

Teleportation of the Bell states on IBM Q 5 Yorktown quantum computer

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Abstract. In this talk, we present realization of a protocol of two-qubit state teleportation on the 5-qubit quantum IBM quantum computer Yorktown and compare its results with those obtained with the Maple-based simulator called Feynman. We compare error rates for implementations on the IBM Q Yorktown achieved in our previous studies to actual error rates for the same quantum circuits and the circuits reduced after IBM Q Yorktown modification. Our experiments show the technical improvement of IBM quantum hardware over the past year.

Noisy Intermediate-Scale Quantum (NISQ) technology is rapidly developing over last years. The near-term quantum computers with 50-100 qubits are able to perform tasks which surpass the capabilities of today's classical digital computers. However, noisy qubits and quantum gates lead to limitation of the size of quantum circuits that can be executed reliably. In the given talk we present our results partially taken from [1] on implementation on the IBM Q 5 Yorktown quantum computer (Fig. 1), and other 5-qubit computers accessible via the IBM cloud (<https://www.ibm.com/quantum-computing/technology/experience/>), the protocol [2] of quantum teleportation of Bell (EPR) states. We adopt the original version of this protocol to set of gates built-in IBM Q which includes one-qubit gate

$$U2(\phi, \lambda) = \begin{pmatrix} \frac{1}{\sqrt{2}} & -\frac{\exp i\lambda}{\sqrt{2}} \\ \frac{\exp i\phi}{\sqrt{2}} & \frac{\exp i(\lambda+\phi)}{\sqrt{2}} \end{pmatrix}, \quad \oplus = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \quad \lambda, \phi \in [0, 2\pi], \quad H = U2(0, \pi),$$

the measurement gate and the 2-qubit control- \oplus (CNOT) gate (Fig. 2).

The Bell states are the maximally entangled 2-qubit states. They are created in the lower left corner of the circuit if the input qubits q_3 and q_4 are in the classical states

$$|q_0\rangle = |x\rangle, |q_1\rangle = |y\rangle \longrightarrow |\beta_{xy}\rangle = \frac{1}{\sqrt{2}} (|0, y\rangle + (-1)^x |1, 1 - y\rangle), \quad x, y \in \{0, 1\}.$$

The bell states $|\beta_{xy}\rangle$ are transported to the states of qubits q_1 and q_2 . Then they are measured in the classical basis on the output. The results of the measurement

shown in Fig. 3. Because of the noise, the obtained probabilities are substantially different of the expected ones shown in Fig. 4. These expected probability values were computed by using FEYNMAN [3], the classical simulator written in MAPLE. Since it does the related computations exactly, i.e. without noise, its output 2-qubit state is exactly equal to the input Bell state.

Thus, for applicability of IBM quantum computers even to small (w.r.t. the number of qubits needed) problems, one has to decrease the hardware errors.

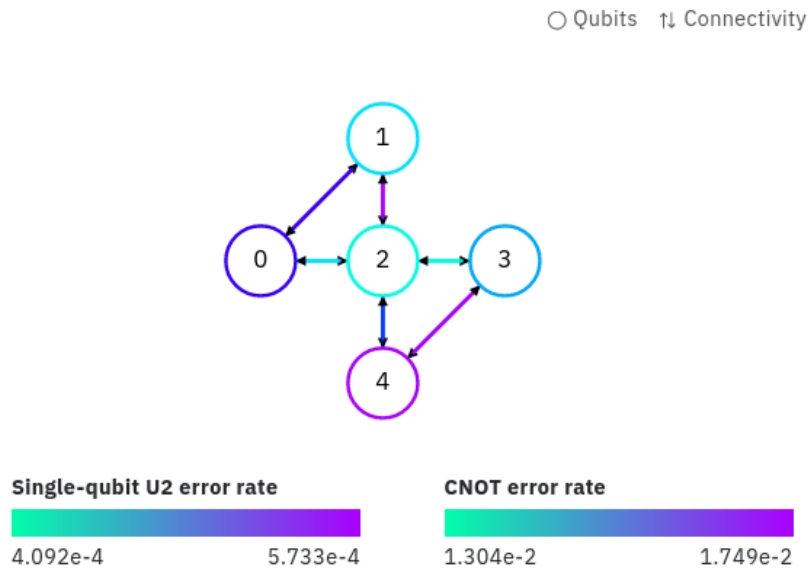


FIGURE 1. Quantum computer IBM Q 5 Yorktown

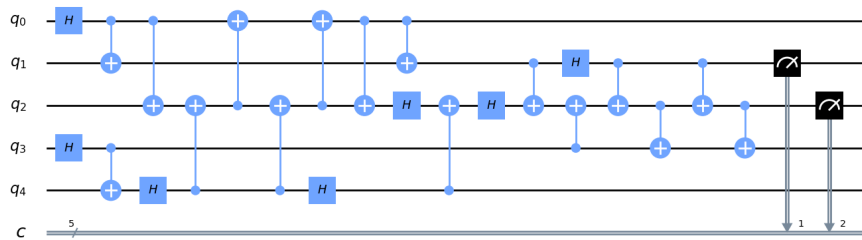


FIGURE 2. Quantum circuit

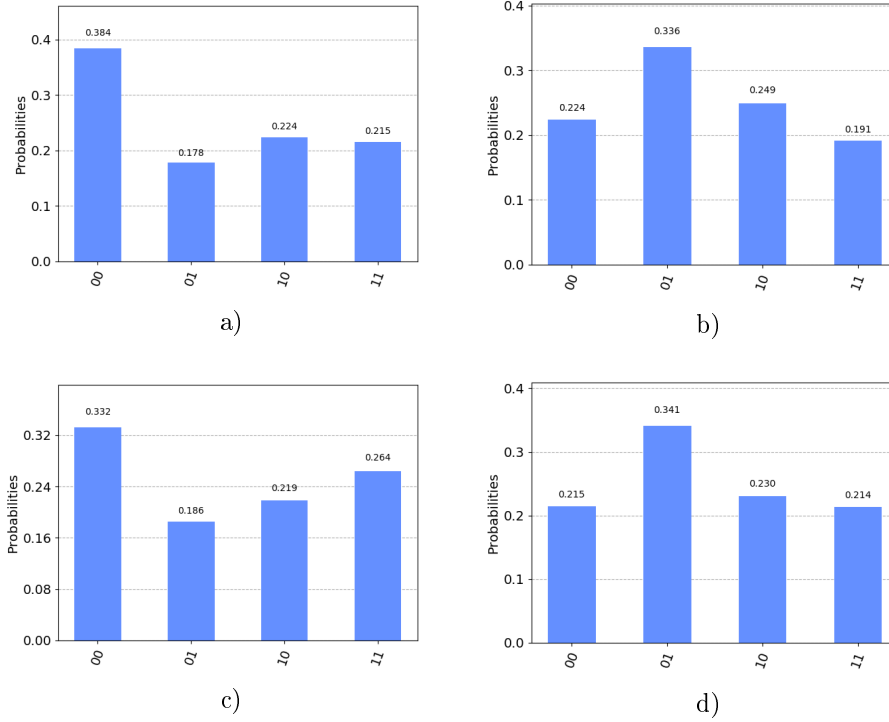


FIGURE 3. Results of teleportation of the Bell states on the IBM Q Yorktown with readout in the classical basis. a) state $|\beta_{00}\rangle$, b) state $|\beta_{01}\rangle$, c) state $|\beta_{10}\rangle$, d) state $|\beta_{11}\rangle$.

References

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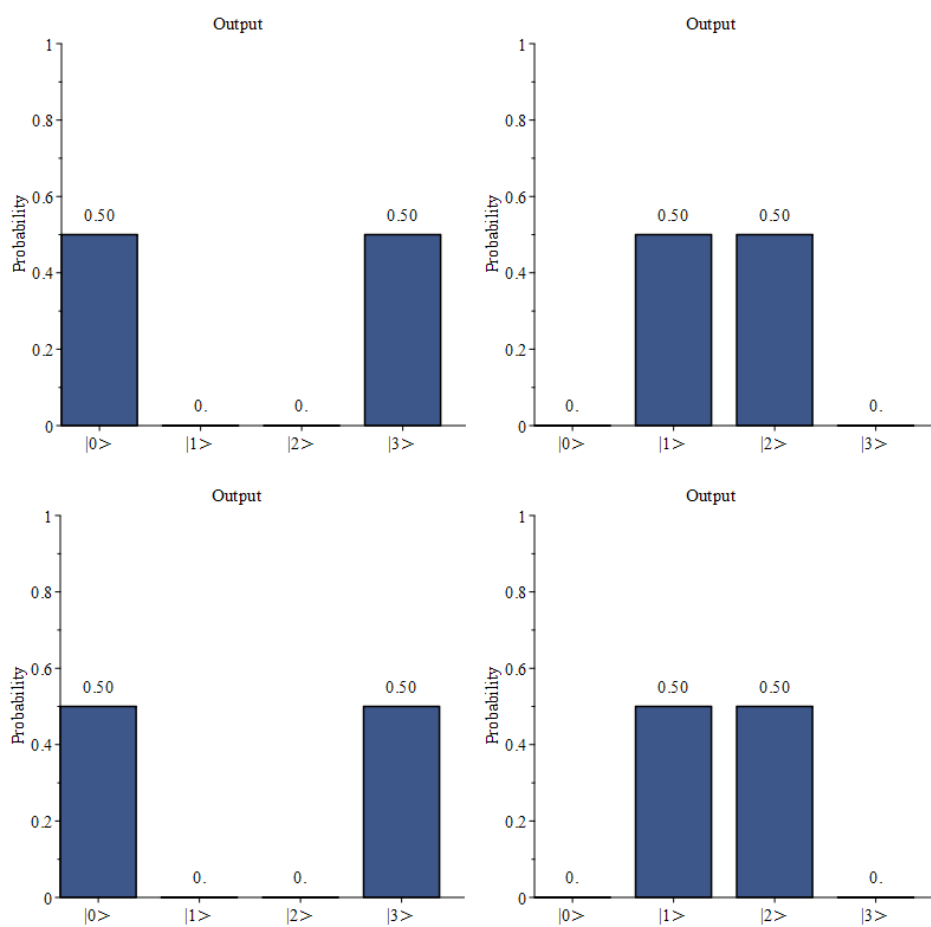


FIGURE 4. Classical simulation with FEYNMAN

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