Energetic Analysis of Emerging Quantum Communication Protocols

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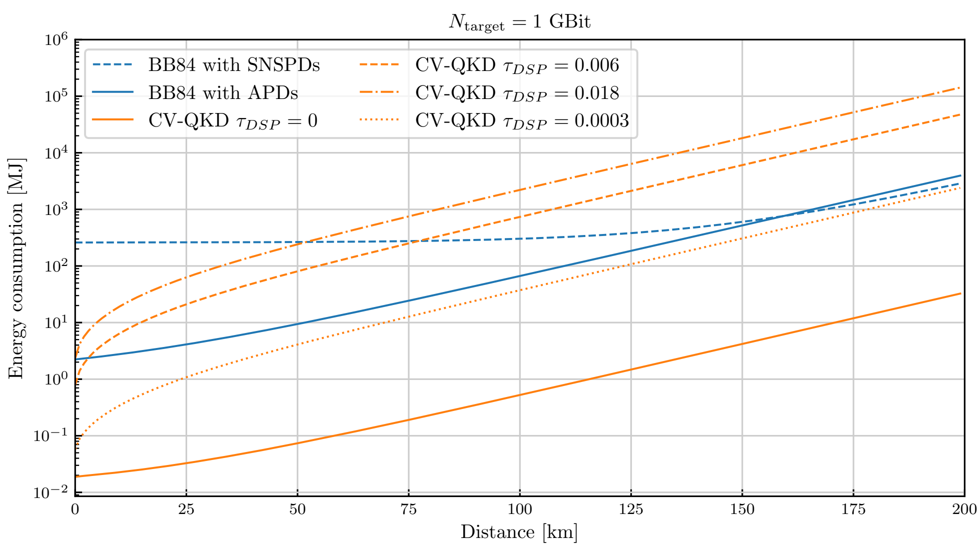
In a world with finite resources where energy demands outgrow energy generation, it is crucial to estimate how much energy quantum networks will consume prior to their deployment [1, 2, 3]. Such a study can reveal limiting factors for future implementations of networks, or even show the energetic advantages of certain quantum technologies over classical ones. This work presents the foundations of a framework to estimate the energy cost of quantum network protocols. We give a first estimation of the energy requirements of basic network functionalities, namely Quantum Key Distribution (QKD) and Conference Key Agreement (CKA), whose goals are to generate a secret private key among end users of a quantum network. The methods and hardware they use are generic to most protocols based on photonic implementations. In particular, the creation and sharing of entangled states among distant parties, believed to be the main goal of most quantum network architectures [4], are the building blocks of many other network protocols [5, 6, 7, 8, 9, 10].

To obtain concrete figures of merit, we take a hardware-dependent approach to compare different implementations of some common protocols. Namely, different QKD implementations are compared, and the implementation of networks of N nodes are analyzed, since their scaling in resources with the number of nodes is non-trivial. Using the energetic cost as a benchmark, instead of the rate or the fidelity, gives a unique perspective. For example, our simulations suggest that there exists regimes of parameters for QKD protocols where using less efficient but more energy effective detectors results in huge energy savings at the cost of increased execution time. Another example of results from this work are the discovery of distance regimes for which the usage of different wavelengths results in energy savings, and the identification of optimal protocols to achieve multipartite tasks as a function of the number of parties.



Example of result from this work : Comparison of of the energy cost to get 1Gbit of Secret key with a DV-QKD BB84 implementation with APDs detectors, SNSPDs detectors and a CV-QKD implementation with Gaussian modulation, heterodyne measurement and double polarization, including the classical costs from Digital Signal Processing (DSP).

Arxiv link: https://arxiv.org/pdf/2410.10661

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