Quantum Teleportation on the IBM Quantum Computer

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Introduction

• Years ago, David Deutsch proposed the following question: Is there a (single) universal computing device which can efficiently simulate any other physical system?
• Deutsch observed that ordinary, everyday computers based on Turing’s model had a lot of trouble simulating quantum mechanical systems.
• To answer his question affirmatively, Deutsch had to invent a new type of computing system known as the Quantum Computer.
• A Quantum Computer can do everything a conventional computer can do, but is also capable of performing quantum computing tasks such as quantum teleportation, quantum clock synchronization, and quantum key distribution.

STATE OF A QUBIT

The state of a qubit can be represented by a two-dimensional vector or by the following equations:

$$\Psi = \cos \theta/2 |0> + \sin \theta/2 e^{i\phi} |1>$$

$$|\psi> = \alpha |0> + \beta |1>$$

$$|0> = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

$$|1> = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

• Like logic gates in classical computing, the state of a qubit can be manipulated by different quantum logic gates which are represented by matrices.

Quantum Logic Gates

**The X Gate**
Acts on a single qubit
Quantum Equivalent of the NOT gate

**The Hadamard Gate**
Acts on a single qubit
Puts qubits in superposition of their states

**The Controlled-NOT Gate**
Acts on two qubits
If the control qubit is in state 1, the target qubit is bit flipped

Simulating Quantum Teleportation on Quantum Computer

• **Quantum Teleportation**: Data transmission (such as a state) from one location to another without physically transmitting the information.
• **Principle of Deferred Measurement**: If measurement results are used at any state of the circuit then the classically controlled operations can be replaced by conditional quantum operations.

References


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Fidelity of Teleportation

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<th>Fidelity without noise</th>
<th>Fidelity with noise</th>
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Figure 1: Traditional Unidirectional Quantum Teleportation Circuit [1]

Figure 2: Modified Unidirectional Quantum Teleportation Circuit based on Principle of Deferred Measurement

Figure 3: Table depicting average fidelity values of different quantum computers compared to their simulation noise models

Figure 4: Table depicting average fidelity values of different quantum computers compared to their simulation noise models

Conclusion/Future Work

• Study Bidirectional Teleportation which involves both parties sending an arbitrary quantum state to the other party.
• Possible Directions:
  - Figure out what trigger qubits are for
  - Try to build a bidirectional super dense coding circuit
  - Try to remodel circuit using fewer qubits

Figure 5: Bidirectional Teleportation Circuit [2]