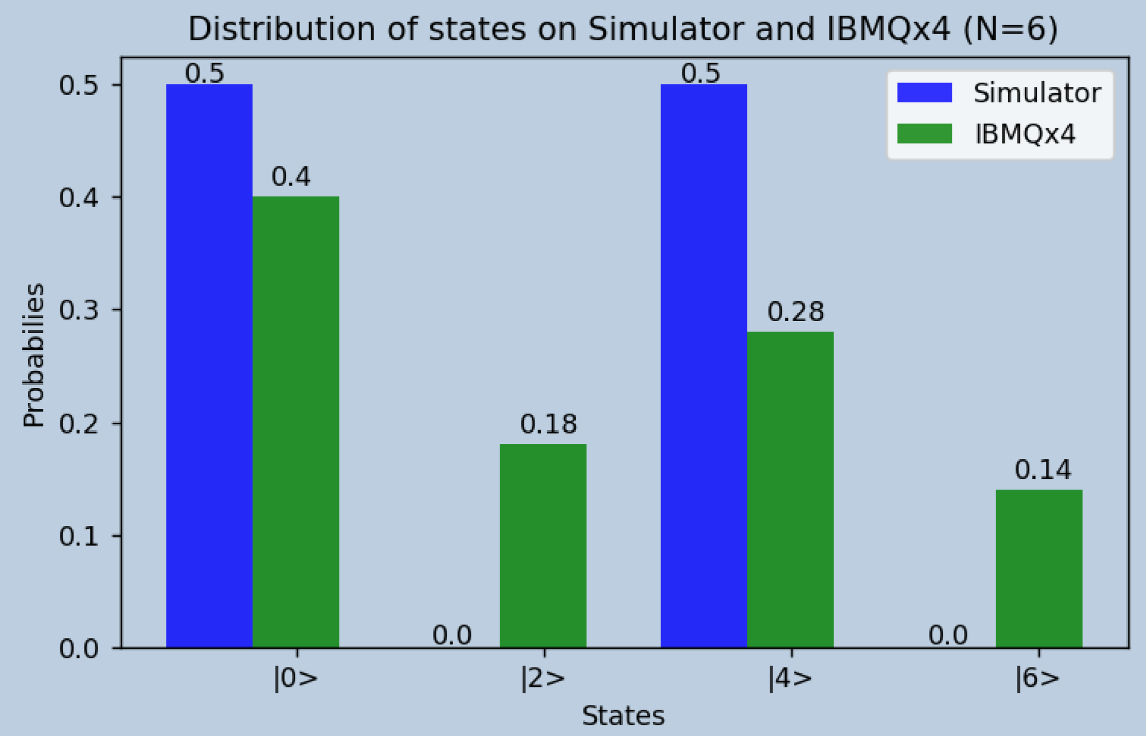
We realize Shor's algorithm using modular multiplication circuits [1] with Quantum Fourier Transform [2] [3]. Reasonable results were collected from IBMQx4, with x = 5, N = 6 (using 2 qubits for the first register and 2 qubits for the second register; the period is 2) and x = 4, N = 15 (using 3 qubits for the first register and 2 qubits for the second register; the period is also 2).

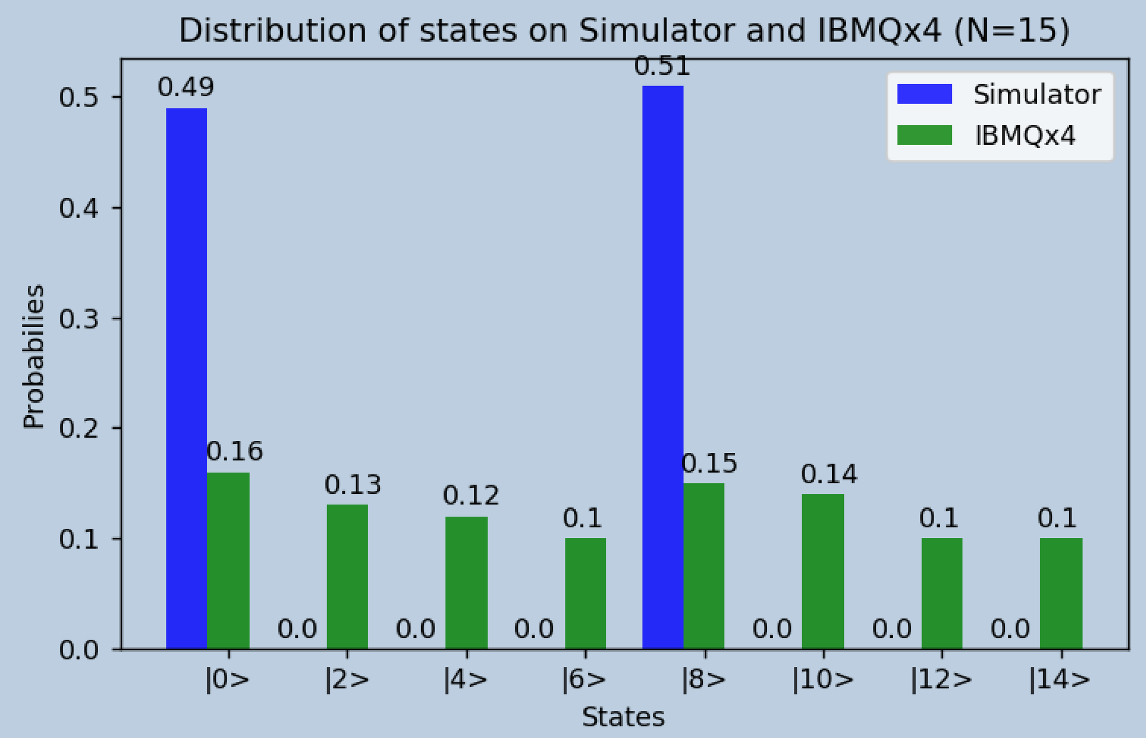
- Shor's algorithm general diagram:



- Shor's circuit for the case of x = 5, N = 6. Other cases' circuits are too big to be shown on the poster, but all results and circuit diagrams can be found on the GitHub address.

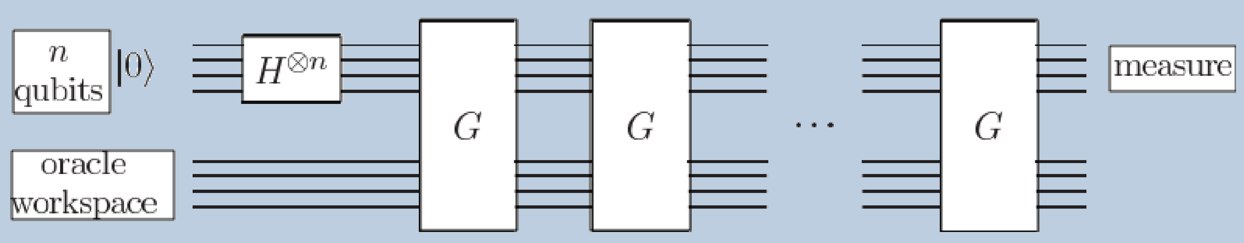


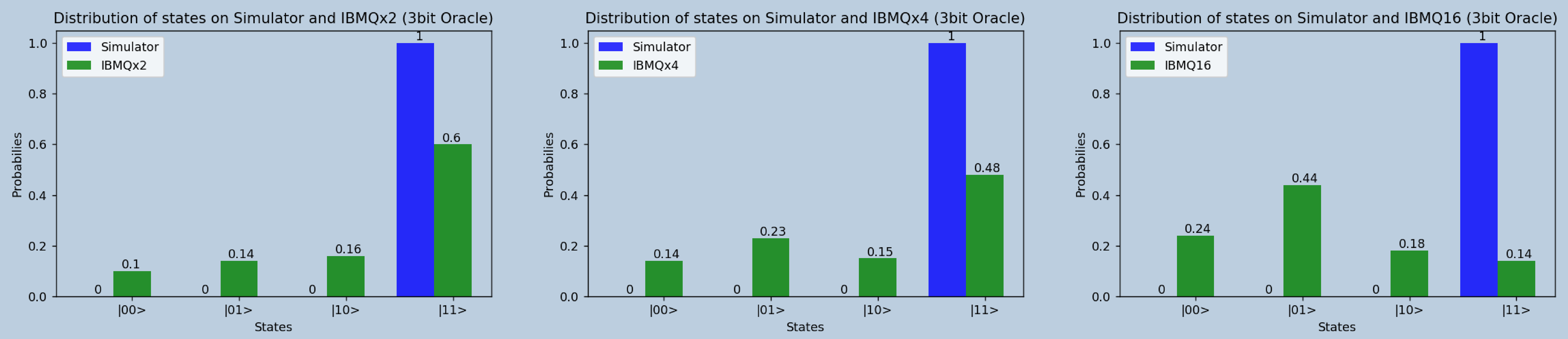


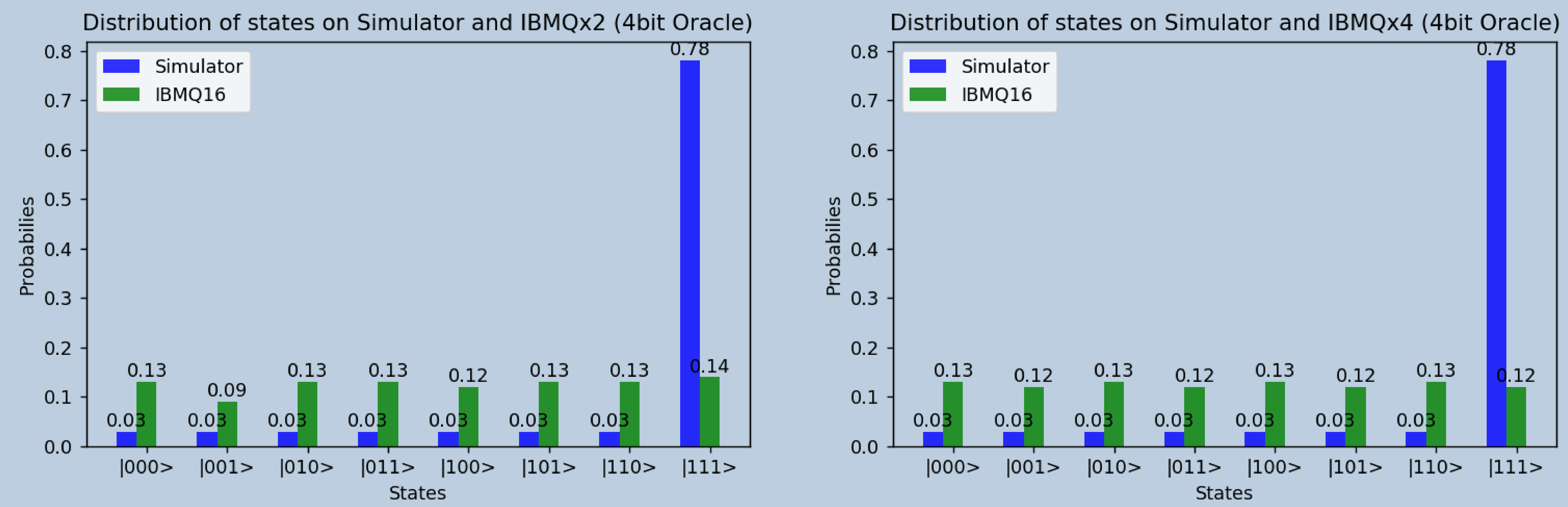


Grover's algorithm on the IBMQ

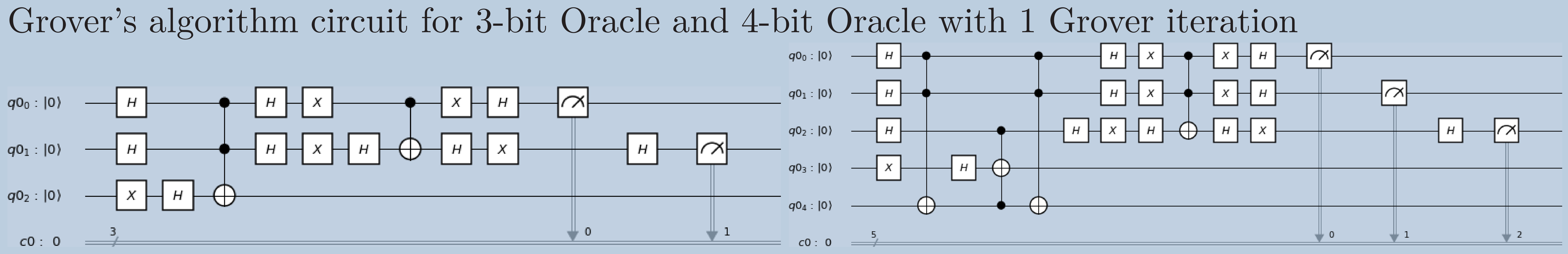
The algorithm were ran with the "oracle" circuit simply be a n-Toffoli gate, therefore the marked input state is $|11\rangle$ and $|111\rangle$. Results from the IBMQx2 and IBMQx4 under 1 Grover iteration [2] [3] for the 3-bit case can be used to correctly interpret the marked input state. Other cases still have significant error rate.







Grover's algorithm circuit for 3-bit Oracle and 4-bit Oracle with 1 Grover iteration



Conclusion

The IBMQx2 was able to run Grover's algorithm, and the IBMQx4 was able to run both Shor's and Grover's. The IBMQ16 did not give decipherable results for any of the test. Even though the results are faulty and the circuits are still small due to significant error rate, these results are evidences for the progress of quantum computing. Breakthroughs in the field of quantum error correction are needed to truly realize the power of quantum computation.