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RELIABILITY ANALYSIS OF PROGRAMS IN THE DISTRIBUTED COMPUTING ENVIRONMENT

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ABSTRACT

Reliability is an important aspect in the distributed system studies and developments. Distributed processes are an instance of a running program, which are either concurrent or parallel. The distributed processes exhibit more dynamism. The processes also have peculiar characteristics like message passing, load sharing, fault tolerance, fault resilience and recovery. The program reliability analysis encounters a variety of distributed programs. These programs reside in several nodes. Each program has a composite structure. The functions and data are composite. In order to perform reliability analysis of distributed programs the programs are run in the distributed computing environment. Studying and analyzing the programs derive the configuration of the programs by reduction. The program code is read and analyzed by the analyzer program. The program flow is checked. Then the appropriate program flow graph is derived. It is then classified into one of serial configured, parallel configured program or mixed configured program. Once configured, the system can be evaluated perfectly. Reliability of such a system can be easily evaluated by taking into account the reliability of independent components.

Keywords: *Reliability, Serial Configuration, Parallel Configuration, Mixed Configuration, Program Reliability*.

1. INTRODUCTION

Distributed Computing System has become very popular for its transparency, fault tolerance, flexibility and reliability. One of the important issues in the design of the distributed computing system is the reliability performance. Program reliability analysis in the distributed computing environment is a key factor. Distributed computing environment is formulated using any generic topology and constraints. The reliability analyzer program analyzes the distributed computing system and detects the configuration of the network. The configuration is classified as one of series, parallel or mixed configurations. The reliability of the independent components is derived, using which the overall reliability is evaluated. If the reliability of any component is low it is removed, repaired and replaced.[1]

2. EXISTING DISTRIBUTED PROGRAM RELIABILITY ANALYSIS APPROACHES

Min-Sheng Lin et al. (1992) has approached to solve the reliability of distributed programs using fast reliability evaluation algorithm based on the generalized factoring theorem. The factorization is generally very time consuming and is not simple. Min-Sang Chang et al.(2000) tried to evaluate the reliability of star network. The star network is not a widely used one because of its centre point failure. Min-Sheng Lin et al. (2001) has constrained to the Ring topology and used a polynomial time algorithm for reliability analysis. This method is also time consuming and not much efficient. There are several other methods which are not cumbersome. To overcome the difficulties of the above said methods the reliability analysis is approached using the reduction by configuration and probabilistic method.[2][5][6][7]

3. SERIES CONFIGURATION

The simplest configuration to form a distributed system is the series configuration. Here the system consists of n units, which are connected in series. In the case of series configuration the functional modules are cascaded. The successful operation of the individual units is represented by X_1, X_2, $X_3 \ldots X_n$ and their respective probabilities by $P(X_1)$, $P(X_2) \ldots P(X_n)$. The system reliability is given

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by

$$P(S) = P(X_1 \wedge X_2 \wedge X_3 \wedge ... X_n)$$

In a series configuration, failure of any component results in failure of the entire system. When considering a complete system, it is better to arrange the components higher reliability-wise. Then the system performance is improved. The reliability of the series system is the probability that unit 1 succeeds, unit 2 succeeds and all of the other units in the system succeed. So, all n units must succeed for the system to succeed. In the case of independent events, the reliability is given by

$$R_S = P(X_1)P(X_2)P(X_3)...P(X_n)$$

3.1 Reliability of Intelligent WAP Application in Series Configuration

Wireless Application Protocol (WAP) was introduced by Wireless Application Forum, which was formed in 1997 by Ericsson, Motorola, Nokia and Unwired Planet. The basic objectives of the WAP Forum are to bring diverse Internet content into digital cellular phones and other wireless, mobile terminals. Moreover a protocol suite enabled global wireless communication across different wireless network technologies like Global System for Mobile Communications (GSM), Code Division Multiple Access (CDMA) and Universal Mobile Telecommunication System (UMTS). Therefore the WAP Forum is extending existing standards and technologies of the Internet wherever possible and is creating a framework for the development of contents and applications that scale across a very wide range of wireless bearer networks and wireless device types. The important properties of WAP are interoperability, scalability, efficiency, reliability and security. The WAP standard specifies two standards for wireless communication, which are end - to - end application protocol and application environment based on a browser.

The network side includes a server component that is capable of communicating with the WAP user agent. The request from the user is passed on to the application server via a gateway. The gateway is implemented using the telecom network or in a computer network or both. The reliability analyzer analyzes the WAP application and this analysis leads to a configuration of cascaded process. All the components should work properly for the efficient processing of WAP, since it is a serial process.

Intelligent WAP (IWAP) is a developed Active Server Pages (ASP) application, which interacts with a commercial database by using a combination of objects defined using an open database connectivity and by using Structured Query Language (SQL). The Open Database Connectivity (ODBC) interface forms a link with a Database Management System (DBMS), while the SQL constructs the message that is sent to the DBMS as requests to perform update, delete, and manipulate data. The client device is a small computing device by Nokia. It also aims at building an application with front-end and back-end business software and transfer the power onto small, mobile and wireless computing device. A Nokia WAP Toolkit (v1.2) and a device Nokia 6150 is used to interact with the application. A thin-client is used for front-end software that depends on the back-end software for much of the processing system. A database server is created and launched which open a connection between the DBMS and the application. It translates low-level equivalents of SQL statements sent by the application into messages that can be processed by the DBMS. It returns the data that conforms to the Java Database Connectivity (JDBC) specification to the ODBC /JDBC driver, returns error messages if exist, provides transaction management routines that conform to the ODBC /JDBC specification, closes the connection between DBMS and the application. The entire setup is as shown in figure 1. This application contains a main DBMS called *"scrap"* which contains five tables. This starts a database by creating a virtual directory for it in an Internet Information Server (IIS) server and also loading the index.asp file onto it. Then the run is automatic. A link is established to all the other transactions and controls. The sequence is as follows. First a user has to login after registration and is authenticated by a password. Next a purchaser auction asks for the purchaser name and password. The user is allowed to search for the items and if desired the auction sale is done and finally the user purchases the product. The user is informed about the auction amount and the delivery of the product takes place on payment of the value. Finally the user logs out with the product getting delivered to him.

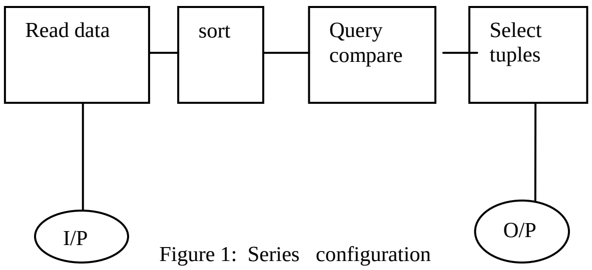

Figure 1: Series configuration

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3.2 Reliability Analysis of Series Configuration

With increasing Internet-based content, individual and personalized delivery of information has become crucial for users. With WAP, the mobile phone becomes an intelligent mobile terminal for tailor-made information by using a personalized WAP portal site. Intelligent WAP enables the users to browse the Internet content from the small computing devices. IWAP also addresses the issue of getting the data from the simulator clients, pass it on to the web server using gateways, which in turn invokes the services. These services interpret the data from the user agents, decode the request and take appropriate steps. It informs back the user agent for the response using the reverse route. The reliability of four functions in the application is varied and the overall reliability of the application is determined. The reliability of such series configuration varies with the reliability of the sub components. As the reliability of sub components increases the overall reliability increases.**[10]**

4. PARALLEL CONFIGURATION

Parallel configuration is one in which several combinations exists as sub-systems and the successful operation of the entire system depends on one of these sub-systems or elements. The reliability of the system can be calculated easily by considering the various failure conditions of the sub-systems. The successful operation of individual units is represented by X_1, X_2, $X_3 \ldots X_n$ and their respective probabilities by P (X_1), P (X_2), P (X_n). The System reliability is given by,

$$P(S) = \mathbf{P}\,(\mathbf{X}_1 \vee \mathbf{X}_2 \vee \mathbf{X}_3 \vee \ldots \mathbf{X}_n)$$

In a simple parallel system, at least one of the units must succeed for the system to succeed. Units in parallel are also referred to as redundant units. Redundancy is an important aspect of the system design. Providing redundancy is one of several methods of improving system reliability. It is widely used in the aerospace industry and generally used in mission critical systems. Other example applications include the RAID computer hard drive systems, nodes in a cluster environment and processors in a super computer environment. If any one of the n units fails, then a parallel configuration can tolerate that failure by bypassing it. It totally fails only if all the n units fail. That is, if unit 1 succeeds or unit 2 succeeds or any of the n units succeeds, then the system succeeds.

4.1 Reliability Analysis of Parallel Configuration

The parallel configuration is tested with the parallel shortest path application. A typical parallel shortest path computation application reads a graph G (V, E) and constructs the adjacency list or matrix for the given graph. Then the adjacency list or matrix is decomposed into components and distributed to various workers typically four in number, by a server process. The workers use shortest path algorithm, to derive the shortest path of the given graph. The reliabilities of the processes are varied and the parallel reliability analysis is carried out. The principle behind parallel shortest path determination is decomposition of the adjacency matrix into sub matrices and the processing of the sub matrices using an algorithm in parallel which detects the shortest path. The algorithm compares and checks if the distance due to direct path is minimal or due to the indirect paths is minimal and outputs the set of intermediate nodes lying on the shortest path. Finally the results of sub matrices are integrated and the all pair shortest paths are determined. Here as part of reliability analysis, faults are simulated. When a particular component fails, the overall system does not fail. The work of the failed node is distributed to the other node, after it finishes its first round of specified work. In between if the failed component is repaired and added, it can resume the work.[9]

As part of analysis a bipartite graph is considered as shown in figure 2 and the adjacency matrix in Table 1.

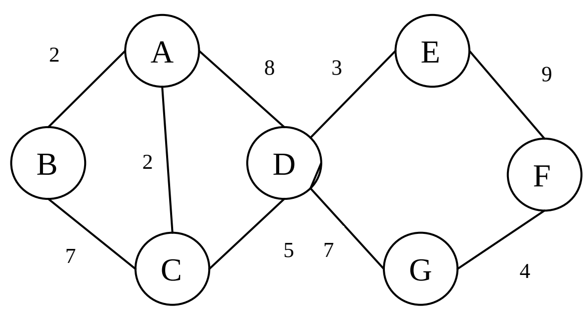

Figure 2: A sample bipartite graph

The shortest path of the given bipartite graph is computed. The number of nodes is varied and the computation time and the communication time is recorded and it is plotted and is shown in figure 3.

5. MIXED CONFIGURATION

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The mixed configuration is the combination of parallel and series configurations. There are various mixed configurations. They are two-element model, three-element model, four- element model respectively. This topic addresses a typical four-

	A	B	C	D	E	F	G
A	0	2	8	2	999	999	999
B	2	0	7	999	999	999	999
C	2	7	0	5	999	999	999
D	8	999	5	0	3	999	7
E	999	999	999	3	0	9	999
F	999	999	999	999	9	0	4
G	999	999	999	7	999	4	0

Table 1: Adjacency matrix

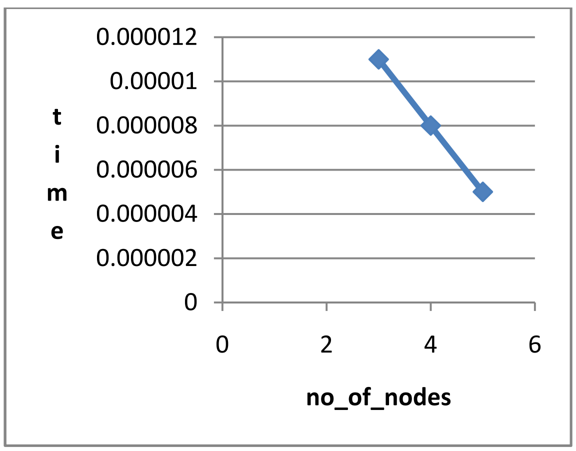

Figure 3: Shortest path

element configuration and its extensions. Let X_1, X_2, $X_3 \ldots X_n$ be the units and their respective probabilities are represented by P (X_1), P (X_2) …P (X_n). These represent the successful operation of the individual units. The system reliability is given by,

$$P(S) = P(X_1 \vee X_2 \vee X_3 \wedge \ldots \wedge X_n)$$

The mixed configuration is an efficient configuration. This consists of series units, in which all the units must be reliable and parallel units, where any one unit if it works is sufficient. Both the series and parallel unit should work properly for the entire unit to be operational. In many computer applications object recognition is the most important issue.

5.1 Reliability Analysis of Object Recognition Process

The recent technological advancements in distributed computing have paved the way for solving object recognition problem. Object recognition ranges from recognizing single static object onto a scene to a complex multiple movable objects in a dynamic environment. It aims at recognizing the object from the scene represented by an image. The problem is solved in a distributed way. First the leader is elected by the HS leader election algorithm. Then the leader passes the message to the corresponding participating nodes about the object recognition. Each node receives the message and acts accordingly. The input image taken for recognition is decomposed into segments and is distributed to the nodes for recognition. Here for scene recognition WALTZ algorithm is used. Then the segments are integrated for recognizing the final object and the leader displays the recognized scene.

A DCE can be assimilated as consisting of various sites. The nodes at different sites interact through communication network. The data set, databases and objects migrate across the heterogeneous networking environment and are sharable. Each process can run redundantly or independently on one or more system and can share files residing at other sites. The DCE considered here is built around the clients and servers. The TCP/IP is used to establish communication between the servers and clients. The servers are created using server sockets. Then they are bind to the well-known addresses listening for the client request. The clients communicate with the server using client sockets. The nodes can be connected to form a ring network. A ring network is created using the multiple sockets. The first step is to elect the leader in DCE. The leader is elected using the Hirschberg and Sinclair (HS) Algorithm using the bi-directional message passing strategy.

Many distributed algorithms require one process to act as the coordinator, initiator, and sequencer or otherwise perform a special role. In general it does not matter which process takes on this special responsibility, but for one process, which has to undertake this. Every process is assigned with a unique identifier and every process knows the unique identifier of every other process. The

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Hirschberg and Sinclair algorithm named after the persons is the efficient algorithm for the leader election, in terms of the number of messages. The process with the maximum unique identifier is elected as the leader. This algorithm is chosen for its message complexity, which is O (n log n). The object recognition is carried out using the Waltz algorithm.

Object recognition using WALTZ Algorithm

1. Start scanning the segment from the topmost row.
2. Check if a vertex could be determined by finding the deviation from the back ground.
3. Label the vertex.
4. Next the other vertices are determined in order in the entire image segment.
5. These vertices are integrated to yield an object part.
6. This is repeated for other segments in parallel in other processors.
7. All the segments are finally integrated and the object is recognized.[3]

A reliability analysis is carried out by increasing both the number of nodes and the size of the image. The scalability yields a reliability of 1. Faults are simulated and reliability is the probability between 0 and 1. The node is assumed to be non-faulty. But processes failure is simulated. . In the case of process failure depending upon the condition of the process the probability is distributed. The reliability analysis of mixed configuration is carried out by varying the image size. Quantitative analysis is performed. If the time taken is finite, then the unit is reliable. If the time taken is infinite the system is not reliable. The time taken is observed and is tabulated. From the experimentation it is observed that even for composite images the reliability of the system is high. It is inferred from the analysis that as the image size grows the time taken is slightly increasing. Hence, the system is efficient in processing larger images. The reliability analysis of mixed configuration in shown in figure 4.

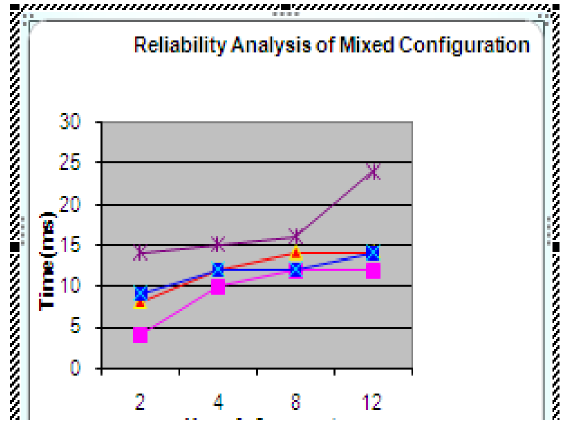

Figure 4: Reliability analysis of mixed configuration

6. CONCLUSION

Reliability analysis is one of the important aspect in the distributed computing environment. The reliability analysis of distributed programs is encountered as discussed above. The distributed programs are very composite and hence the reliability analysis is approached using reduction by configuration and probability. Three program specific configurations are used for series, parallel and mixed. The programs are reduced to one of these. It is detected experimentally that the mixed and parallel configured programs are more reliable than series configured ones.

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