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Distributed Systems: Time-Reliability Trade-Off for Performance Analysis

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Abstract

A distributed system consists of a collection of autonomous computers linked by a computer network and equipped with distributed system software. Distributed systems are implemented on hardware platforms that vary in size from a few workstations interconnected by a single local area network to thousands of computers connected via multiple wide area networks. This paper is an attempt to analyze the performance of the distributed system based on its reliability-time trade-off through an exhaustive search process. The Execution Reliability (ER), Communication Reliability (CR), Execution Time (ET) and Communication Time (CT) are considered in the study and represented in form of matrices namely ERM (,), CRM (,), ETM (,), CTM (,), respectively. These matrices are modified and manipulated according to the task combinations. The reliability for the distributed computing system is evaluated for each task combination along with the execution and communication Times. The optimal reliable solution for distributed computing system is obtained from the calculated reliability values for all task combinations. Finally, the Index value, a measure of performance optimization, is obtained.

Keywords—*Distributed Systems, Reliability, Execution Time, Performance Index, Communication Time*

I. INTRODUCTION

Distributed system offers the potential for improved performance and resource sharing. The distributed network environments in which services provided for the network reside at multiple sites. However, the term has different meanings to different systems because processors can be interconnected in many ways for various reasons. In the most general form, the word distribution implies that the processors are in geographically separate locations. Occasionally, the term is also applied to an operation using multiple mini-computers, which are not hardware, connected with each other and are connected through satellite. Distributed processing applications range from large data base installations where processing load is distributed for organizational efficiency to high-speed signal processing systems where extremely fast processing must be performed in a real-time environment. The distributed real time environment in which, the services provided for the network reside at multiple site. There are several approach have been reported in the literature for solving the task allocation problem in distributed system and roughly can be classified into four categories: (i) Graph theoretical [1,4,6,12,14], (ii) Mathematical programming [5,10,13,18], (iii) Heuristic approach [2,7,8,15,17], [22], and (iv) Probabilistic approaches [3,9,11,15].Many of these methods try to minimize the total processing Time and do not consider load balancing criterion. The exhaustive search model has been discussed to provide an optimal solution for assigning a set of "m" tasks of a program to a set of "n" processors (m > n) in a Distributed Computing Environment with the goal to maximize the overall reliability of the system and allocated load on all the processors are optimum.

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II. DEFINITIONS & NOTATIONS

Execution Time: Each task ti has an Execution Time when executed on jth processor ETij (1≤ i ≤ m and 1≤ j ≤ n),

$$ET = \sum_{i=1}^{m} \left\{ \sum_{j=1}^{n} EC_{ij} x_{ij} \right\}$$

Communication Time: The Communication Time CTij (1≤ i ≤m and 1≤ j ≤n) of the interacting tasks ti and tj is incurred due to the data units exchanged between them during the process of execution.

$$CT = \sum_{j=1}^{n} \left\{ \sum_{j=1}^{n} CC_{ij} y_{ij} \right\}$$

Total Time: TTime = CT + ET

Execution Reliability: The Execution Reliability [ER] of a task ti on the processor pj is the probability ERij (1≤ i ≤ m and 1≤ j ≤ n), that task ti will be successfully executed on processor pj, within specified conditions.

$$ER = \prod_{i=1}^{m} \left\{ \sum_{j=1}^{n} ER_{ij} x_{ij} \right\}$$

Communication Reliability: The Communication Reliability CRij (1≤ i ≤ m and 1≤ j ≤ n), is the probability of successfully data units exchanged between the task ti and tj under the given conditions.

$$CR = \prod_{j=1}^{n} \left\{ \sum_{j=1}^{n} CR_{ij} y_{ij} \right\}$$

Total Reliability Treliability = CR * ER

Where $x_{ij} = \begin{cases} 1, \text{if } i^{th} \textit{ task is assigned} \text{ to } j^{th} \text{ processor, and} \\ 0, \text{otherwise} \end{cases}$

$y_{ij} = \begin{cases} 1, \text{if the } \textit{task assigned} \text{ to processor i communicate with the task assigned to processor j} \\ 0, \text{otherwise} \end{cases}$

Index: The index represents the ratio of Treliability to the total Time TTime.

Index = Treliability / TTime.

III. PROBLEM STATEMENT

Let the given system consists of a set of n processors P = {p1, p2, ...,pn }, interconnected by communication links and a set of m tasks T = { t1, t2,.....,tm }. The processing Execution Reliability and Execution Time of individual tasks corresponding to each processor are given in the form of matrices ERM (,) and ETM (,) of order m x n respectively. The Communication Reliability and Communication Time are taken in the square symmetric matrices CRM (,) and CTM (,) of order m*m.

IV. PROPOSED METHOD

Initially, we obtain the task combinations in order to make the set of task(s) equals to number of processor as

[(n * mCm-n) / $\lceil m/n \rceil$ **] (= nl, say)**

These combinations are stored in TCOMB () and accordingly modified matrices ETM (,), ERM (,), CTM (,) and CRM (,). To get the allocation a modified version of row and column assignment method of Yada et al [21] is employed which allocates a task to a processor where it has minimum execution Time and correspondingly maximum reliability. The total assignment Time [TTime] and reliability [Treliability] is expressed as the sum of execution Times along with communication Time and product of the products of the execution reliabilities along with communication reliabilities respectively of all the tasks. Then an index, which is based on the reliability along with the total Time of the tasks to the processors, is obtained. The maximum value of the index shall give the optimal result. The computational flow chart of the Algorithm has been shown in fig-1.

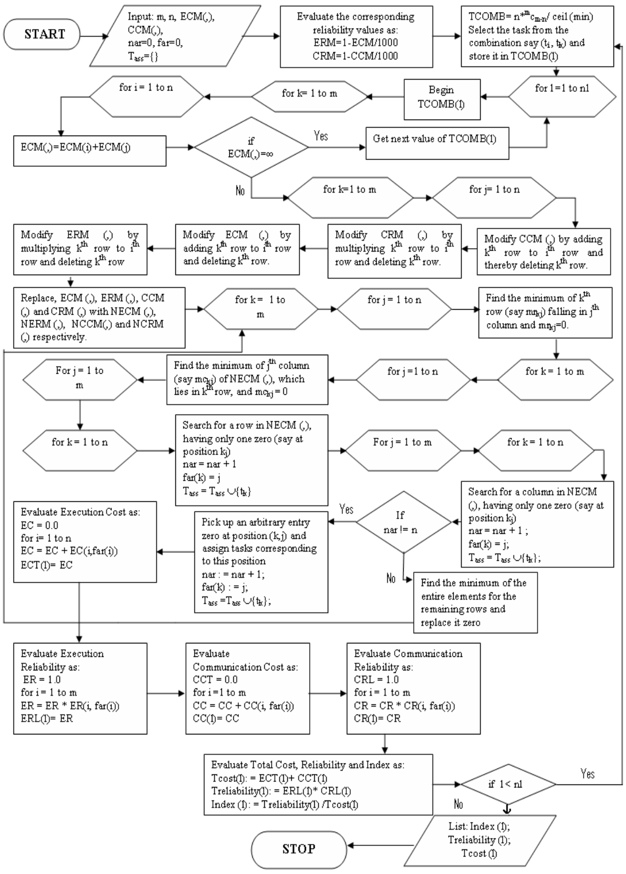


Fig 1 Computational Flow Chart of Algorithm

V. RESULTS & DISCUSSIONS

Consider a system consisting of a set T = {t1, t2, t3, t4, t5, t6, t7} of 7 tasks and a set P = {p1, p2, p3} of 3 processors,

Input: m = 7, n = 3, ETM(,) and CTM(,)

ETM(,) =

	p1	p2	P3
t1	4	8	2
t2	3	5	4
t3	6	3	2
t4	2	8	5
t5	9	6	7
t6	10	5	6
t7	10	11	12

CTM(,) =

	t1	t2	t3	t4	t5	t6	t7
t1	0	4	3	5	6	8	0
t2	4	0	3	5	7	0	0
t3	3	3	0	4	3	2	1
t4	5	5	4	0	3	3	2
t5	6	7	3	3	0	2	1
t6	8	0	2	3	2	0	5
t7	0	0	1	2	1	5	0

Evaluate the ERM (,) and CRM (,)

ERM (,) = 1 – ETM/1000

ERM(,) =

	p1	p2	P3
t1	0.996	0.992	0.998
t2	0.997	0.995	0.996
t3	0.994	0.997	0.998
t4	0.998	0.992	0.995
t5	0.991	0.994	0.993
t6	0.990	0,995	0.994
t7	0.990	0.989	0.988

CRM (,) = 1 – CTM/1000

CRM(,) =

	t1	t2	t3	t4	t5	t6	t7
t1	1.000	0.996	0.997	0.995	0.994	0.992	1.000
t2	0.996	1.000	0.997	0.995	0.993	1.000	1.000
t3	0.997	0.997	1.000	0.996	0.997	0.998	0.999
t4	0.995	0.995	0.996	1.000	0.997	0.997	0.998
t5	0.994	0.993	0.997	0.997	1.000	0.998	0.999
t6	0.992	1.000	0.998	0.997	0.998	1.000	0.995
t7	1.000	1.000	0.999	0.998	0.999	0.995	1.000

Compute the total combination as and store them in TCOMB ():

TCOMB = [(n * mCm-n) / Γ (m/n)] = 35

TCOMB (1) = (123, 456, 7)

By implementing the steps of algorithm and method suggested by Yada et al. [21] for allocating the task following result are obtained

Tasks	Processors	ET	CT	ER	CR
t1t2t3	p1	13	41	0.98705	0.95971
t4t5t6	p3	18	48	0.98210	0.95301
t7	p2	11	09	0.98900	0.99102

ETT (1) = 42 and ERL (1) = 0.95871

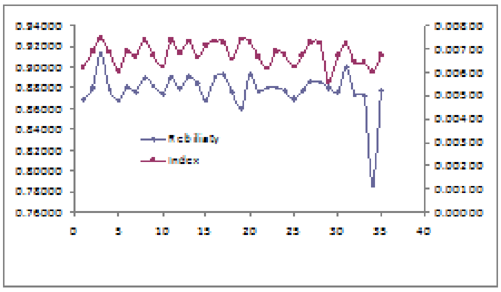
CTT (1) = 98 and CRL (1) = 0.9064

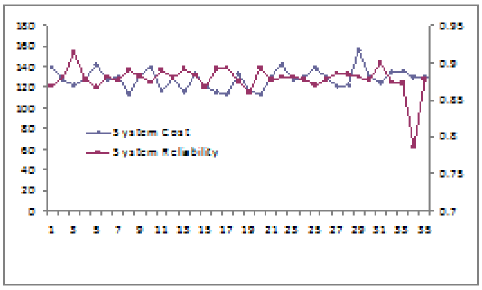
TTime(l) = 140 and Treliability(l) = 0.8689

Index (l) = 0.0062

Repeating the process, suggested in the algorithm the corresponding values of ET, CT, ER, CR, TTime, Treliability and Indexes are obtained and are shown in the following table for the table It is conclude the maximum computational reliability of the system at TCOMB(3) but the computation Time is slightly on higher side which can be tolerate keeping in view of the performance of the system.

It is observed that there is a relation between the Reliability and Index. It is also observed that the Reliability of the system and their Index value are directly related to each other which are depicted in Fig.2 also from the study it may be concluded that the System reliability and their Time are inversely proporsnal to each other i.e. where system Time throughput is higher the system reliability is poor and depicted in Fig. 3.





The present method is compared with [19]. In [19], it seems that they have assumed all the parameters for evaluating the performance of the distributed system. They have not considered any relation between Time and reliability. But, in present method, author takes care to maintain the relationship between Time and reliability, the two parameters that have been considered for the performance evaluation of the system. To justify the efficiency of the present method, we have evaluated the run time complexity of our method as well as that of [19], based on time complexity of [20], and the result shows that the present method's runtime complexity O(mn2) is better than that of suggested by [19] O(m2n) which is also depicted with the help of Fig. 4.

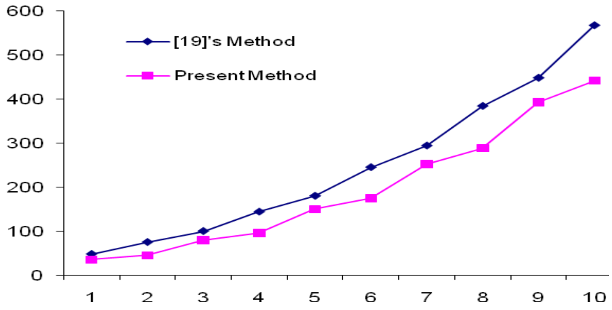


Fig. 4: Comparison of present method with that of [19] based on Run Time Complexity

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