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Hybrid method for mapping a parallel program onto computing network

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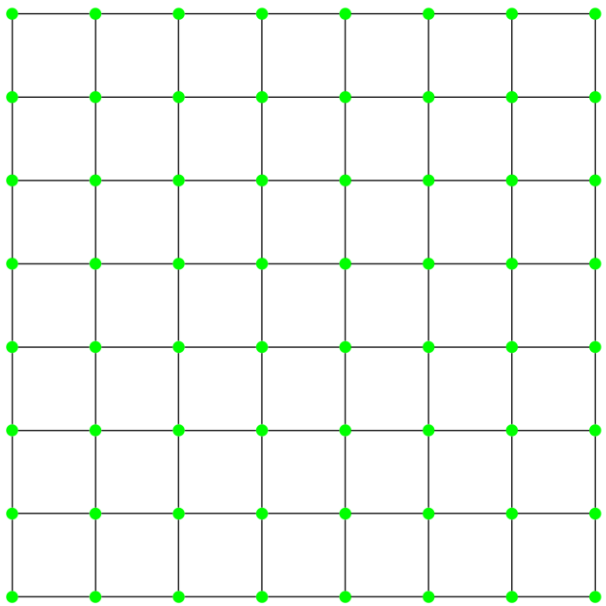
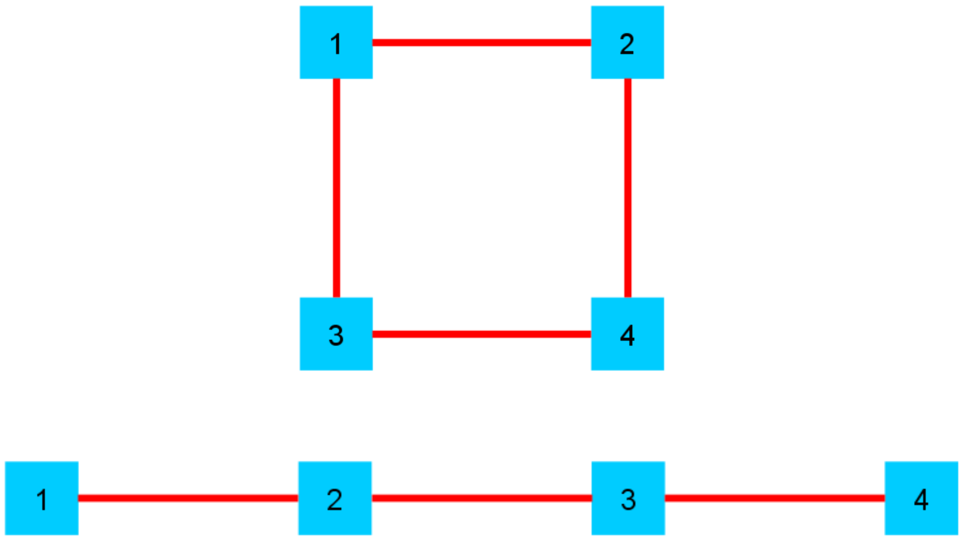
The 5th International Conference on Network Analysis
Nizhny Novgorod, May 18-20, 2015

Introduction

- We study the architecture depending graph decomposition problem that is the problem of decomposition and mapping a parallel program onto a computing network



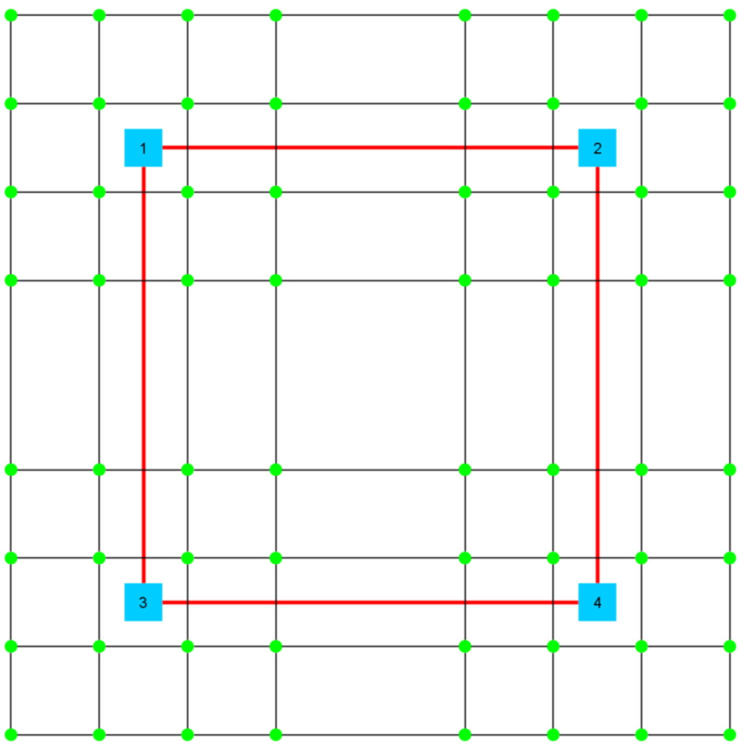
Parallel program

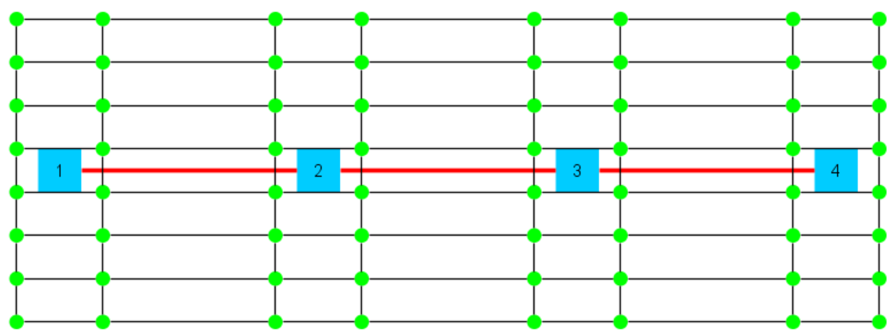


Computing networks

Introduction

- The goal of this problem is to assign the decomposed program to the processors and to minimize the common cost of communications.





Mathematical model

$G'(V', E', w', u')$ - parallel program

$V' = \{v'_1, ..., v'_n\}$ - parallel parts of program

$E' \subseteq V'^{(2)}$ - communication links

$w': V' \to N$ - computational complexity of parts

$u': E' \to N$ - the intensity of communications

Matrix $S = \{s_{ij}\}_{k \times k}$

$s_{ij} \in N, i, j = \overline{1, k}$ – communication costs

$w'' = (w''_1, ..., w''_k)$ - processors' performance

Mathematical model

Vector $x = \{x_1, \ldots, x_n\}$ - solution of problem

$x_i \in \{1, \ldots, k\}$ - number of processor

$i = \overline{1, n}$ - number of parallel part of program

Mathematical model

$W_i(x) = \sum_{x_j = i} w'(v'_j), i = \overline{1,k}$ - load of processor i

$\tilde{W}_i = \frac{\sum_{j=1}^{n} w'(v'_j)}{\sum_{j=1}^{k} w''(v''_j)} \cdot w''(v_i''), i = \overline{1,k}$ - ideal load of processor i

$\varepsilon \in [0,1]$ - balance coefficient

$$\max_{i=\overline{1,k}} \left(\left| \frac{W_i(x)}{\tilde{W}_i} - 1 \right| \right) < \varepsilon \qquad (1)$$

$$\sum_{i=1}^{k} \left(\left| \frac{W_i(x)}{\tilde{W}_i} - 1 \right| \right) < \varepsilon k \qquad (2)$$

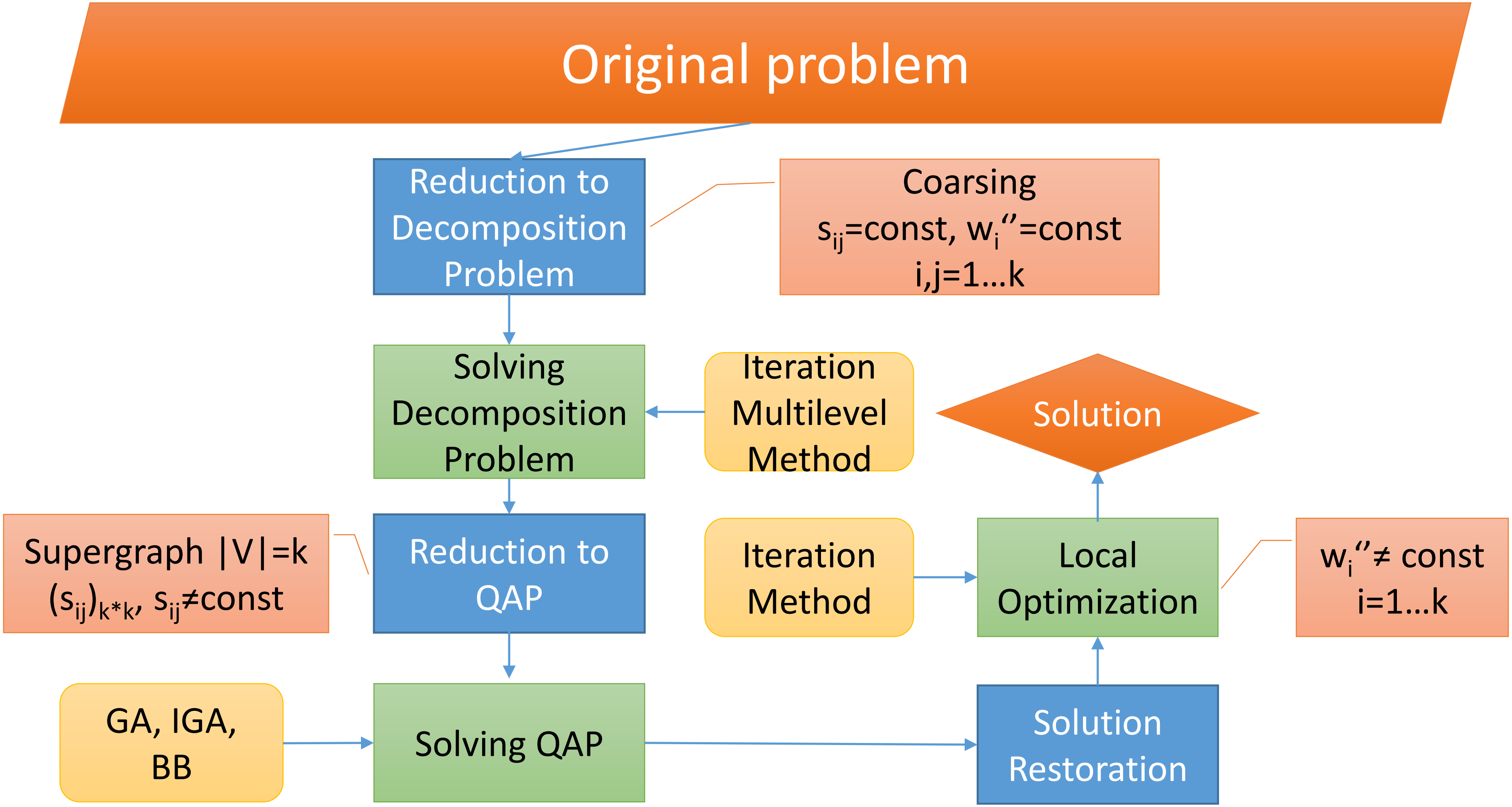
Mathematical model

Function $\beta(x, v'_i, v'_j) = \begin{cases} u'(v'_i, v'_j) \cdot s_{x_i x_j}, (v'_i, v'_j) \in E', \\ 0, (v'_i, v'_j) \notin E' \end{cases}$ - estimates the cost of communication between two parts of program

$$F_1(x) = \max_{(v'_i, v'_j) \in E'} \beta(x, v'_i, v'_j) \to \min \qquad (1)$$

$$F_2(x) = \sum_{(v'_i, v'_j) \in E'} \beta(x, v'_i, v'_j) \to \min \qquad (2)$$

Method with preprocessing and local optimization



Computation Results

Program	Size	Computing Network	Size	Scotch			Preprocessing+Scotch		
				Criterion	Max Load Disbalance	Average Load Disbalance	Criterion	Max Load Disbalance	Average Load Disbalance
gr_30_30	900	fattree	16	645	1,33	0,67	602	13,8	7,9
bcsstk29	13992	fattree	16	32270	0,97	0,77	27142	5,55	1,95
bcsstk32	44609	fattree	16	55491	0,97	0,91	43877	2,8	1,8
bcsstk33	8738	fattree	16	70401	1,12	0,61	69265	15,04	5,7
barth5	15606	fattree	16	1212	0,96	0,58	1131	4,96	3,08
vibrobox	12328	fattree	16	50705	1,36	0,6	56091	4,99	3,76
ef_sphere	16386	fattree	16	2438	0,99	0,58	2550	4,99	4
ef_4elt2	11143	fattree	16	1294	0,64	0,15	1191	4,8	3,1
fe_rotor	99617	fattree	16	25236	0,99	0,83	27800	4,96	2,7
star_100_100_1	10000	Node2_1	10	15089	0,8	0,16	16575	2	1,4
cube.1e4	11165	Node2_1	10	40568	0,49	0,15	50501	4,34	1,39

Computation Results

Program	Size	Computing Network	Size	Hybrid Method			Hybrid Method + LO			Scotch		
				Criterion	Max Load Disbalance	Average Load Disbalance	Criterion	Max Load Disbalance	Average Load Disbalance	Criterion	Max Load Disbalance	Average Load Disbalance
gr_30_30	900	fattree	16	600	13,8	7,9	632	5,8	3,5	645	1,33	0,67
bcsstk29	13992	fattree	16	27142	5,55	1,95	27384	4,29	1,95	32270	0,97	0,77
bcsstk32	44609	fattree	16	43877	2,8	1,8	43877	2,8	1,8	55491	0,97	0,91
bcsstk33	8738	fattree	16	69265	15,04	5,7	69584	10,7	5,3	70401	1,12	0,61
barth5	15606	fattree	16	1131	4,96	3,08	1256	4,37	2,68	1212	0,96	0,58
vibrobox	12328	fattree	16	52352	4,99	3,76	52352	4,99	3,76	50705	1,36	0,6
ef_sphere	16386	fattree	16	2354	4,99	4	2354	4,99	4	2438	0,99	0,58
ef_4elt2	11143	fattree	16	1191	4,8	3,1	1802	2,7	1,8	1294	0,64	0,15
fe_rotor	99617	fattree	16	24082	4,96	2,7	33992	3,18	1,76	25236	0,99	0,83
star_100_100_1	10000	Node2_1	10	15246	2	1,4	15446	1,6	1,32	15089	0,8	0,16
star_100_100_1	10000	Node2_11	10	15246	552,8	236,3	20857	2,8	1,9	17336	0,48	0,19
cube.1e4	11165	Node2_1	10	41156	4,34	1,39	41156	4,34	1,39	40568	0,49	0,15
cube.1e4	11165	Node2_11	10	41156	567,8	240,6	56247	7,19	5,85	46946	0,31	0,13