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An exponential separation between entanglement-assisted and unassisted one-way quantum communication

A longstanding question in quantum communication complexity is whether some task can be accomplished with a small amount of communication in the presence of entanglement, yet require much more quantum communication in the absence of entanglement. Separations of this nature were previously known for relational problems and, in the simultaneous message passing model, for partial functions. But it has remained unresolved whether any such separation exists for a total Boolean function. We resolve this question with an exponential separation in the one-way setting: we exhibit a family of total Boolean functions that can be computed with bits of one-way classical communication given prior entanglement, but that require qubits of one-way quantum communication without entanglement. Our function is a special case of the subgroup membership problem, first studied in the communication setting by Aaronson, Le Gall, Russell, and Tani.