Contention-aware Mapping and Scheduling Optimization for NoC-based MPSoCs

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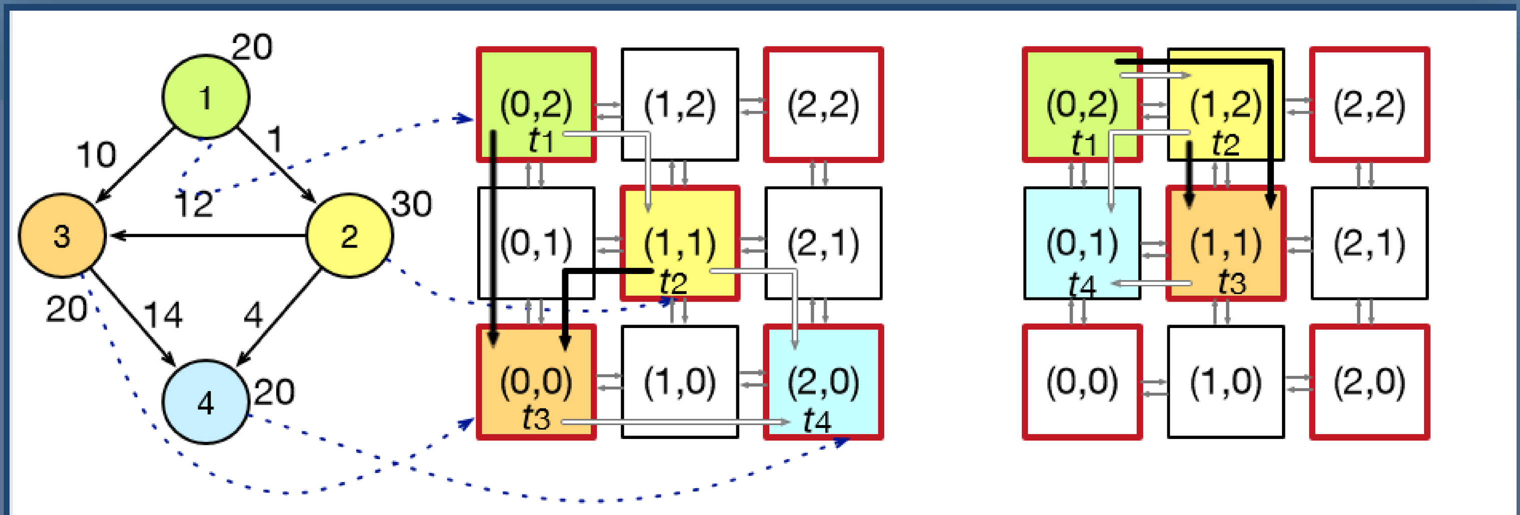
Motivation

- We consider spatial and temporal aspects of communication to avoid contention in Network-on-Chip (NoC)-based architectures.
- Deal with the mapping and scheduling for NoC-based MPSoCs from a practical view, i.e., optimizing three objectives: makespan, energy consumption and contention. probability.

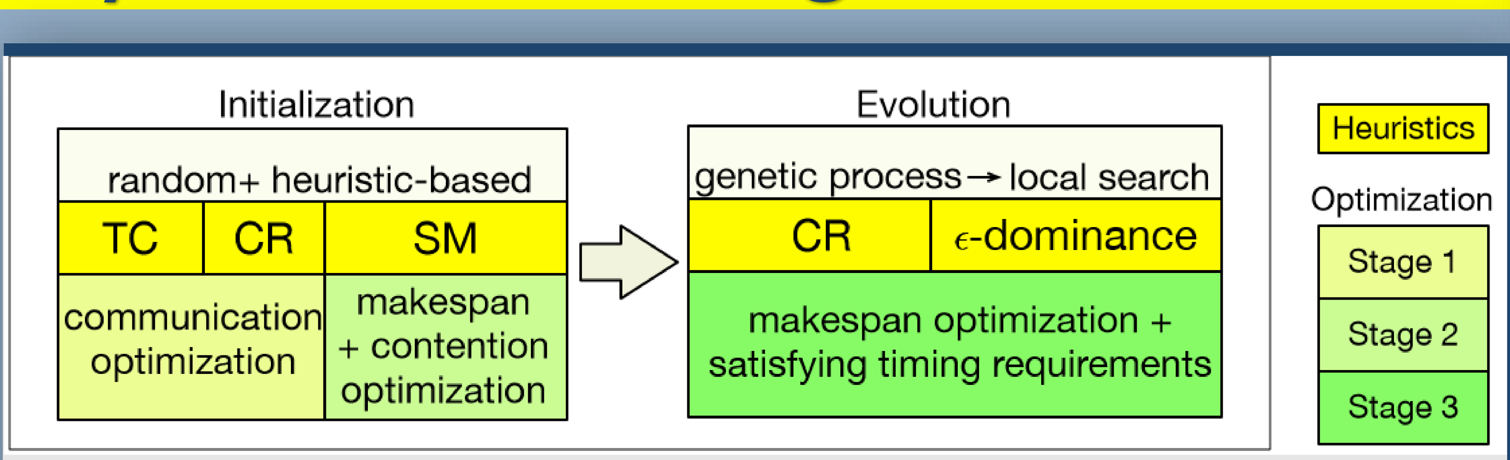
Problem Definition



(a) task graph (b) computation-oriented (c) communication-oriented

- We consider applications represented with task graphs (TGs). For example, the model shown is a task graph with 4 tasks and 5 dependency relations (edges).

Hybrid Search Algorithm



- Task Clustering (TC)
- Capacity Constrained Cluster Refinement (CR)
- Spiral Mapping (SM)
- Encoding
- Initialization
- Genetic Process
- Pareto Local Search

Constraint formulation

We provide a flexible constraint formulation for NoC-based mapping and scheduling in the format of logical formulas.

Static constraints

$$m_{ik} \rightarrow \neg(\bigvee_{k' \neq k} m_{ik'}), \quad \ell_{ik} \rightarrow \neg(\bigvee_{k' \neq k} \ell_{ik'}) \tag{1}$$

$$(\sum_{i=1}^{|T|} m_{ik}) \leq \omega_k \tag{2}$$

$$d_{ij} \wedge m_{ik} \wedge m_{jk'} \wedge (k \neq k') \rightarrow o_{ij}, \quad o_{ij} \rightarrow d_{ij} \tag{3}$$

$$(\gamma_{k_1 k_2 k_3 k_4} > 0) \wedge \ell_{ik_1} \wedge \ell_{jk_2} \wedge \ell_{lk_3} \wedge \ell_{rk_4} \wedge o_{ij} \wedge o_{lr} \rightarrow cf_{ijlr} \tag{4}$$

Behavior constraints

$$f_i^u = s_i^u + a_i / (\sum_{k=1}^{|P|} m_{ik} \cdot \rho_k) \tag{5}$$

$$\hat{f}_{ij}^u \geq \hat{s}_{ij}^u + o_{ij} \cdot (c_{ij} \cdot \tau \cdot D_{ij}/bw + \tau' \cdot (D_{ij} + 1)) \tag{6}$$

$$\bigvee_{j=1}^{|T|} d_{ji} \rightarrow \hat{f}_{ji}^u \leq s_i^u, \qquad f_i^u \leq \hat{s}_{ij}^u \tag{7}$$

$$n_{ij} \rightarrow f_i^u \leq s_j^v, \text{ for } u \leq v \tag{8}$$

$$m_{ik} \wedge m_{jk} \rightarrow f_j^u \leq s_i^v, \text{ for } u < v \tag{9}$$

$$m_{ik} \wedge m_{jk} \rightarrow s_j^u \geq f_i^u \vee s_i^u \geq f_j^u \tag{10}$$

$$cf_{ijlr} \wedge abs(f_i^u - f_l^u) \leq \xi \rightarrow \hat{s}_{ij}^u \geq \hat{f}_{lr}^u \vee \hat{s}_{lr}^u \geq \hat{f}_{ij}^u \tag{11}$$

Optimization objectives

$$\mathcal{M} = \max\{f_i^N \mid t_i \in T\} \tag{12}$$

$$E_p = \sum_{p_k \in P'} (N \cdot \mathcal{E}_{d_k} \cdot \mathbb{T}_k + \mathcal{E}_{i_k} \cdot (\mathcal{M} - N \cdot \mathbb{T}_k)) \tag{13}$$

$$E_m = \sum_{p_k, p_{k'} \in P'} \sum_{i,j=1}^{|T|} c_{ij} o_{ij} m_{ik} m_{jk'} (\varepsilon D_{kk'} + \varepsilon' (D_{kk'} + 1)) \tag{14}$$

$$\wp_c(k_1, k_2, k_3, k_4) = \gamma_{k_1 k_2 k_3 k_4} / (D_{k_1 k_2} \cdot D_{k_3 k_4}) \tag{15}$$

$$\mathcal{P}_{i_1 i_2} = \sum_{j_1 \in \mathcal{S}_{i_1}, j_2 \in \mathcal{S}_{i_2}} o_{i_1 j_1} \cdot o_{i_2 j_2} \cdot \wp_c(k_{i_1}, k_{j_1}, k_{i_2}, k_{j_2}) \tag{16}$$

$$\bar{\mathcal{P}}_c = \sum^{|T|} abs(\mathcal{P}_{ij} - \mathcal{P}_c / |T|) \tag{17}$$

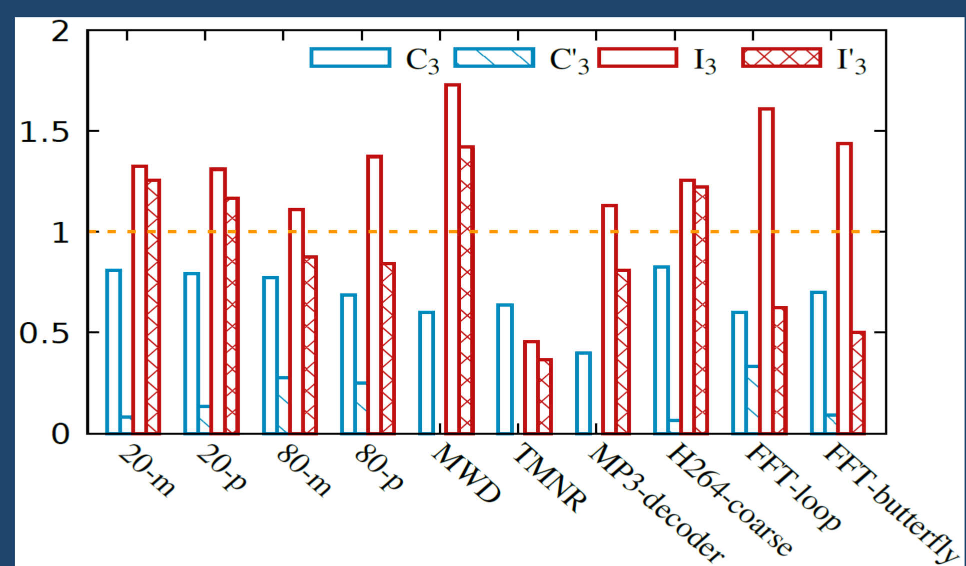
$$minimize(\mathcal{M}),\ minimize(E_p + E_m), minimize(\bar{\mathcal{P}}_c) \tag{18}$$

Experimental Results

Comparison between MOHA and various methods

Case	$\|T\|$	$\|E\|$	MOHA	NSGAII	CPLEX(MILP)		CPLEX(CP)		Z3	
			sol	sol	sol	time	sol	time	sol	time
5-m	5	4	3	2(=)+2(≻)	2(=)	687.63	2(=)	53.62	3(=)	3.68
5-p	5	4	3	3(=)	2(=)	829.39	2(=)	49.22	3(=)	6.49
7-m	7	6	2	2(=)	2(=)	-	2(=)	158.96	2(=)	9.14
7-p	7	6	2	2(=)	2(=)	-	2(=)	247.59	2(=)	19.85
8-m	8	7	2	2(=)	1(=)+1(≻)	-	1(=)+1(≻)	287.50	2(=)	12.92
8-p	8	7	2	2(=)	2(=)	-	2(=)	316.83	2(=)	23.13
10-m	10	9	1	1(=)	1(=)	-	1(=)	-	1(=)	93.45

Comparison between MOHA and NSGAII on large instances



MOHA can find all the pareto fronts on small-scale benchmarks and outperforms NSGAII on large-scale instances.