Channel Modelling and Capacity Determination for Wireless Quantum Communication

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ABSTRUCT : Quantum communication is more secure than classical communication. Long distance wireless quantum communication has several issues to address. In this project, our aim is to design the wireless channel for the classical-quantum-classical communication using superdense coding protocol that should work for long distance. We will find the classical capacity of a noisy quantum channel.

KEYWORDS: super dense coding, classical capacity, noisy quantum channel.

INTRODUCTION:

- A large amount of data are encrypted and transmitted over classical channels as classical bits 0 and 1.
- The classical bit can easily be read and copied.
- In contrast, Quantum communication is based on transmission of qubits, and qubit can not be copied.
- To read or measure the qubits they are collapsed to either 0 or 1.

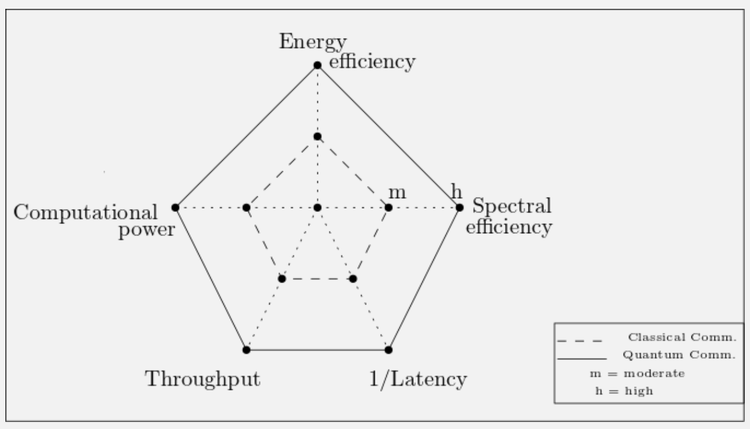

Fig 1: Quantum channel's performance indicators

- Quantum communication computational power helps us to achieve energy efficiency , spectral efficiency, near-zero latency, high network throughput, secrecy capacity.

RESEARCH QUESTION:

- The classical wireless and wired channel are already modelled, and the capacity of the classical channel is well known.
- The main challenge is to design the classical-quantum – classical communication.
- Our aim is to model the quantum channel and calculate the classical capacity of a noisy quantum channel.

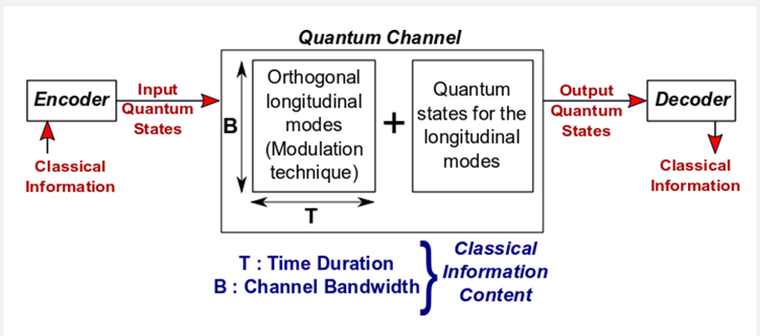

Fig 2: A design of the classical-quantum –classical communication.

METHODOLOGY:

- A quantum channel $\mathcal{N}$ is a liner map which is trace preserving (TP) and completely positive (CP) , its image is an ellipsoid on the Bloch sphere.
- A noisy channel transform Alice's pure state (qubits on the surface of the Bloch sphere) to a mixed sated (qubits inside the Bloch sphere) received by Bob (Fig.3).

- For a noisy channel (ie, $\mathcal{N}(I) \neq I$) the center of the channel ellipsoid is different from the Bloch sphere (Fig. 4).
- A qubits' inheritance noise $\mathcal{N}$ *can be visualized as* depolarizing channel like bit-flip and phase flip, state preparation and measurement (SPAM) channel, thermal decoherence (or relaxation) and dephasing channel.

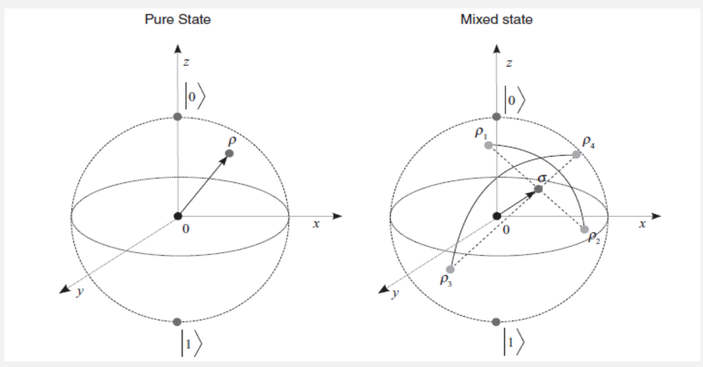

Fig 3: Pure and mixed state qubits respectively (source: ref 4)

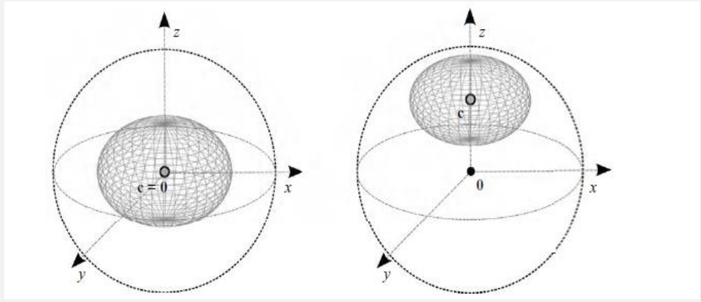

Fig 4: Quantum channel ellipsoid for (a)unital and (b) non-unital channel (source: ref 4)

- Considering the environmental noise n, our channel model

$$\mathbf{y} = f(\mathcal{N}, \mathbf{H}, \mathbf{n}, \mathbf{x})$$

where **y** is the output signal , **x** is the input signal, **H** is the channel matrix, $\mathcal{N}$ is qubits noise, and **n** is environmental noise (Fig 6).
- Here we are considering the noise **n** is Gaussian distributed, even the transmitted signal is also Gaussian distributed as it gives the maximum capacity.

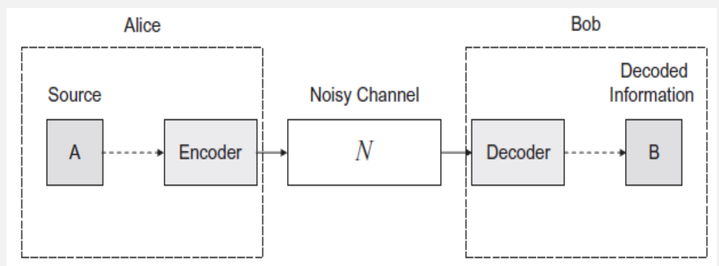

Fig 5: A basic model of a noisy channel (only qubit's noise $\mathcal{N}$ has been consider) (source: ref 4)

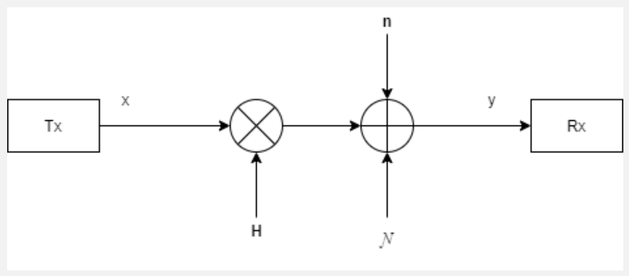

Fig 6: A channel model of a noisy channel (qubit's noise $\mathcal{N}$ and environmental noise n both have been considered)

- Focus on how the classical-quantum-classical communication can be designed(Fig 7).
- Super dense coding protocol has been used to send two classical bits using one qubit. Here we need at least 3 quantum channels to transmit (Fig 8).

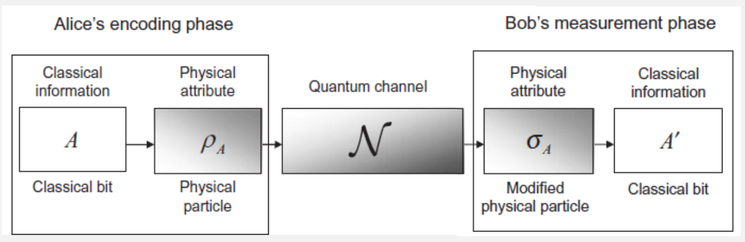

Fig 7: A classical-quantum-classical communication model (source: ref 4)

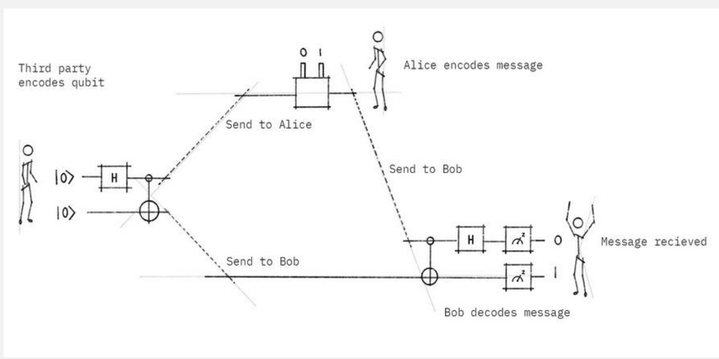

Fig 8 : Superdense coding protocol (source: ref 4)

- For the qubit's noise $\mathcal{N}$ we already have an *eccentric* channel ellipsoid (Fig 4(b)).
- We claim adding environmental noise **n** will distort the surface of channel ellipsoid further and will change the center of the ellipsoid.
- Our next work is to calculate the classical capacity for this quantum channel.

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