Future Computing Architecture and Programming Paradigms

(mod. Quantum Computing Architectures, Programming and Applications)

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(I) Quantum Random Number Generator

Implement the quantum random number generator in a simulator of your choice.
Then change the probabilities of measuring $|0\rangle$ and $|1\rangle$ to $\frac{3}{4}$ and $\frac{1}{4}$ respectively.

(II) Entanglement

The four Bell states addressed in the lecture are:

$$|a_1 a_0\rangle = |00\rangle \Rightarrow \Phi^+ = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle) \quad |a_1 a_0\rangle = |10\rangle \Rightarrow \Phi^- = \frac{1}{\sqrt{2}}(|00\rangle - |11\rangle)$$

$$|a_1 a_0\rangle = |01\rangle \Rightarrow \Psi^+ = \frac{1}{\sqrt{2}}(|01\rangle + |10\rangle) \quad |a_1 a_0\rangle = |11\rangle \Rightarrow \Psi^- = \frac{1}{\sqrt{2}}(|01\rangle - |10\rangle)$$

In this task, you are working with a 2-qubit register.

1. Draw the circuit that sets a register to the Bell state $\Psi^- = \frac{1}{\sqrt{2}}(|01\rangle - |10\rangle)$.
2. Calculate the intermediate states $|\psi_0\rangle$, $|\psi_1\rangle$ and $|\psi_2\rangle$ of the circuit in a).

(III) Teleportation

In this task, a qubit is to be teleported; however, $|a\rangle$ and $|b\rangle$ are not in the Bell state $|\beta_{00}\rangle$ at the beginning – as in the example from the lecture – but in the Bell state $|\beta_{10}\rangle$.

1. Calculate the state $|\psi_2\rangle$ of the teleportation circuit.
2. How to adapt the circuit to perform a successful teleportation based on $|\beta_{10}\rangle$?
   Note: All you have to do is take care of the gates after the measurement!