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An advanced Task Assignment Model to Optimize Time Cost and Reliability in Distributed Computing Environment

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Abstract—**The entire system of Distributed Computing Environment (DCE) looks like a centralized system to the user submitting a task. DCE distribute the computational modules of the given task to various processing nodes for their execution in efficient manner. Task assignment in DCE is one of the main and critical activity by matching the task with processor and schedule task processing in order to achieve optimize solution i.e. finding an allocation of the tasks to the processors in such a way where the total execution cost and time are minimized or improve the performance in terms to minimize cost and time and maximize reliability of DCE. In DCE various computational and informational devices are dispersed over a wide geographical area and providing services to clients. In DCE a problem is divided into one or multiple task modules and each of the task modules allocate on available processor for its execution. In case of multiple task modules where the number of task modules are greater than the number of available processors in DCE then the task modules execution perform in concurrent fashion of given task. Different task modules processed on different processors in the DCE and sent back to the requested user in combined form known as information. This research paper addresses task assignment problem for processing of 'm' tasks to 'n' processors (m>n) in a DCE. Task assignment model, present in this paper assign the tasks module to the processor to improve the performance of the DCE in static manner and it is based on the consideration of processing cost (c), time (t) and reliability (r) of the task to the processors.**

Keywords- Assignment Model, Cost, Distributed Computing Environment, Cost, Time, Reliability

INTRODUCTION

A Distributed Computing System is a combination of various processors integrated in such a manner so as to appear as one system aiming at distributing the task modules submitted to it, to various participating processes of the system. Distribution of computation load across the processor in DCS is always a critical activity in order to minimize the execution time, processing cost or maximize processing reliability of task modules submitted to it by distributing to as many processors as possible. Task assignment of various task modules on particular process may be preceded by appropriate assignment of task modules of the different task module to various processors, so that performance of DCS can be enhanced. The problem consists of assignment of task modules to various processors as to incur as minimum as possible processing overhead and thereby obtaining good processing speed as opposed to a single processor execution. Task assignment model present here will deal with assignment problem by finding an optimal assignment of task modules to the processors so that the processing time and cost can be minimized and processing reliability can be maximized for task assignment in DCE, with the objective is to make processors busy by processing task modules all the time by ensuring that no one should get idle and this serves the purpose. Task optimization is highly dependent on the task assignment method onto the available processor. The problem is demonstrate here with an optimal assignment of task modules of an application on to the processors in parallel fashion and optimal assignment is one that maximizes the processing reliability function or minimizes processing cost or processing time function subject to the processing constraints. A task module is a smallest piece of instruction that serves as a unit of work. Processing time is a duration of time taken by the instruction to its processing, processing cost can be defined as the cost incurred during its processing and processing reliability can be termed as product of the probability that each processor is operational during the time of processing the task modules assigned to it, and the probability that each communication path is operational during the active period of data communication between the terminal processors of path. In the present research paper considering a task allocation problem with n number of processors and m number of tasks where m>n in DCE and these tasks are required to allocate on the available processors in optimize way with satisfying the constraints i.e. time (t), cost (c) and reliability (r). Some of the task allocation schemes have been reported in the literature, such as task allocation for minimizing cost [1, 2, 4, 5], Bi-modal network resources [3], distributed task allocation scheme [6], static task allocation [7, 11, 15], task allocation model [8, 13, 20], reliability and cost optimization in distributed computing systems [9, 18], cost in a cloud computing system [10], inter process communication [12], allocation problem [14], maximizing reliability [16, 18] and optimized time, cost, and reliability [17]. This research paper deals with task assignment problem through a new advanced assignment model in DCE by assigning available processors in such a way that overall load should be balanced that avoid the situation of overloading by using the proper utilization of processors.

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NOTATION

p	Processor
t	Task
n	Number of Processors
m	Number of Tasks
PCTR	Processing Cost Time Reliability
MPCTR	Modified Processing Cost Time Reliability
STPT	Sum of Temporary Processing Time
STPC	Sum of Temporary Processing Cost
CM	Combination Matrix

OBJECTIVE

The goal of this research paper is search task module assignment that minimizes the processing cost (c), processing time (t) and maximizes processing reliability (r) simultaneously while satisfying all of the resource constraints in Distributed Computing Environment (DCE). The assignment model present in this research paper would also ensure that processing of all the task modules as task modules are more than the numbers of processors in the DCE. In this paper performance is measured in term of processing time, cost and reliability of the task module that have to be getting processed on the processors of the environment. The type of assignment of tasks to the processor is static.

TECHNIQUE

In order to evaluate the overall optimal processing time, processing cost and processing reliability of a Distributed Computing Environment (DCE), we have taken a problem of task allocation where a set P = $\{p_1, p_2, p_3,\ldots\ldots\ldots p_n\}$ of 'n' processors with same configuration and a set T = $\{t_1, t_2, t_3,\ldots\ldots\ldots t_m\}$ of 'm' tasks, and n-1 imaginary tasks will be added for any number of task to complete the frame of n x n, to ensure that each task gets allocated where m>n. Every task has also contained some numbers of sub task modules. Processing time, cost and reliability are known for each task module to each processor and arrange in PCTR of order (n * m). After arranging the task modules PCTR matrix will break into three separate matrixes for processing task time (PTT), processing task cost (PTC) and processing task reliability (PTR). For each matrix a frame of order (n * n) will be form and will also initialize the processing load for all processors by zero in case of processing cost and processing time and 1 for processing reliability then all possible combinations of elements column wise by using PTT, PTC and PTR will be draw. Here the total number of possible combination will be n^3 and will also calculate the sum of all possible combination for processing time and cost, processing time will store in Sum of Temporary Processing Time Matrix STPT (,), processing cost will store in Sum of Temporary Processing Cost Matrix STPC (,), and for processing reliability will compute product instead of sum and will store in Product of Temporary Processing Reliability Matrix (PTPR). After compute the sum and product of all possible combination in the matrix will find minimum value of sum for processing time, cost and maximum value for processing reliability and compare processing load on within the available processor if task got matched with the correct processor where the processing load is also minimum (maximum for processing reliability) then assign the task otherwise search for next appropriate match and the task will get assign, repeat these steps until all the task modules will assign to the processors in DCE. The function to calculate overall time [Etime], cost [Ecost] and reliability [Ereilability] is given here:

$$\text{Etime} = \left[\sum_{i=1}^{n}\left\{\sum_{i=1}^{n} ET_{ij}\, X_{ij}\right\}\right] \qquad (\text{i})$$

$$\text{Ecost} = \left[\sum_{i=1}^{n}\left\{\sum_{i=1}^{n} EC_{ij}\, X_{ij}\right\}\right] \qquad (\text{ii})$$

$$\text{Ereliablity} = \left[\prod_{i=1}^{n}\left\{\sum_{i=0}^{n} ER_{ij}\, X_{ij}\right\}\right] \qquad (\text{iii})$$

ALGORITHM

1. Start Algorithm
2. Read the number of task in m
3. Read the number of processor in n
4. Store task and Processing Cost, Time and Reliability into Matrix PCTR(,) n x m of order
5. From PCTR derived new Matrix MPCTR by differentiate values for processing time, processing cost and processing reliability.
6. While (All task! = Assigned)

{

   i. Consider n tasks in sequence and store for processing time, cost and reliability in order of n x n.
   ii. Create all possible combination and calculate the sum for each combination and store values for processing time and cost tables, and product for processing reliability.
   iii. Search the minimum value of sum for processing time, cost, maximum value of product for processing reliability and draw Combination Matrix (CM)
   iv. Check the processing load of matching processor for eligible task (with minimum processing time, cost and maximum reliability).
   v. If the criteria are matched then the task will get assign otherwise will go to step iii and search next appropriate value to task get assigned.

}

7. State the result
8. End of algorithm

IMPLEMENTATION

In the present research paper, we have taken Distributed Computing Environment (DCE) which consist a set P of 3 processors $\{p_1, p_2, p_3\}$, and a set T of 3 tasks $\{t_1, t_2, t_3\}$. Each tasks contained six modules as mentioned in Table 1.

Table 1: Tasks and their modules

t_1	$\{m_{11}, m_{12}, m_{13}, m_{14}, m_{15}, m_{16}\}$
t_2	$\{m_{21}, m_{22}, m_{23}, m_{24}, m_{25}, m_{26}\}$
t_3	$\{m_{31}, m_{32}, m_{33}, m_{34}, m_{35}, m_{36}\}$

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And these modules belongs to different tasks would be process on available processors in DCS as shown in Fig 1.

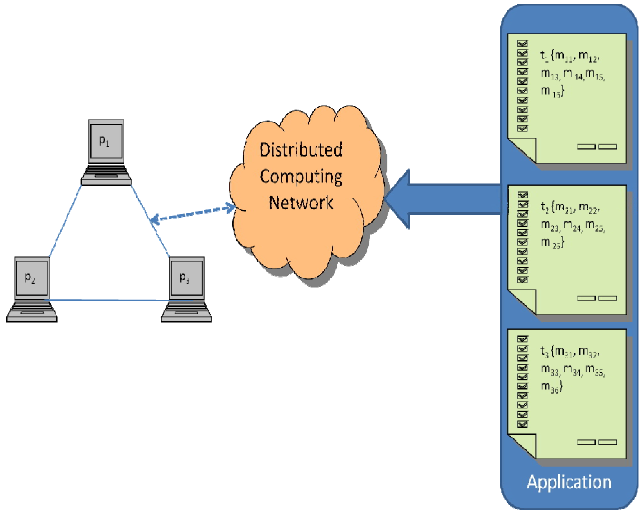

Fig 1: Task assignment problem in DCS

The processing time (t), processing cost (c) and processing reliability (r) of each module are known and mentioned in Processing Cost Time Reliability Matrix (PCTR).

Table 2: Processing Cost Time Reliability Matrix

	Processors	p_1	p_2	p_3
Task	Modules	t-c-r	t-c-r	t-c-r
t_1	m_{11}	11-2.1-0.999450	13-2.1-0.999450	10-2.1-0.999450
	m_{12}	12-2.8-0.999429	14-2.8-0.999429	13-2.8-0.999429
	m_{13}	10-2.7-0.999428	11-2.7-0.999428	12-2.7-0.999428
	m_{14}	21-2.6-0.999418	23-2.6-0.999418	20-2.6-0.999418
	m_{15}	29-2.1-0.999450	31-2.1-0.999450	27-2.1-0.999450
	m_{16}	31-2.8-0.999429	33-2.8-0.999429	35-2.8-0.999429
t_2	m_{21}	11-1.52-0.999425	114-2.5-0.999427	114-0.95-0.999427
	m_{22}	19-1.25-0.999425	195-1.8-0.999425	195-1.65-0.999425
	m_{23}	11-2.02-0.999321	110-2.01-0.999321	110-2.01-0.999321
	m_{24}	16-1.52-0.999222	166-0.98-0.999222	166-1.22-0.999222
	m_{25}	11-1.35-0.999450	110-2.03-0.999450	110-1.94-0.999450
	m_{26}	15-1.55-0.999429	155-1.23-0.999429	155-2.00-0.999429
t_3	m_{31}	08-2.5-0.999567	08-2.5-0.998877	08-2.5-0.998765
	m_{32}	19-2.3-0.999712	19-2.3-0.998865	19-2.3-0.999222
	m_{33}	18-3.1-0.998877	18-3.1-0.997755	18-3.1-0.987345
	m_{34}	13-2.2-0.999334	13-2.2-0.987652	13-2.2-0.999763
	m_{35}	11-27-0.998543	11-2.7-0.999723	11-2.7-0.999431
	m_{36}	18-3.1-0.998855	18-3.1-0.998124	18-3.1-0.998745

To proceed further with task assignment problem in PCTR matrix, considering that t_1 is based on processing time (it may be processing cost or reliability), task t_2 is based on processing cost (it may be processing time and reliability) and task t_3 is based on processing reliability (it may be processing time and processing cost). Hence a new matrix named MPCTR can be derived by using PCTR, In MPCTR task t_1 will represent processing time (t), t_2 task processing cost (c) and t_3 task processing reliability (r). New matrix MPCTR represent as Table 3:

Table 3: Modified Processing Cost Time Reliability Matrix

	Processors	P_1	P_2	P_3
Task	Modules	t-c-r	t-c-r	t-c-r
t_1	m_{11}	11-…-…	13-…-…	10-…-…
	m_{12}	12-…-…	14-…-…	13-…-…
	m_{13}	10-…-…	11-…-…	12--…-…
	m_{14}	21-…-…	23-…-…	20--…-…
	m_{15}	29-…-…	31-…-…	27--…-…
	m_{16}	31-…-…	33-…-…	35--…-…
t_2	m_{21}	…-1.52-…	…-2.5-…	…-0.95-…
	m_{22}	…-1.25-…	…-1.8-…	…-1.65-…
	m_{23}	…-2.02-…	…-2.01-…	…-2.01-…
	m_{24}	…-1.52-…	…-0.98-…	…-1.22-…
	m_{25}	…-1.35-…	…-2.03-…	…-1.94-…
	m_{26}	…-1.55-…	…-1.23-…	…-2.00-…
t_3	m_{31}	…-…-0.999567	…-…-0.998877	…-…-0.998765
	m_{32}	…-…-0.999712	…-…-0.998865	…-…-0.999222
	m_{33}	…-…-0.998877	…-…-0.997755	…-…-0.987345
	m_{34}	…-…-0.999334	…-…-0.987652	…-…-0.999763
	m_{35}	…-…-0.998543	…-…-0.999723	…-…-0.999431
	m_{36}	…-…-0.998855	…-…-0.998124	…-…-0.998745

MPCTR can be break into three different tables for each constraint i.e. Table 4 for processing time, Table 5 for processing cost and Table 6 for processing reliability and two imaginary modules would be added for each task i.e. for t_1 $\{m_{17}, m_{18}\}$, t_2 $\{m_{27}, m_{28}\}$ and t_3 $\{m_{37}, m_{38}\}$ to complete frame in order of n * n, so none of the task module remain gets unexecuted.

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Table 4: Processing Time

	m_{11}	m_{12}	m_{13}	m_{14}	m_{15}	m_{16}	m_{17}	m_{18}
p_1	11	12	10	21	29	31	0	0
p_2	13	14	11	23	31	33	0	0
p_3	10	13	12	20	27	35	0	0

Table 5: Processing Cost

	m_{21}	m_{22}	m_{23}	m_{24}	m_{25}	m_{26}	m_{27}	m_{28}
p_1	1.52	1.25	2.02	1.52	1.35	1.55	0	0
p_2	2.58	1.86	2.01	0.98	2.03	1.23	0	0
p_3	0.95	1.65	2.00	1.22	1.94	2.00	0	0

Table 6: Processing Reliability

	m_{31}	m_{32}	m_{33}	m_{34}	m_{35}	m_{36}	m_7	m_{38}
p_1	0.999567	0.999712	0.998877	0.999334	0.998543	0.998855	0	0
p_2	0.998877	0.998865	0.997755	0.987652	0.999723	0.998124	0	0
p_3	0.998765	0.999222	0.987345	0.999763	0.999431	0.998745	0	0

By considering Table 4 for task assignment we take first three tasks for the first frame and will create a temporary matrix TPTM of [n][n] as mentioned in Table 7.

Table 7: Temporary Processing Time Matrix

	m_{11}	m_{12}	m_{13}
p_1	11	12	10
p_2	13	14	11
p_3	10	13	12

Here we will make all the possible combinations of elements and find out the smallest sum of possible combinations. For the first frame the combinations as mentioned in Table 8:

Table 8: Combination Matrix

	m_{11}	m_{12}	m_{13}
p_1	-	-	10
p_2	-	-	11
p_3	10	-	-

Here m_{11} will get assign to p_3 processor. By the following the same procedure for the rest frames, we find following assignment table:

Table 9: Task Assignment

Processor	Modules
p_1	$m_{13} * m_{15}$
p_2	$m_{12} * m_{16}$
p_3	$m_{11} * m_{14}$

Table 10: Overall Processing Time

Processors	Tasks Module	Processing Time	ETime
p_1	$m_{13} * m_{15}$	39	
p_2	$m_{12} * m_{16}$	47	116
p_3	$m_{11} * m_{14}$	30	

Resulting processing time can be shown in graphical form in Fig 2:

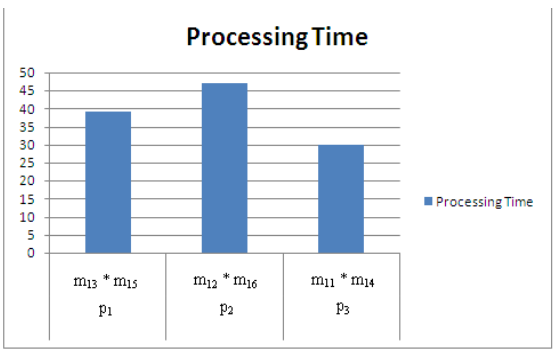

Fig 2: Processing Time

Table 11: Overall Processing Cost

Processors	Tasks Module	Processing cost	ECost
p_1	$m_{22} * m_{25}$	2.6	8.54
p_2	$m_{23} * m_{24}$	2.99	
p_3	$m_{21} * m_{26}$	2.95	

Resulting processing cost is representing in graphical in Fig 3:

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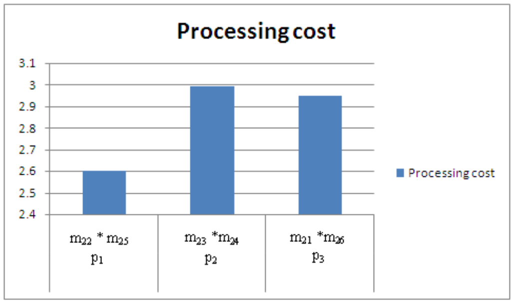

Fig 3: Processing cost

Table 12: Overall Processing Reliability

Processors	Tasks Module	Processing Reliability	Ereliability
p_1	$m_{31} * m_{32} * m_{33}$	0.998135	0.996370
p_2	m_{35}	0.999723	
p_3	$m_{34} * m_{36}$	0.998508	

Resulting processing reliability as mentioned in Fig 4.

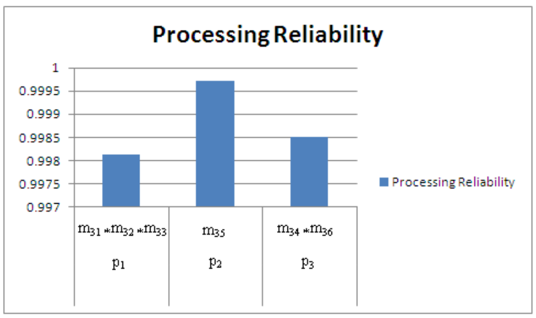

Fig 4: Processing Reliability to the processing in DPE

CONCLUSION

In this research paper we have solved the problem of task assignment through a newly designed assignment model, in which the number of the task modules is more than the number of processors in Distributed Computing Environment (DPE). The optimization technique will ensure to satisfy all the three constraints in regards DCE i.e. processing time (t), processing cost (c) and reliability (r). The task assignment model is presented in pseudo code and implemented on the several sets of input data to test the performance and effectiveness of the pseudo code. It is the basic requirement of DCS for any assignment problem that the task have to be processed with optimal time, cost and reliability. Here, we have taken three tasks i.e. t_1, t_2 and t_3 with different tasks module and process t_1 with minimum time, t_2 process with minimum cost and t_3 process with maximum reliability in DCE. The optimal result of the example that is considered to test the assignment model is mentioned in the implementation section of the paper are mentioned in Table 13.

Table 13: Optimal Results for Time, Cost and Reliability

Task	p_1	p_2	p_3	Optimal ETime	Optimal ECost	Optimal Ereliablity
t_1	$m_{13} * m_{15}$	$m_{12} * m_{16}$	$m_{11} * m_{14}$	116	---	---
t_2	$m_{22} * m_{25}$	$m_{23} * m_{24}$	$m_{21} * m_{26}$	---	8.54	---
t_3	$m_{31} * m_{32} * m_{33}$	m_{35}	$m_{34} * m_{36}$	---	---	0.996370

Fig 5 shown final task assignment in Distributed Computing system.

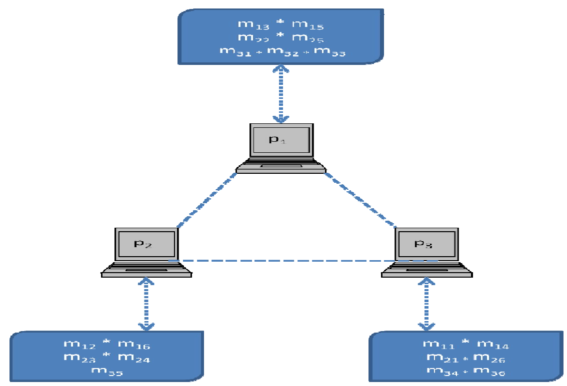

Fig 5: Final task assignment in DCS

Time complexity is the major factor for calculating the performance of the algorithm. The time complexity of present research paper is compared with Richard et.al. [20] and is mentioned in Table 14.

Table 14: Complexity comparison between present algorithm and algorithm [20]

Processors (n)	tasks (m)	Time Complexity of Richard et. Al. (21) $O(n^m)$	Complexity of present algorithm $O(mn^n)$
3	6	729	1296
3	7	2187	2401
3	8	6561	4096
3	9	19683	6561
3	10	59049	10000
4	6	4096	7776
4	7	16384	16807
4	8	65536	32768
4	9	262144	59049
4	10	1048576	100000
5	6	15625	46656
5	7	78125	117649
5	8	390625	262144
5	9	1953125	531441
5	10	9765625	1000000

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