Information as a resource in distributed quantum systems *

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Quantum entanglement lies in heart of quantum information theory. It allows for quantum teleportation, dense conding, some versions of quantum cryptography and is very important resource for quantum computing. Because quantum entanglement unabled us to send quantum bits there were approaches aiming at establishing link between entanglement theory and thermodynamics. In particular there is entanglement - energy analogy that is useful in analysis of some entanglement aspects.

Still there have been no *direct* relationship between entanglement and physical energy. On the other hand it has been known that the link between energy and information exists due to so called Landauer principle. According to this there is an equivalence between information about given system and tha work that can be performed with the help of the system. We assume the validity of the Landauer principle as a starting point of our analysis [1–4] and point out that the principle has been considered only for single (nondistributed) systems so far. We consider the case of quantum state of distributed bipartite and multipartite system and ask [1]: how much information can be extracted ("distilled") locally from the state ? This information can be further spent by local heat engines for work.

We illustrate the problem in context of Schumacher compression and show the analogy to entanglement distillation. However, suprisingly, it is enormously hard to answer the above question even in (usually the simplest) case of singlet state shared by Alice and Bob. The key point is that in the present paradigm one is *not* allowed use pure local ancillas for free as it was before in entanglement distillation. This is because pure ancillas represent information which is the resource that we just want to "distill". Summarising, the usually applied so called LOCC operations subject here quite nontrivial restrictions.

Using some method based on semidefinite programming we calculate explicitely the amount of locally "distillable" information I_l in case of pure states [3,1]. We define the heat engines work deficit Δ as a difference between information that is extractable globally I_g and the one that can be distilled locally I_l. We find that for pure states the deficit is equivalent to entanglement contained in the state. This is first direct connection between entanglement and physical energy. We also calculate the deficit for some mixed states under additional assumptions [1]. Furthermore we have some evidences that the deficit can be also nonzero for mixed states. This gives rise to the interpretation of Δ as a kind of general correlation measure similar to quantum discord recently introduced by Ollivier and Żurek. We also find, somewhat suprisingly, that it is possible to extract local information (which, due to Landauer principle, is equivalent to work) from bound entanglementthat is contained in some free entangled states. We find some complementarity rule between locally "distilled" information and number of qubits that is transmitted coherently with help of given state in asymptotic regime [2]. Moreover some kind of phase transitions are found within the paradigm [4]. Finally we mention some interesting open problem thet emerges from the above paradigm.

The support for European Commission (project EQUIP No. IST-1999-11053) is gratefully acknowledged.

* This work was done with K. Horodecki, M. Horodecki, R. Horodecki, J. Oppenheim, Aditi Sen (De) and Ujiwal Sen.

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