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Simultaneous Scheduling, Binding and Routing for Coarse-Grain Reconfigurable Architectures

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We consider performance optimization for coarse-grain computing devices, such as *processor-like reconfigurable architectures*; such devices combine the flexibility of hard-wired multi-purpose processors with short execution time and low energy consumption of specialized microprocessors. Their efficiency depends on a suitable mapping of applications to the underlying architecture, which consists of an orthogonal grid of processing elements (PEs) that can be configured dynamically to execute any of a given set of elementary algebraic or logic operations per clock cycle.

On an abstract level, an application is modeled as a directed *data-flow* graph, where vertices represent operations, and arcs stand for dependencies between them. A feasible binding assigns to every operation a PE and an execution time while complying with all data dependencies. Traditionally, the mapping is done sequentially: only after scheduling clock cycles, a feasible mapping is sought. By considering scheduling, binding and routing simultaneously, we achieve much better objective values. Our comprehensive study yields both theoretical and practical results.

Mathematically, we are dealing with a special case of the Directed Subgraph Homeomorphism problem. By describing a logic engine reduction from

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NAE-3-SAT, we show that the Simultaneous Scheduling, Binding and Routing (SSBR) problem is NP-complete, even if the input graph is a directed tree. We also give a $|V|^{3/2}$-approximation algorithm for the time minimization problem.

On the practical side, we present the first exact algorithm for the SSBR problem. Our Integer Linear Program (ILP) formulation finds time-optimal solutions for instances of about 50 vertices within a few minutes. We also address energy consumption by using an alternative objective function. We propose and benchmark a promising new heuristic that can be used in combination with the ILP approach and solves practical instances to near-optimality within seconds.