Adaptive Resource Allocation Technique to Stochastic Multimodal Projects: A Distributed Platform Implementation in JAVA

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1. Problem Definition

- Given a multimodal activity network under stochastic conditions, we want to optimize the resource allocation to minimize cost

$$\downarrow$$

Optimization via DP

1. Problem Definition

- Goal
  - Determine the resource allocation vector X_a, such that the total expected cost is minimized

$$\boxed{\min_{x} \varepsilon \left\{ \sum_{a \in A} x_a . W_a + c_L . \max \{ 0 , \Upsilon_n - T \} \right\}}$$

2. The DP Model

- Process used to select set F
  1. Determine the longest path in the network
  2. The activities on the longest path will be the decision variables (set D)
  3. The others will be the activities to be fixed (set F)
- Resource cost of fixed variables

$$\boxed{rcf = \varepsilon \sum_{i \in F} x_i . W_i = \sum_{i \in F} x_i . \varepsilon (W_i)}$$

2. The DP Model

- First stage

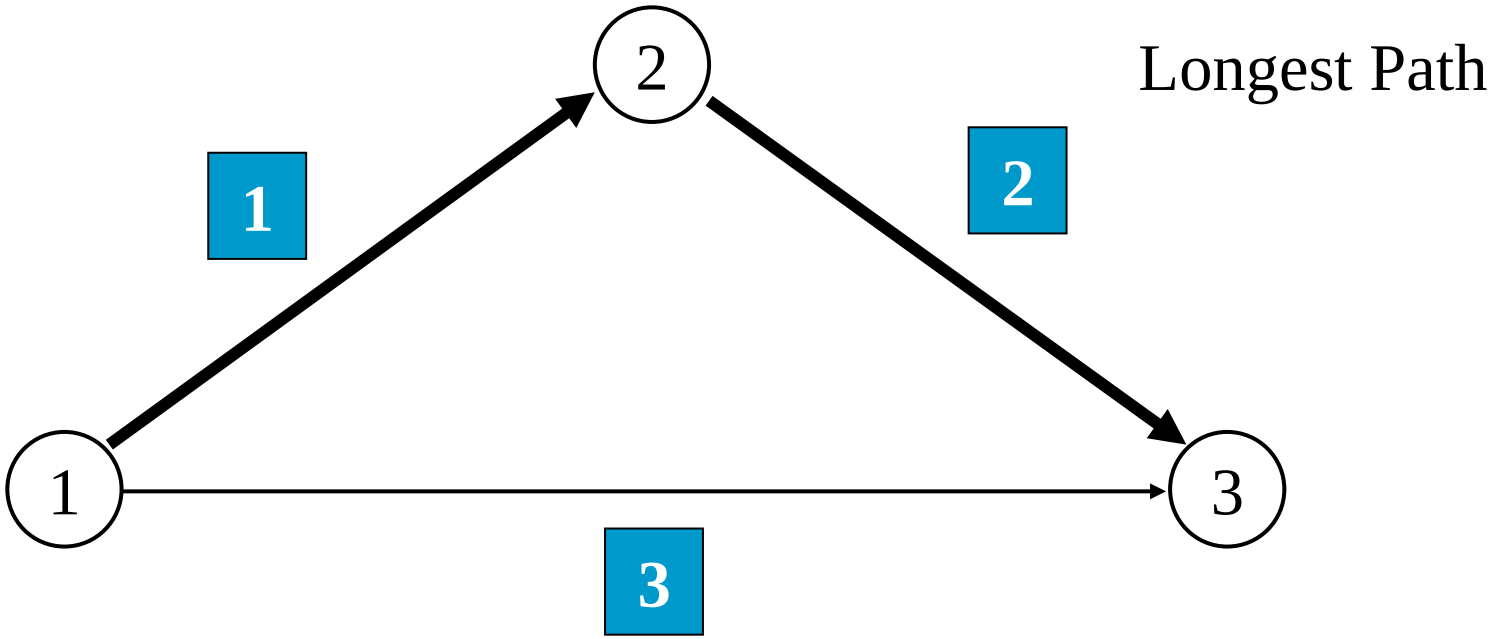
$$f_1(s_1|F) = \min_{x_{[1]} \in D} \varepsilon \{ x_{[1]}.W_{[1]} + rcf + c_L . \varepsilon (U) \}$$

where $U = \max \{ 0 , \Upsilon_n - T \}$

- Next stages

$$f_k(s_k|F) = \min_{x_k \in D} \varepsilon \{ x_k.W_k + \varepsilon f_{k-1}(s_{k-1}|F) \}$$

3. Example Network



D = {x1, x2}   F={x3}

3. Example Network

Activity a	Parameter λ_a	Expected Work Content
1	0.20	5.0
2	0.10	10.0
3	0.07	14.29

$T=16$

$C_L=2$

$0.5 \leq x_a \leq 1.5$

Unit: weeks

3. Example Network

- D: discretized in {0.5, 0.75, 1.0, 1.25, 1.5} (k_1=5)
- F: discretized in {0.5, 1.0, 1.5} (K_2=3)
- W: discretized in 4 values

  p.e. W2 ~ exp(0.1) $\rightarrow$ {1.37, 4.77, 10.0, 23.86}

- rcf = x_3 . E (W_3) = x_3 / 0.07

3. Example Network

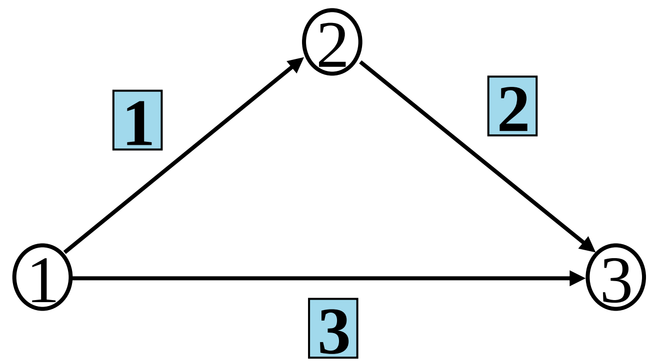
- DP iterations

  - Stage 1

$$f_1(\, t_2 \mid F=\{3\}) = rcf + \min_{x2} E\,\{\, x_2.W_2 + 2.\, E\,(U)\,\}$$

$$U = \max\{\, 0\,,\, \Upsilon_3 - T\,\}$$

$$\Upsilon_3 = \max\{\, t_2 + W_2/x_2,\; W_3/\hat{x}_3\,\}$$



  - Stage 2

$$f_2(\, t_1=0 \mid F=\{3\}) = \min_{x1} E\,\{\, x_1.W_1 + E\,[f_2\,(\Upsilon_2)]\,\}$$

$$\Upsilon_2 = W_1/x_1$$

3. Example Network

- Computational Tests
  - Pentium IV E, 3 GHz, 1 GB
  - Windows XP Professional

- Solution

  $(x_1^*, x_3^*) = (1.0, 1.0)$

  with a total expected cost of 43.32

  (running time: 0.094 s)

4. Matlab Implementation

- Code dependent on the network topology
- Code composed dynamically
- Code not very structured
- High running times
- Single station implementation

5. JAVA Implementation

- Better running times
- Fast development application
- OO Language
- Code better structured
- Better use of computational resources (dual thread and cluster)
- Different architectures / operating systems
- Open source platform / free of charge

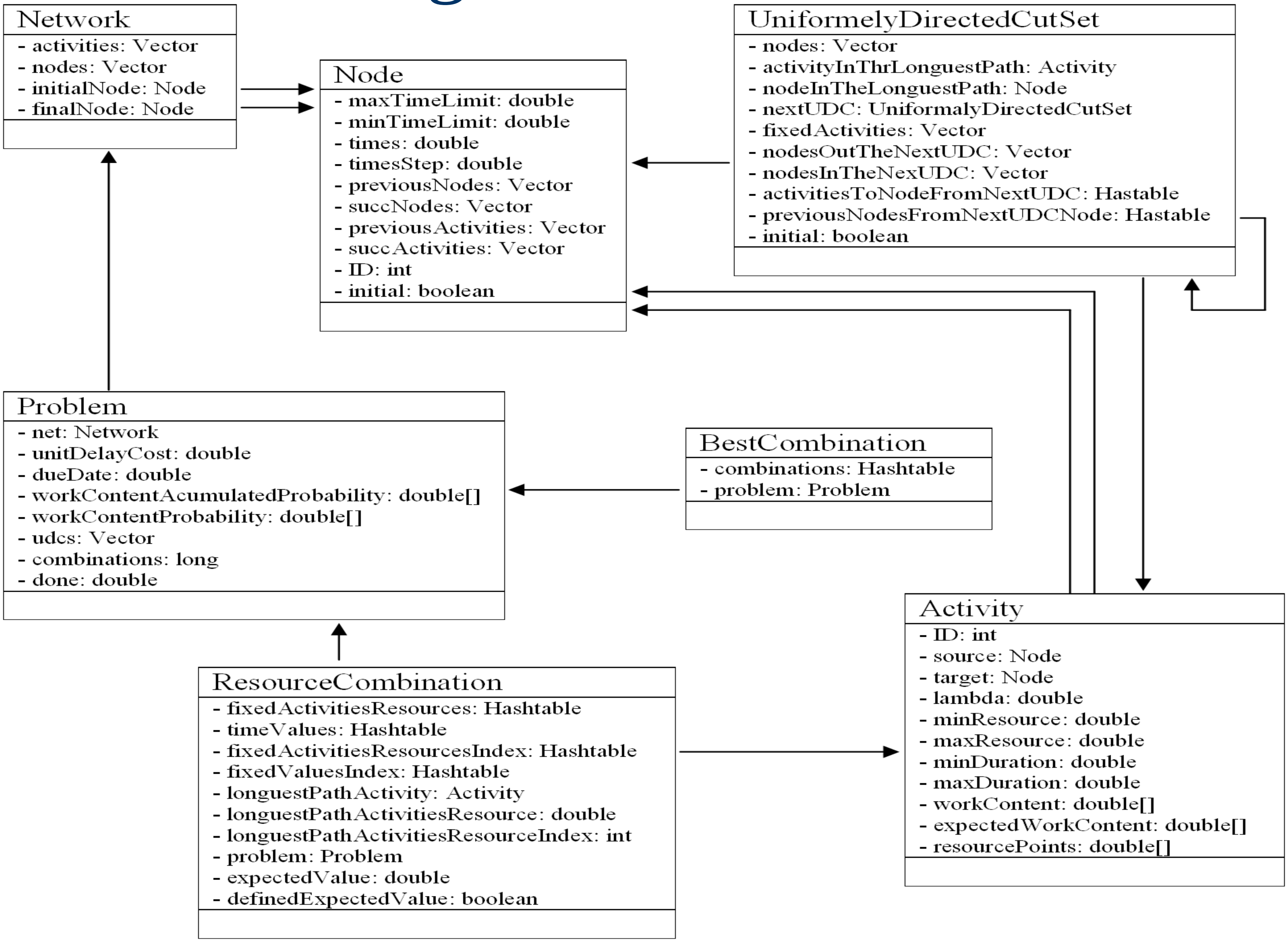
6. Data Structures

- Node
  - Immediately preceding / succeeding nodes
  - Activities that connect to the node
- Activity
  - Parameter λ
  - Lower/upper bounds on resource allocation
- Network
  - List of activities
  - List of nodes

6. Data Structures

- Resource Combination
  - Object cloned at each stage
  - A clone: a combination of the node’s time values belonging to the present UDC
  - At the end each clone will contain the optimal value of the decision variable, and the expected value of the cost for that stage

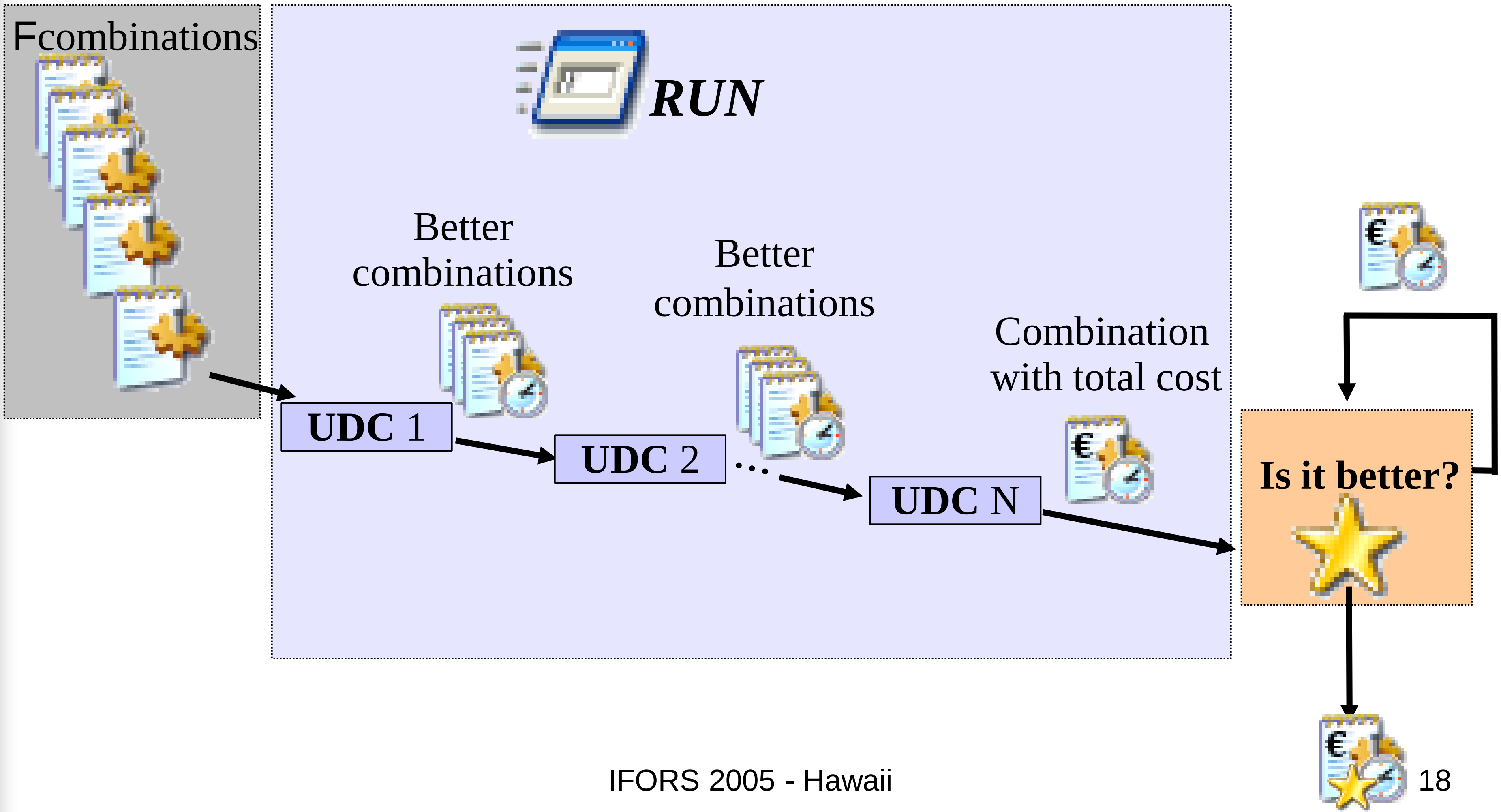
7. Class Diagram



8. Code Optimization

- Search method to find the closest combination of node due times
  - Matlab: Sequential search
    - find(value,array)
  - JAVA: Hash table (90% faster)
    - HashFunction: Combination → Integer
    - Hash(combination)=$\sum_{i=1}^{N} T_i \times MTV^i$

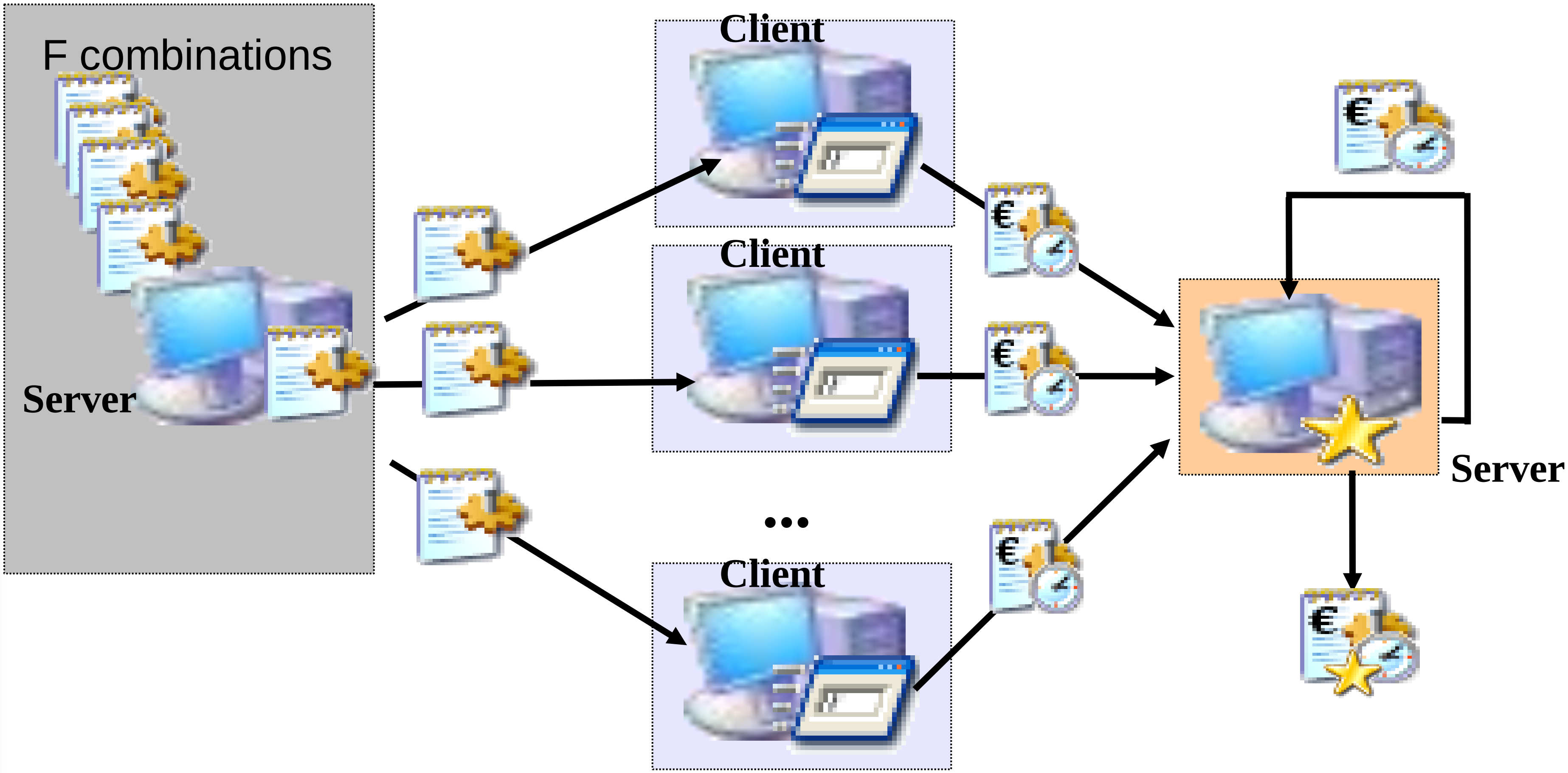
9. Single Station



10. Cluster

- Client / server model
- Similar to the SETI@Home project
- 250 resource combinations → client
- End: best solution found
- Communications: TCP/IP sockets

10. Cluster



11. Results

Net	n	T	cL	DP Time Matlab $k_2 = 3$	DP Time Java *dual thread* $k_2 = 3$	DP Time Java *cluster* $k_2 = 3$	DP Time Java *cluster* $k_2 = 5$
1	3	16	2	0.094s	0.015s	$\star$	$\star$
2	5	120	8	1.188s	0.140s	$\star$	$\star$
3	7	66	5	4.078s	0.188s	$\star$	$\star$
4	9	105	4	5m 39s	5.218s	$\star$	$\star$
5	11	28	8	10m 08s	22.422s	$\star$	$\star$
6	11	65	5	1h 03m 06s	2m 33s	29s	9m 11s
7	12	47	4	7h 43m 09s	19m 10s	2m 14s	1h 48m 06s
8	14	37	3	38h 45m †	1h 36m 17s	9m 45s	25h 31m 20s
9	14	188	6	441h 30m †	18h 16m 56s	1h 54m 12s	314h 46m †
10	17	49	7	117h 40m †	4h 52m 23s	29m 26s	135h 13m †
11	18	110	10	5285h †	218h 50m †	24h 19m 27s	11174h †

12. Accuracy of the Solutions

Net	k_2	DP Best Cost	Set of best allocations to the first UDC and $\mathcal{F}_i$
			$\{x_1, x_2, x_3, x_5, x_6, x_8, x_9, x_{10}\}$
6	3	272.298	$\{1.25, 0.5, 1.5, 0.5, 1.0, 1.0, 1.5, 1.0\}$
	5	266.498	$\{1.5, 0.5, 1.25, 0.5, 1.25, 1.0, 1.5, 1.0\}$
			$\{x_1, x_2, x_3, x_4, x_6, x_7, x_8, x_{10}, x_{12}\}$
7	3	182.914	$\{1.25, 1.0, 1.0, 0.5, 1.0, 1.0, 0.5, 1.0, 1.5\}$
	5	172.251	$\{1.5, 1.0, 0.75, 0.5, 0.75, .75, 0.5, 0.75, 1.5\}$
			$\{x_1, x_2, x_3, x_4, x_6, x_7, x_8, x_9, x_{10}, x_{12}, x_{14}\}$
8	3	120.335	$\{1.5, 1.5, 0.5, 0.5, 1.0, 0.5, 0.5, 1.0, 1.0, 1.0, 1.0\}$
	5	114.163	$\{1.5, 1.25, 1.25, 0.5, 0.75, 0.5, 0.75, 1.0, 0.75, 1.0, 0.75\}$

13. Conclusions and Future Research

- JAVA 25 times faster than Matlab (single machine). No limits for a cluster.
- JAVA code easier to understand.

- Write a new client program to be used in a cluster with computers with light tasks.
- Chunk size dynamically adapted to each client.
- Improve performance by using a small k_2, and successively finer mesh.
- Convert AoN to AoA.

References

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