Resource theories of communication

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A series of recent works has shown that placing communication channels in a coherent superposition of alternative configurations can boost their ability to transmit information. Instances of this phenomenon are the use of communication devices in a superposition of alternative causal orders, and the transmission of information along a superposition of alternative trajectories. To shed light on these new types of communication protocols, we develop a general framework of resource theories of communication, formulating a minimal requirement for meaningful allowed operations on communication resources. *The following is an extended abstract of [1]:* `https://iopscience.iop.org/article/10.1088/1367-2630/ab8ef7/pdf`

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Quantum Shannon theory describes communication where information is encoded in quantum states. In a series of recent works, a generalisation of quantum Shannon theory has been proposed where not only the information carriers, but also the configuration of the transmission lines can be in a quantum superposition. In particular, communication channels can be combined in a superposition of different causal orders [2–9], using an operation known as the quantum `SWITCH` [10, 11] (Fig. 1a), or in a similar spirit, information can be sent along a superposition of trajectories [12–15] (Fig. 1b). Both of these types of coherent control over channel configurations have been shown to yield a wide range of communication advantages in comparison to standard quantum Shannon theory.

Some of these communication advantages have stimulated experiments in quantum optics [5, 16–18]. From a practical point of view, it is also possible to construct similar protocols using a superposition of encoding and decoding operations [19]. This motivates a formal comparison between three types of coherent control: (1) control over the causal order of communication channels [2–4], (2) control over the choice of communication channels [12–14], and (3) control over encoding and decoding operations [19].

In this paper, we construct a general framework for resource theories of communication, and use it to shed light on the different extensions of quantum Shannon theory that have been proposed so far. In this framework, the resources are communication devices, and the allowed operations are (a) the placement of communication devices between the communicating parties, and (b) the connection of communication devices with local devices in the parties' laboratories. The allowed operations are required to satisfy the minimal condition that they do not enable communication independently of the devices representing the initial resources.

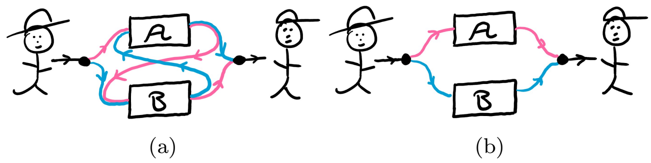

FIG. 1: (a) Communication in a superposition of the causal orders of communication channels. (b) Communication in a superposition of the information carriers' trajectories.

Our framework captures the differences between the different types of control (1)–(3), and helps clarify various comparisons that have been made across protocols using them. Applying our resource-theoretic framework, we argue that (a) the comparison between control of causal orders and control of communication channels proposed in Ref. [13] is uneven, because the control of communication channels requires stronger initial resources than the control of causal orders, and (b) the examples of communication with control over encoding and decoding proposed in Ref. [19] do not satisfy the minimal requirement of a resource theory of communication.

More generally, our framework enables a formal construction and comparison of novel communication paradigms.

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