Quantum Networks

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Monday, July 9, 2012, 14:00

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Yorgo Istefanopulos Meeting Lounge (KB 217)

Abstract

A quantum network is a physical arrangement of spins with Heisenberg or XX coupling energy. In the single excitation subspace of the Hamiltonian H, a message is encoded as excitation pattern |i> of a spin and read out as |j> at any other spin. We develop a distance d(i,j) between quantum states that reflects the fidelity <i|exp(-Ht)|j> or Information Transfer Capacity (ITC) from spin i to spin j in an amount of time t. The dependency on the time forces us to deviate from the polarized distance arcos|<i|j>| and its simple positively curved geometry to a distance of the form log(1/pmax(i,j)), where pmax is the maximum over all tôs of the transfer probability of the excitation from spin i to spin j in an amount of time t. The major difficulty is twofold: (1) prove that the maximum transfer probability can be reached and (2) prove that log(1/pmax(i,j)) is indeed a distance, that is, it satisfies the triangle inequality. Next, we examine the geometry of the distance, with special attention to spin chains (quantum wires) and spin rings (quantum token rings). Contrary to traditional network where packets follow a single path, here, the excitation is multi-path, as specified by the Feynman path integral. It will be shown that this single fact only gives the geometry an ñanti-core,ò contrary to the congestion ñcoreò of classical networks. Finally, as an illustration of the concept of ñcontrol enabled geometry,ò it will be shown how the ñanti-coreò can be removed by local magnetic field control. (Note: This is joint work with S. Schirmer and F. Langbein.)

Edmond Jonckheere is a Professor of Electrical Engineering and Mathematics and a member of the Center for Quantum Information Science and Technology at the University of Southern California, Los Angeles, USA. After spending the first 20 years of his career in controls, for which he was elected to the grade of Fellow of the IEEE, he moved to communications networks and introduced the concept of delta-hyperbolic networks and their ñcongestion core.ò More recently, he moved to quantum networks, where he is currently developing a geometric model of Information Transfer Capacity.