Entanglement Swapping

Presentation

[1]Samarth Pandey
[2]Urvish Pujara
[3]Sreejan Patil
[4]George Paul
5Jay Gaveriya

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Types of Entanglement

Quantum Entanglement comes in two types:

- Bipartite Entanglement

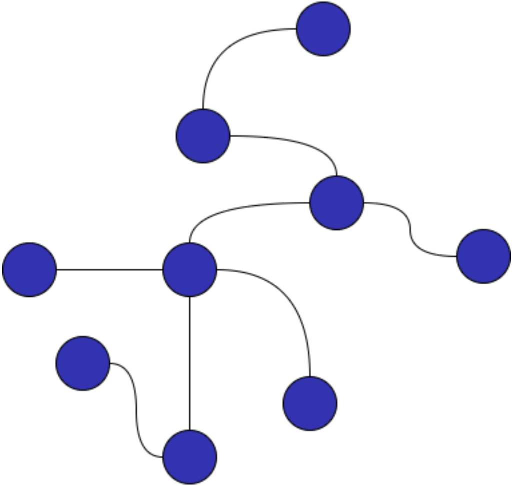
Types of Entanglement

Quantum Entanglement comes in two types:

- Bipartite Entanglement
- Multipartite Entanglement

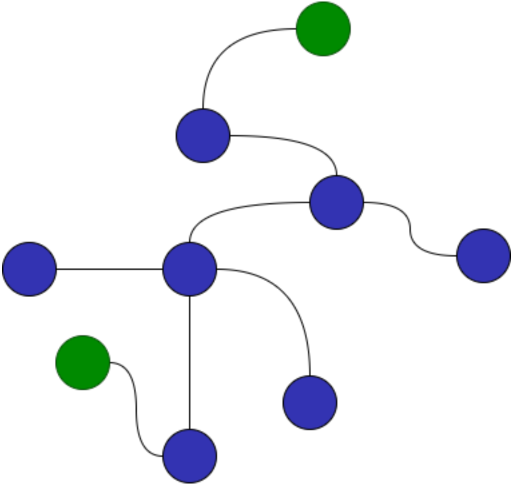
Bipartite Entanglement

Consider a quantum network:



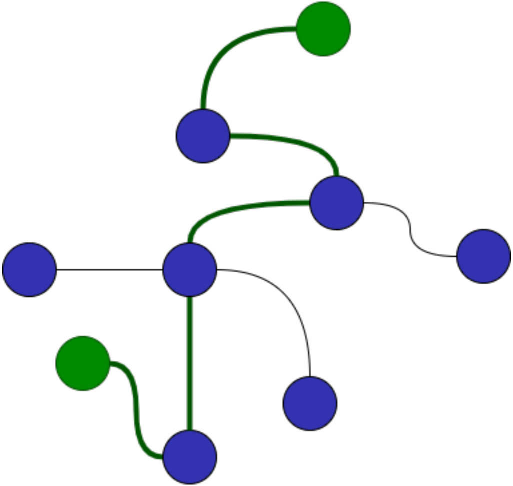
Bipartite Entanglement

Suppose a method of quantum communication must be established between the highlighted nodes.



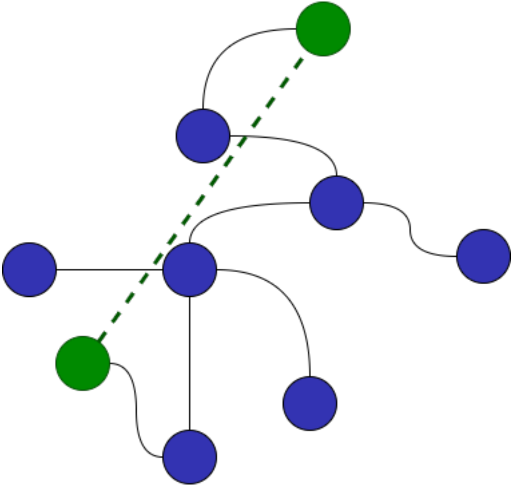
Bipartite Entanglement

Entanglement swapping is conducted using the highlighted physical links



Bipartite Entanglement

And like that, The two nodes can share an entangled pair.



Challenges with QKD

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Encryption of messages entails the need for Quantum Key Distribution (QKD).

Challenges with QKD

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Challenges with QKD

Secure entanglement-based QKD assumes maximally entangled states because:

- Only then can the network ensure a fully correlated key.
- Eavesdroppers can find information about the key otherwise.

Metrics for entanglement quality

To ensure a maximally entangled state a measure of the level of entanglement is required.

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To ensure a maximally entangled state a measure of the level of entanglement is required.
This can be done by using the following function:

$$|\psi\rangle - \text{Reference State}, \ \rho - \text{Actual State}$$

$$F(\rho, |\psi\rangle) = \langle\psi|\rho|\psi\rangle$$

Metrics for entanglement quality

Consider, though, an orthogonal state.

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$$\rho = |\phi^-\rangle\langle\phi^-|$$

$$\begin{aligned} F(\rho, |\phi^+\rangle) &= \langle\phi^+|\rho|\phi^+\rangle \\ &= \langle\phi^+|\phi^-\rangle\langle\phi^-|\phi^+\rangle \\ &= 0 \end{aligned}$$

Even though, the state is entangled and can be used to communicate.
Hence, Fidelity cannot be used.

The CSHS Inequality

Instead we can use the CSHS Inequality to check the quality of entanglement.
Consider,

$$A_1 = Z$$
$$A_2 = X$$
$$B_1 = \frac{Z - X}{\sqrt{2}}$$
$$B_2 = \frac{Z + X}{\sqrt{2}}$$

The CSHS Inequality

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\begin{aligned}
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\end{aligned}
$$

Then the CSHS Inequality is

$$S = |\langle A_1 B_1 \rangle + \langle A_1 B_2 \rangle + \langle A_2 B_1 \rangle - \langle A_2 B_2 \rangle|$$

The CSHS Inequality

For Entanglement Quality

If $S > 2$, the state is entangled.
If $S = 2\sqrt{2}$, the state is maximally entangled.
If $S \leq 2$, the test was inconclusive.