Bi-directional Classical Transmission Using One-way Entanglement-assisted Quantum Transmission

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April 2, 2024

Abstract

In this note the authors study a system which is a one-way quantum transmission that serves as a two-way classical communication. This analogy suggests a way to construct schemes that achieve the optimal quantum reliability function for the one-way quantum transmission.

Consider that when two particles are entangled, when a measurement of one is performed and yields a result, say, a_k, then instantly the state of the second particle is affected. This means that the probability of the a_k outcome on the second particle is different from that on the first. Now take the second particle, keep it with the transmitter. On the first particle, which is a bona-fide quantum state, do no measurement until a quantum channel has been applied to it: a completely positive, trace-preserving (CPTP) map. Since a CPTP map is distinct from a measurement, the transmitter particle is not yet affected. But now perform a measurement on the receiver particle. Instantly, the transmitter particle state is affected. The receiver measurement yields a classical result. Following this measurement, the transmitter particle is measured and we get another classical result. The first classical result is on the receiver side and the second classical result is on the transmitter side. But this is exactly what happens in a Gaussian channel with noisy Gaussian feedback. First a classical result is obtained on the receiver side and next a (different) classical result is obtained on the transmitter side. Thus sending an entangled particle one-way over a CPTP map, is equivalent to a complete classical feedback loop.

Inspired by this analogy, we can propose the following method to find a good lower bound on the reliability function of a quantum channel. Take the forward channel and resolve to send (one part of) entangled pairs only over it. Now consider the induced classical feedback loop. Find the best scheme for lower bounding the error exponent on this classical system. Carefully map it back to a one-way quantum transmission with entanglement over the given quantum channel. The optimality of the classical version will yield then a good lower bound on the quantum reliability function.