Ultrafast and Fault-Tolerant quantum communication across Long Distances

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There are two main challenges that need to be overcome for quantum key distribution across long distances thorough optical fiber networks. Firstly, the attenuation in the fiber scales exponentially with the length of the fiber. Secondly, there are operation errors such as memory errors, channel decoherence, measurement errors etc. that limit the key generation rates severely. Having quantum repeater stations between the sender and the receiver allows quantum key distribution without an exponential scaling in terms of resources and time. Recently, a new type of quantum repeaters were proposed where one can perform quantum communication without the establishment of a remote entangled pair \cite{1, 2}. In these quantum repeaters \cite{2}, quantum information is encoded into a quantum error correcting code and transmitted to the neighboring repeater station, where a fault-tolerant teleportation based error correction procedure can be performed to correct both loss and operation errors (see Fig. 1). We optimize the resource requirements for these quantum repeaters using a cost function and show numerically that the number of qubits required for the generation of one secure bit has a poly-log scaling with respect to the total distance of communication.

![Diagram](https://placehold.it/500)

**FIG. 1:** This Figure is from Ref. \cite{2} (a) A schematic view of the third class of QRs showing individual matter qubits in the repeater stations connected by an optical fiber. The quantum state is encoded into an error correcting code with photonic qubits, which are multiplexed and transmitted through the optical fiber to the neighboring repeater station. The quantum state of photonic qubits is transferred to the matter qubits and error correction is performed. After the error correction procedure, the quantum state of the matter qubits is transferred to photonic qubits and transmitted to the next repeater station. This procedure is carried out until the information reaches the receiver. (b) The TEC procedure consists of Bell state preparation and Bell measurement at the encoded level. Each line in the circuit represents an encoding block and the CNOT gate has a transversal implementation for CSS codes.
