A Review of Fault Diagnosis in Distributed Systems using Comparison Model

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ABSTRACT
The motive of this paper is to propose a novel approach for fault diagnosis in distributed systems. The fault diagnosis is also known as system level self-diagnosis in multicomputer and multiprocessor systems using various comparison models. There are two different classes of models: the test-based models and the comparison-based models. In the test-based model which includes PMC model, every node of the system is assigned to test some other nodes and the collection of all the test syndrome is interpreted to locate the faulty node. In comparison-based model which includes MM model, the responses of two nodes to the same task are compared and the collection of all the comparison syndrome is analyzed for detection of faulty nodes. The comparison model is proved to be more effective, since it provides faster diagnosis of faulty nodes using its time diagnosis algorithm for n node diagnosable system.

General Terms
Algorithm, Analysis, Result, Performance.

Keywords
Multicomputer, System level diagnosis, Comparison model, MM model, PMC model, Diagnosis algorithm.

1. INTRODUCTION
The need of dependable computing systems for critical applications have motivated researchers to investigate self-diagnosable large scale distributed systems in multicomputer and multiprocessor systems using comparison models. Nodes in the multiprocessor system need to be diagnosed as faulty or fault free, known as system level fault diagnosis.

A set of tasks is assigned to pairs of nodes and their outcomes are compared by neighboring nodes. Three types of diagnosis models have been studied in the context of system level diagnosis i.e. testing, comparison and probabilistic models. The fault diagnosis under testing and comparison model assumes in general a worst case behavior. The probabilistic models on the other hand do not assume any bound, but instead, only fault sets that have a no negligible probability of occurrence are considered.

In this paper, a novel diagnosis approach using comparison model have been proposed. The MM comparison model is proved to be more effective, since it provides faster diagnosis of faulty nodes using its time diagnosis algorithm for n node diagnosable system.

Mourad Elhadef, Shantanu Das and Amiya Nayak[1], have proposed a comparison model for system fault diagnosis using artificial immune system(AIS) in multiprocessor systems consisting of several hundred nodes. The AIS based diagnosis approach is found to be more efficient and allows faster diagnosis in worst case situations where large system is considered.

Xiaofan Yang and Yuan Yan Tang [2], introduced the MM comparison model for fault identification of diagnosable multicomputer systems. A time diagnosis algorithm is presented for n node MM diagnosable system. The proposed algorithm is the fastest and more efficient.

Guey-Yun Chang [3], has introduced PMC model for system level diagnosis. Each processor can test its neighboring processors and declare them faulty or fault free. The random fault models and conditional fault models under PMC models are more efficient.

Elias P. Duarte Jr., Andrea Weber and Keiko V. Ono Fonseca[4],have introduced Distributed Network Reachability(DNR) algorithm for distributed system level diagnosis. This algorithm allows every node of a partitionable arbitrary topology network to determine which portions of the network are reachable and unreachable. A working node computes the network reachability using local diagnostic information. The simulation results show that the proposed algorithm works correctly under a dynamic fault situation leading to network partitions and healing.

In this paper, a novel approach using MM comparison model has been proposed. This comparison model is proved to be more effective, since it provides faster diagnosis of faulty nodes using its time diagnosis algorithm for n node diagnosable system.

2. MM COMPARISON MODEL

2.1 Overview
The MM model is a realistic comparison based model to acquire comparison syndrome since, the comparisons are performed by the nodes themselves instead of the centralized node. A node is a comparator of two nodes if and only if the comparator is connected to them through direct communication links. The MM model assumes that the two nodes are fault free, provided the comparator is fault free. The disagreement implies that at least one of the three relevant nodes is faulty.

Two nodes are allocated the same task and input and their outputs are compared by a comparator node. A node is a comparator of two nodes, if and only if it is a common neighbor of them. Let s (u; v,w)=0(correspondingly, 1) denote that u evaluates v and w as having an identical response(correspondingly, different responses)(Fig.1).

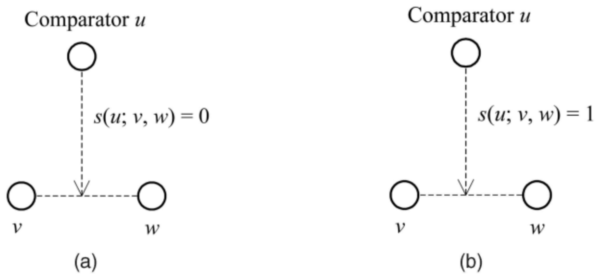

Fig 1: Two possible comparison results: (a) s (u; v, w)=0 and (b) s (u; v, w)=1.

The collection of all comparison results forms a comparison syndrome, denoted as s.

2.2 Analysis

Consider three nodes involved in a comparison. We have

1. at least one of the three nodes is faulty if the comparison result is 1 and
2. either the comparator is faulty or the three nodes are all fault –free if the comparison result is 0.

Let s be a comparison syndrome on a system G (V,E) with a fault set F. An allowable fault set (AFS) of s is a subset U⊆V such that, for any u∈V-U and any v, w ∈ $N_G(u)$, v≠w, we have 1) s (u; v,w)=0 if v, w ∈V-U and 2) s(u; v,w)=1 if v∈U or w∈U. A t-AFS of s is an AFS of s having at most t nodes. F must be an AFS of s, but the converse is not necessarily true. For the sake of correct diagnosis, the following notion is necessary: A system is MM t-diagnosable if every comparison syndrome on this system with a t-fault set has a unique t-AFS.

Table 1. The MM model

Comparator	Two nodes being compared	Comparison result
Fault-free	Both are fault-free	0
	Either is faulty	1
Faulty	Any case	0 or 1

3. PMC MODEL

In PMC model, one node is assigned to test another node if and only if they are adjacent. Let s(u,v)=0 (correspondingly,1) denote that u evaluates v as fault free (correspondingly, faulty). The collection of all the test results forms a test syndrome, denoted as s. The PMC model assumes that a test result is 0 if the two relevant nodes are fault free, is 1 if the tester is fault free but the tested node is faulty, and is unpredictable if the tester is faulty(Table 2). For the sake of correct diagnosis, the following notion is necessary: A system is PMC t- diagnosable if and only if every test syndrome on the system with a t-fault set has a unique t-AFS.

Table 2. The PMC model

Tester	Tested node	Test result
Fault-free	Fault-free	0
	Faulty	1
Faulty	Any case	0 or 1

4. ALGORITHM

The goal of this paper is to develop a faster diagnosis algorithm for general MM diagnosable system consisting of three phases:

Phase 1: Define the s-1 comparators which are classified into s-10 comparators,s-11 comparators, and s-12 comparators. All s-12 comparators are faulty. For every s-11 or s-10 comparator, all possible candidates are checked for the unique t-AFS provided that this comparator is fault free. If a t-AFS is found, the diagnosis is complete. Otherwise, all s-1 comparators are faulty (Fig. 2a,2b) (Fig 3a,3b).

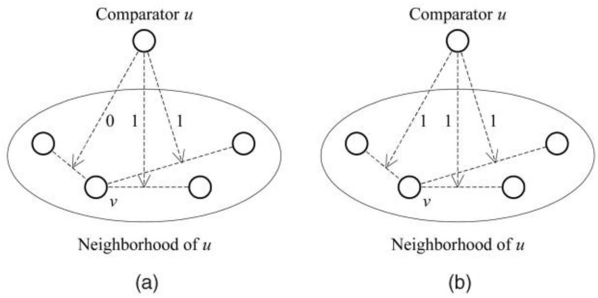

Fig 2: (a) v is an s-0 son of u and (b) v is an s-1 son of u

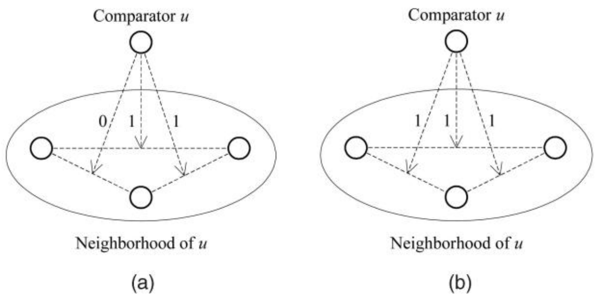

Fig 3: (a) u is an s-0 comparator and (b) u is an s-1 comparator

Phase 2: The s-conflicting nodes are defined and they are all faulty nodes. The s-0 predecessors of a node are defined which are all faulty if this node is faulty(Fig. 4). A node u is a s-conflicting if u has two s-0 sons v and w such that s(u; v,w)=1. u is an s-0 parent of v if there exists a node w such that s(u; v,w)=0 (Fig. 5).

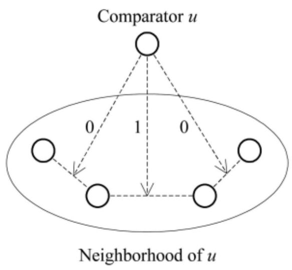

Fig 4: An s-conflicting node u.

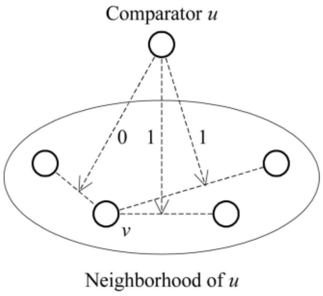

Fig 5: Node u is an s-0 parent of node v

Phase 3: All the nodes that have not been considered as faulty nodes in the previous two phases are taken into consideration. A test syndrome is induced from the original comparison syndrome and minimum AFS is calculated by using Sullivan's algorithm with time complexity O (t^3+m) time.

5. CONCLUSION

Thus, a time diagnosis algorithm O (n× Δ^3 × δ) has been proposed in this paper for diagnosis of n node MM diagnosable system which is much more efficient than the fastest known diagnosis algorithm with time complexity of O(n^5).

6. REFERENCES

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