Qubit connectivity comparison - entanglement bound in linear qubit array, equi-distance configuration, and star configuration

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Generation of multi-qubit entanglement is an important issue since entanglement plays a crucial role in quantum information processing, particularly in quantum computation. There have been several proposals for realization of a set of entangled qubits. For trapped ions, the control signal is carried by phonons, which allows the simultaneous interaction between any arbitrary pair of ions[1]. For semiconductor quantum dots[2], only the adjacent qubits interact so that the quantum signal should be propagated in a bucket-relay manner. It is thus interesting to compare how quantum information can be carried among the different configuration of qubits, such as linear qubit array, equi-distance configuration, and star configuration. (Here, "equi-distance" means that a qubit is connected to any other qubits equivalently.)

For these different configurations, we investigated to what extent entanglement can be shared by the qubits. Particularly, we obtained the rigorous upper bound of the amount of entanglement for the equi-distance case, which shows the value of 2/N [3], where N is the total qubit number, and the amount of the entanglement is measured by "concurrence"[4].

For finite linear-array case, there is a conjecture [5] for the maximum entanglement, which gives 0.43 concurrence as N goes to infinite. For star configuration, a conjecture is given for the concurrence to be of the order of $N^{1/2}$. Together with the rigorous upper limit for the equi-distance case, these results may give new insight to the property of entanglement for multi-qubit systems. For example, if we know which pair of the qubits is to be entangled, we can form a complete entanglement to that pair. If we only know one qubit of the pair and do not know which of N qubits is selected as the counterpart, the amount of entanglement that can be prepared beforehand scales as $N^{1/2}$. If we must meet the request of an arbitrary selected pair among N qubits, the maximum entanglement is further reduced to the order of 1/N. It is thus necessary to take this scalability into account in designing quantum algorithm with many interacting qubits.

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