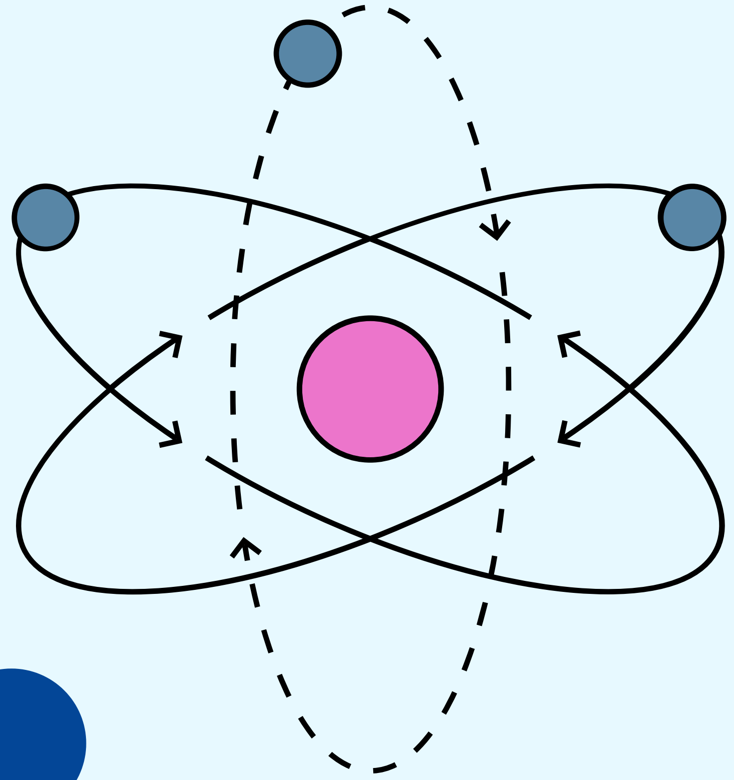
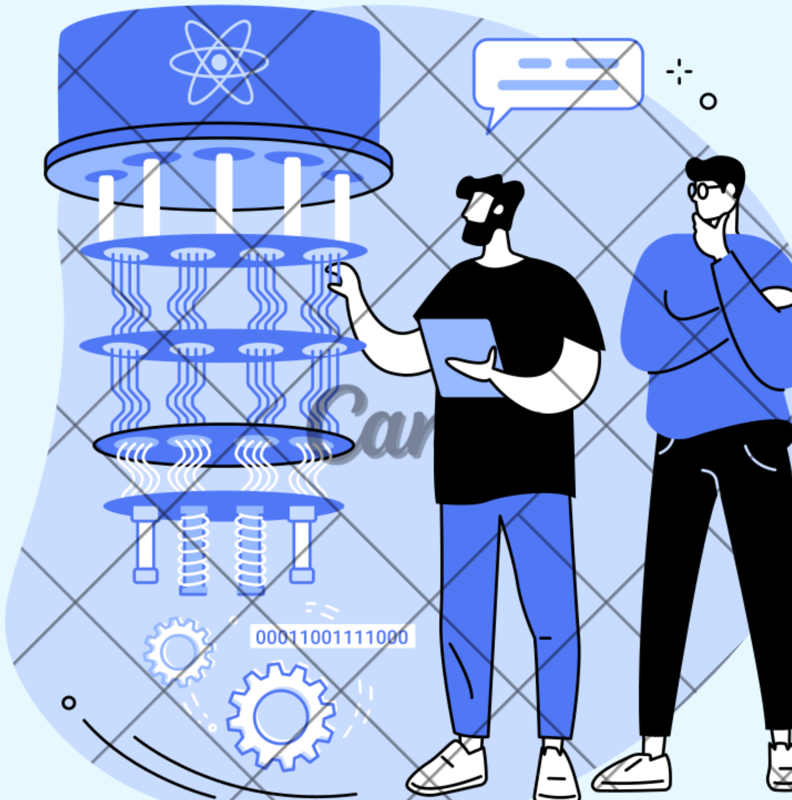
RESOURCE-EFFICIENT QUANTUM TELEPORTATION: MINIMIZING ENTANGLEMENT AND CLASSICAL BITS





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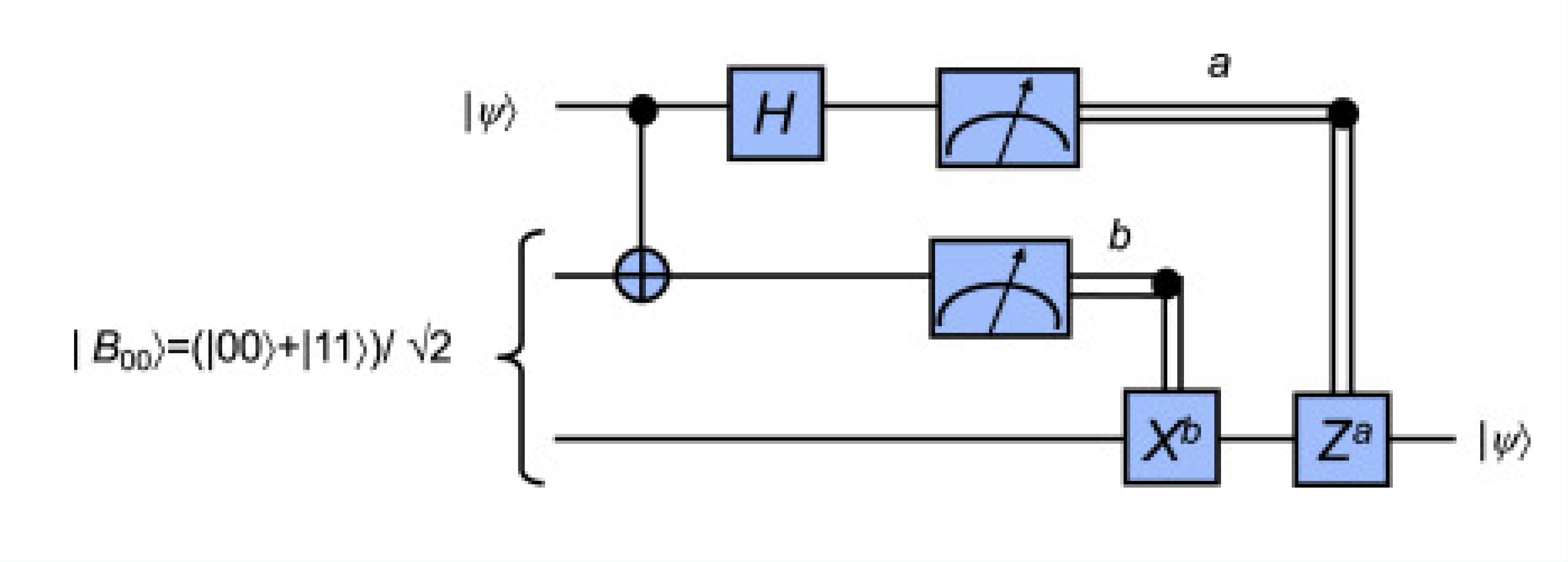
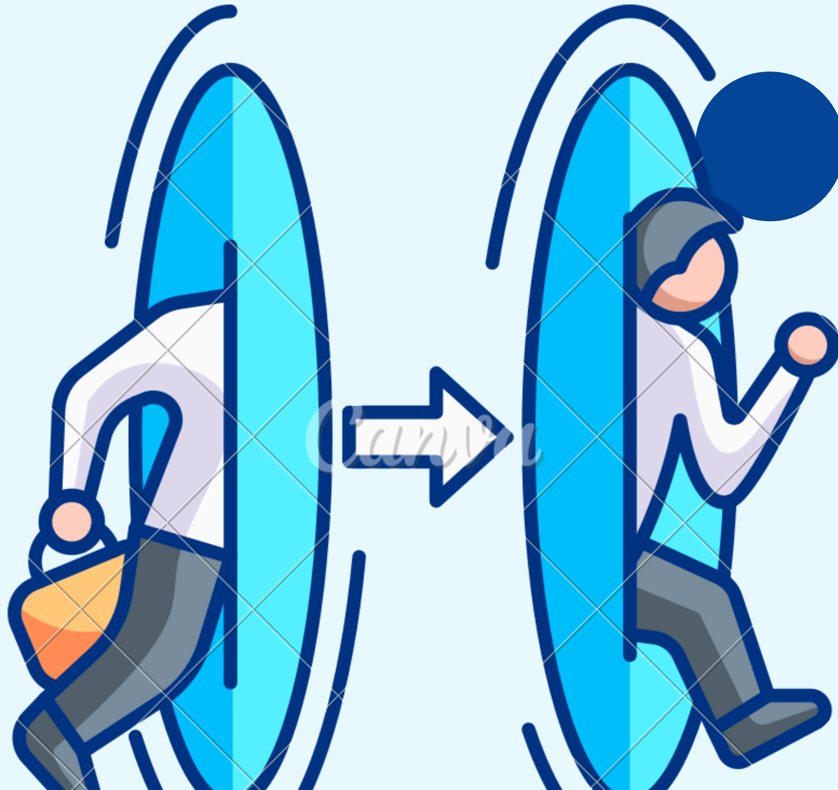
INTRODUCTION

Quantum Teleportation allows transferring the quantum state of a qubit from one location to another without physically moving the particle.
Goal: achieve teleportation with fewer resources.

It relies on two main resources:

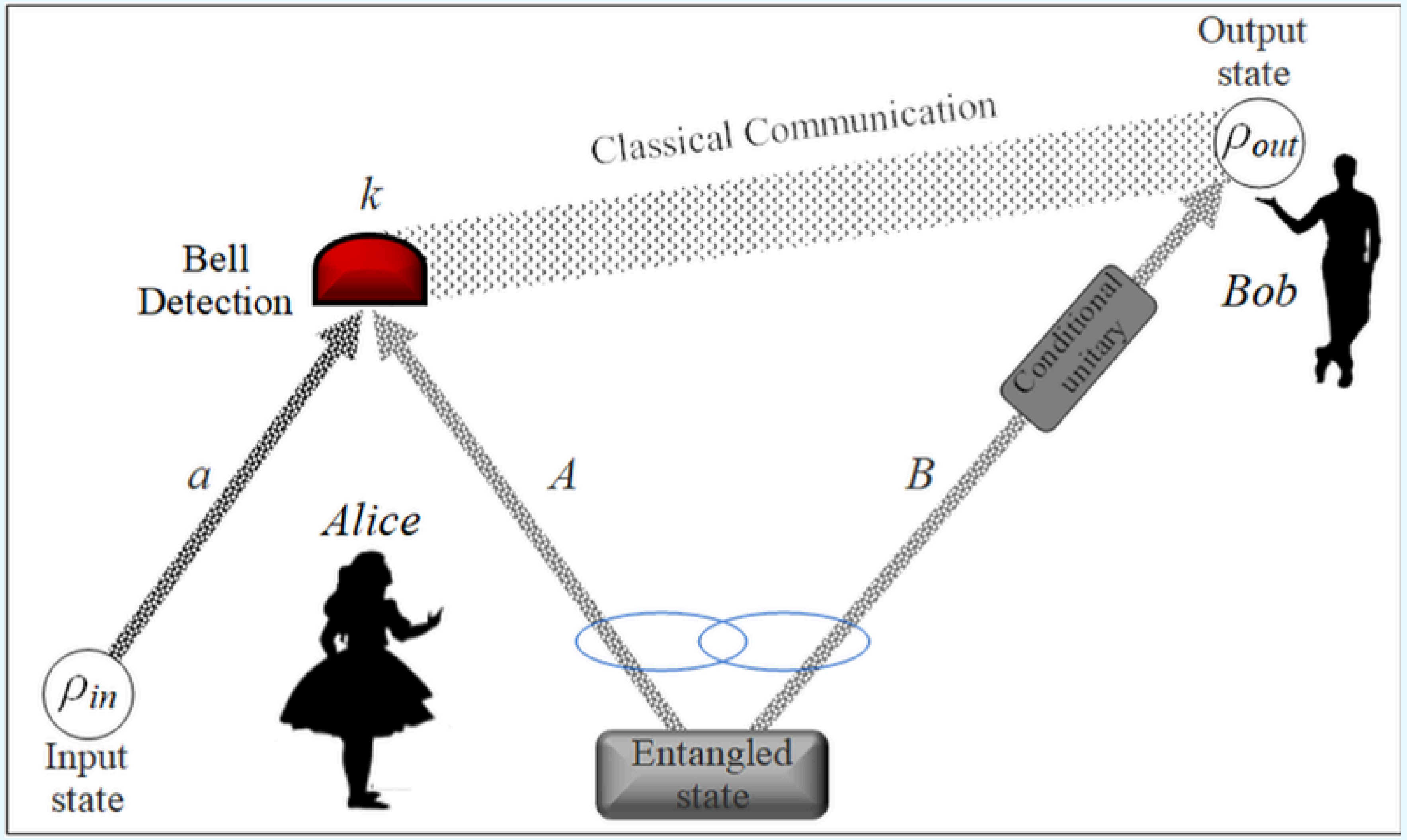
1. Quantum Entanglement (shared between sender and receiver)
2. Classical Communication (two classical bits sent to reconstruct the state)





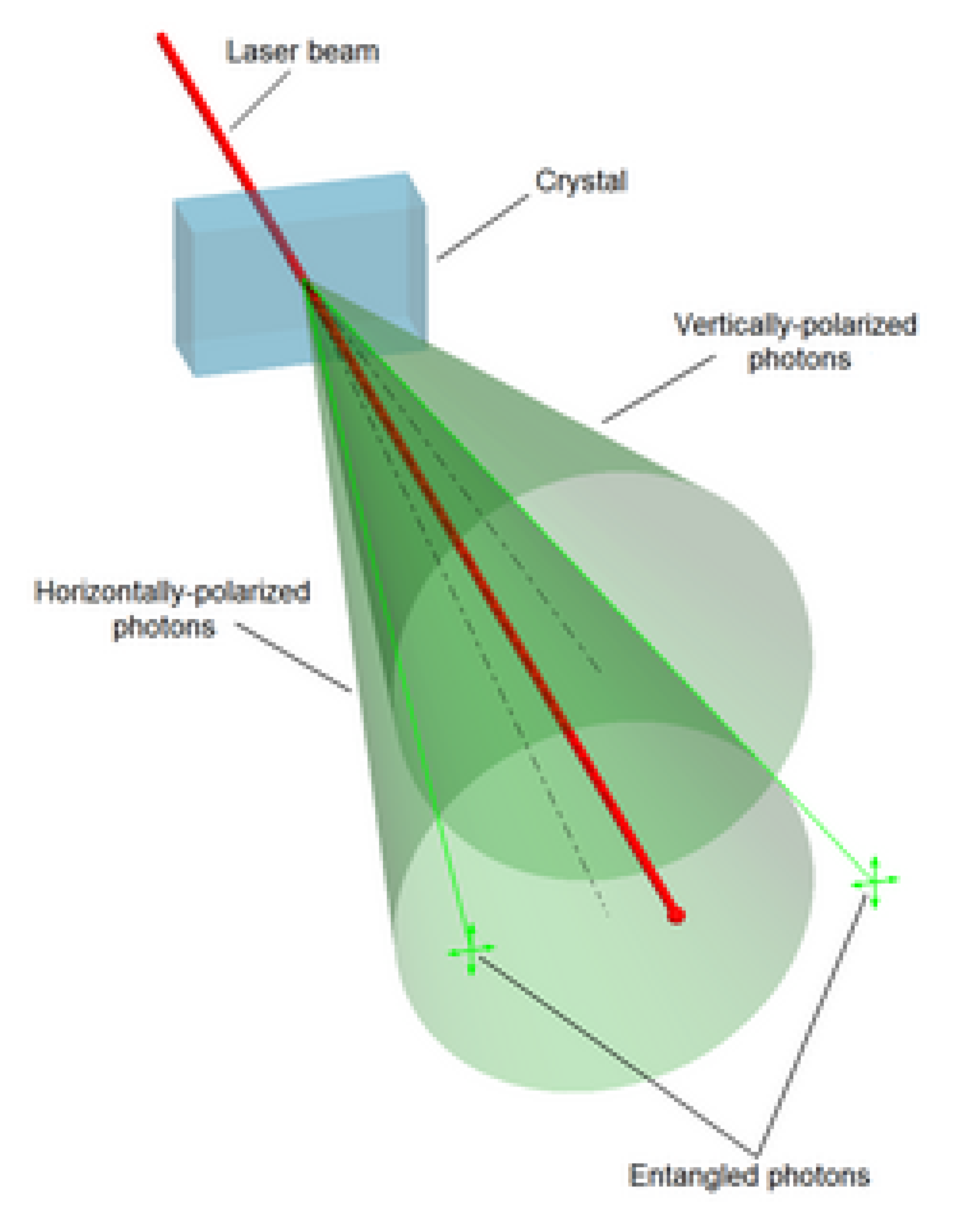
STANDARD QUANTUM TELEPORTATION

- Alice has an unknown qubit
- $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$.
- Alice & Bob share a maximally entangled pair (Bell pair).
- Alice performs Bell measurement on her qubit + entangled qubit.
- Sends 2 classical bits to Bob.
- Bob applies Pauli operations to reconstruct $|\psi\rangle$.



LIMITATIONS OF STANDARD TELEPORTATION

- Entanglement generation is costly.
- Classical communication requires bandwidth.
- Scaling to large networks increases resource demands.
- Environmental factors can reduce fidelity (decoherence).



RESOURCE-EFFICIENT TELEPORTATION

Reduce resources while maintaining high fidelity.

- Approach:
  - Partial entanglement
  - Reduced classical bits (compression, side info)
  - Probabilistic teleportation

PARTIAL ENTANGLEMENT

In standard teleportation, Alice and Bob share a maximally entangled state, such as the Bell state:

$$|\Phi^+\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$$

Here both terms ($|00\rangle$ and $|11\rangle$) have equal probability amplitudes ($1/\sqrt{2}$).
That's maximal entanglement — the strongest possible quantum correlation.

Now, if we change the amplitudes to be unequal, we get a partially entangled state:

$$|\Phi(\theta)\rangle = \cos(\theta)|00\rangle + \sin(\theta)|11\rangle$$

where $0 < \theta <= \pi/4$

- When $\theta = \pi/4$, we get full entanglement (standard teleportation).
- When $\theta < \pi/4$, the entanglement is weaker — meaning less correlation but also less resource cost.

REDUCED CLASSICAL BITS

- In standard teleportation, Alice sends 2 classical bits (always).
- In partial entanglement, certain measurement results occur far more often (e.g., “00”).
- Alice can send information only when teleportation is successful (e.g., 1-bit “success” message).
- This reduces the average classical communication cost.
- The information about probable outcomes acts as side information, letting Bob interpret fewer bits.

PROBABILISTIC TELEPORTATION

The teleportation succeeds only for specific measurement results (e.g., (00)).
Success probability depends on entanglement strength (θ).
High fidelity is achieved on success, even with fewer resources.

- Because the entanglement is partial, teleportation isn't deterministic.
- Alice performs her measurement; if the result is favorable (say, 00), Bob's qubit matches the input state with high fidelity.
- If not, the teleportation fails — those results are discarded.

CONCLUSION

Efficient quantum teleportation focuses on transferring quantum information with high fidelity while using fewer resources. By employing partially entangled states and filtering operations, it achieves accurate teleportation probabilistically rather than deterministically.

This approach reduces the need for maximal entanglement and excessive classical communication, making the process more practical for real-world quantum networks.

Overall, it demonstrates that high-fidelity teleportation is possible even with limited resources, paving the way for resource-efficient, scalable, and robust quantum communication systems.

THANK YOU