Qubit Routing with a Mediating Computational Resonator

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The qubit routing problem is the well-established issue of optimally translating an arbitrary quantum circuit to one where the connectivity constraints between the qubits on a quantum computer are observed. This is usually addressed by a transpiler that inserts SWAP gates into the circuit to move the logical qubit states to a different physical qubit register [1] [2] [3, 4]. Alternatively, it is possible to completely recreate the circuit with gates that are natively allowed on the quantum computer [5] [6] [7].

The qubit connectivity of the quantum computer is normally sufficient for solving the qubit routing problem. However, on IQM's new Deneb quantum computer [4] [8] all 6 qubits are connected to a central computational resonator that is currently restricted to hold a single qubit state at a time. Thus, two-qubit gates are supported between any pair of qubits but only after one of the qubits has been moved into the computational resonator. Alternatively, one can think of this as a 7-qubit star-shaped quantum computer where (i) neither single qubit gates nor readout can be applied to the central qubit and (ii) SWAP gates are a native gate that can only be applied when one of its arguments is the zero state. We call this restricted version of a SWAP gate the MOVE gate. The restrictions are enforced in practice by a set of "safeguard rules". We require MOVE gates to come in pairs, where both MOVEs address the same MOVE qubit. In addition, we disallow single qubit operations on the MOVE qubit in between such a pair.

This new quantum architecture is not compatible with existing qubit routing solutions. On the one hand, if one pretends that the computational resonator does not exist, qubit routing is unnecessary because of the all-to-all connectivity. On the other hand, if we pretend that the resonator is a qubit, traditional qubit routing or quantum circuit resynthesis might result in gates that are not allowed by the resonator. Thus, new solutions need to be found.

For the Deneb quantum computer, we have opted to pretend to the existing transpiler that the resonator does not exist. Only in a second step, the resonator is inserted into the circuit and the MOVE gates are added (available on Github [9] [10] [11]). In this step, we use a simple lookahead moving strategy where MOVE gates are added as late as possible, and the MOVE qubits are determined by how many gates can be done with the qubit in the resonator before it needs to be moved out. This allowed us to rely on the existing transpiler workflow.

Clearly, this is not an optimal strategy, and better strategies than the one presented here can be developed in future works..

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