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DESIGN AND SIMULATION OF A RELIABLE DISTRIBUTED SYSTEM BASED ON FAULT TREE ANALYSIS

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ABSTRACT:

Distributed Systems is the study of geographically separated processors, connected to one another with the help of intermediate devices such as routers and/or switches. Simulation provides an insight into the behavior of these distant apart systems. The internal details like designing, configuring and maintaining a reliable distributed system through protocols that include routing, switching, etc is well understood by this paper. The paper describes how the design of a distributed system be built on a Network Designer while using leased line, serial ports and Ethernet technologies. Further, these designs have been simulated on a Network Simulator with the use of routing protocols. For this scheme to be implemented successfully different equipment like routers, switches, Ethernet and serial connection, PCs, etc are used and techniques like IP addressing schemes and RIP are implemented. Further, the developed system is decomposed to form a Fault tree and its reliability is evaluated with the help of Fault tree Analysis.

Keywords: ***Reliable, Router, Switches, Ethernet, Serial, IP Address, Routing Information Protocol, Clock Rate, System Reliability, Fault Tree Analysis.***

[I] INTRODUCTION

The distributed computing system is designed to complete certain computing tasks given in a networked environment [1], [2]. Distributed systems provide cost effective means for resource sharing and extensibility, and obtain potential increases in performance, reliability, and fault tolerance [3], [4], [5], [6]. Such systems have gained popularity due to the low-cost processors in the recent years. A common Distributed System is made up of several hosts connected by a network where computing functions are shared among the hosts [7]. Further, these networks are mutually connected with one another with the help of routers and/or switches. Installing and configuring the router/switch is very cumbersome and highly technical task [8], [9], a very small mistake in the configuration process can lead to blunders in the network and can affect the reliability as well as the availability of distributed resources.

Raghavendra et. al. [10] described the reliability of the distributed computing system as dependent not only on reliability of a communication network but also on the reliability of the processing nodes and distribution of the resources in the network where as according to Shatz et al [11], when the system hardware configuration is fixed the system reliability mainly depends on the allocation of resources.

Simulation of a real distributed system helps in understanding the behaviors of it. It helps the learner to enhance analytical and design skills by providing safe and reliable environment for making practice [12]. The present piece of research is an attempt to design and establish a reliable Distributed System with multiple PC's, routers and switches, and to make them communicate with 100% reliability and 0% data or packet loss.

Fault tree analysis is "To design the system that work correctly we often need to understand and correct how they can go wrong" [13]. Fault tree analysis identifies, models and evaluates the unique inter relationship of events leading to failure, undesired events and/or unintended states. In the beginning of 21st Century, FTA methodology was adopted for high quality fault free commercial codes, robotics and software Industry. The same technique is applied here to evaluate the reliability of the distributed system.

The rest of the paper is organized as follows. In section II, we discuss in brief what concept we wish to implement with the means of this paper. Section III is the computational algorithm for how the system will be simulated to make the data transfer reliable. Section IV is a sample problem instance of a real distributed system, Section V is a detailed description of Fault Tree Analysis of the configured Distributed System and finally we conclude the research work in the Section VI with the future prospects of the concept.

[II] PROBLEM STATEMENT

Let the given system consists of a set of processors interconnected with one another by the means of routers and switches. Individual processors can be connected to one another (using a switch) in any random manner and in any form of network topology, and these small-distributed networks can further be connected to a different network (using a router) and so on. i.e. whatever be the complexity of the distributed system, we have to come out with an optimal algorithm to design and simulate the system so as to make the communication between each communicating node as reliable. Further, to compute the authenticity of the system, the system goes under Fault tree analysis to evaluate the reliability of the distributed system.

[III] PROPOSED METHOD

Once the distributed environment is established according to the choice of the user, its design and simulation part begins. The reliability of the system exists in safe assignment of IP addresses, synchronization of clock rate and definition of default gateways. Authors explain the complete design and simulation process with the help of a three – phase – protocol.

Phase 1: Configuration of routers.

Phase 2: Applying the routing information protocol.

Phase 3: Assignment of IP address and default gateway for the distributed processors.

The computational algorithm for the design and simulation of a distributed system with 'n' processors connected with the help of 'm' routers is as follows:

3.1.Algorithm:

Step 1: Input i, j, m, n.
Step 2: Enable the network.
Step 3: Configure the connections.
Step 4: For i =1 to m do
  Begin
    4.1 Assign IP address for s0 port.
    4.2 Synchronize the clock rate.
    4.3 Assign IP address for e0 port.
    4.4 Assign IP address for s1 port.
    4.5 Synchronize the clock rate.
  End
Step 5: Run the routing protocol between the networks (say RIP).
Step 6: For j =1 to n do
  Begin
    6.1 Assign IP address to the PCj.

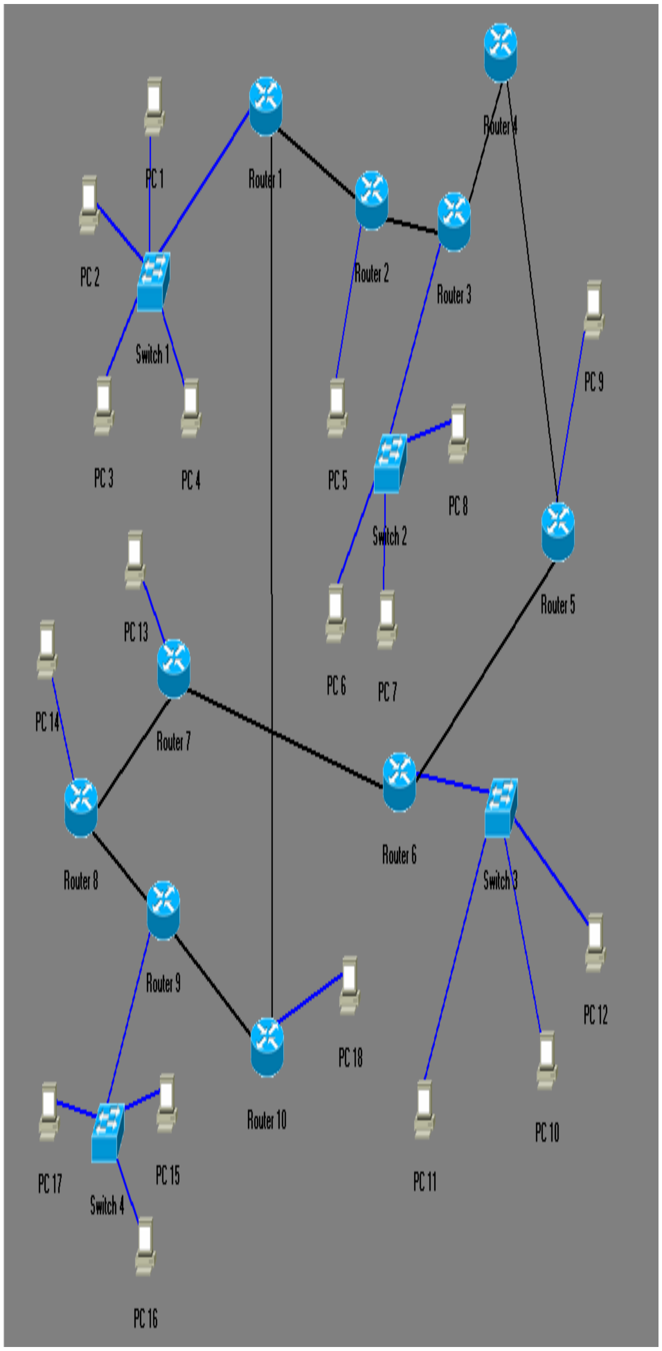
6.2 Assign Subnet mask.
6.3 Define default gateway.
End
Step 7: ping a PC from any other PC in the network.
Step 8: If (Loss = 0%) OR (Packets sent = Packets received)
Print result and exit.
Else
Go to step 4.

Having gone through, three phase protocol, the outcome is a complex distributed system whose nodes are communicating with one another in reliable manner. Now to check the reliability of these communicating nodes, the distributed system undergoes fault tree analysis to compute how reliable configured distributed system is. If the Output Reliability comes above 0.8, we can say that the system is reliable.

[IV] DISCUSSION OF THE ALGORITHM WITH PROBLEM INSTANCE

Consider the following distributed system with multiple processors connected with one another with the help of switches and routers. In the presented problem (Fig. 1), we have used 2501 series router that contains an Ethernet port and two serial ports and a 3550 series switch that contains twelve fast Ethernet ports and two Gigabit Ethernet ports. All the processors are connected with the help of these routers and switches to form this distributed environment.

Fig.1: A sample distributed system



As per the algorithm, the design and simulation part is done with three – phase – protocol. Here is the detailed implementation of the algorithm.

In the first phase, IP addresses are assigned to each of the router for its distinct serial and Ethernet ports.

4.1. Phase 1: Configuring the routers:

Router Name	Port	IP Address	Subnet Mask
Router 1	e0	10.0.0.1	255.0.0.0
	s0	11.0.0.1	255.0.0.0
	s1	28.0.0.1	255.0.0.0
Router 2	e0	12.0.0.1	255.0.0.0
	s0	11.0.0.2	255.0.0.0
	s1	13.0.0.1	255.0.0.0
Router 3	e0	14.0.0.1	255.0.0.0
	s0	13.0.0.2	255.0.0.0
	s1	15.0.0.1	255.0.0.0
Router 4	s0	15.0.0.2	255.0.0.0
	s1	16.0.0.1	255.0.0.0
Router 5	e0	17.0.0.1	255.0.0.0
	s0	16.0.0.2	255.0.0.0
	s1	18.0.0.1	255.0.0.0
Router 6	e0	19.0.0.1	255.0.0.0
	s0	18.0.0.2	255.0.0.0
	s1	20.0.0.1	255.0.0.0
Router 7	e0	21.0.0.1	255.0.0.0
	s0	20.0.0.2	255.0.0.0
	s1	22.0.0.1	255.0.0.0
Router 8	e0	23.0.0.1	255.0.0.0
	s0	22.0.0.2	255.0.0.0
	s1	24.0.0.1	255.0.0.0
Router 9	e0	25.0.0.1	255.0.0.0
	s0	24.0.0.2	255.0.0.0
	s1	26.0.0.1	255.0.0.0
Router 10	e0	27.0.0.1	255.0.0.0
	s0	26.0.0.2	255.0.0.0
	s1	28.0.0.2	255.0.0.0

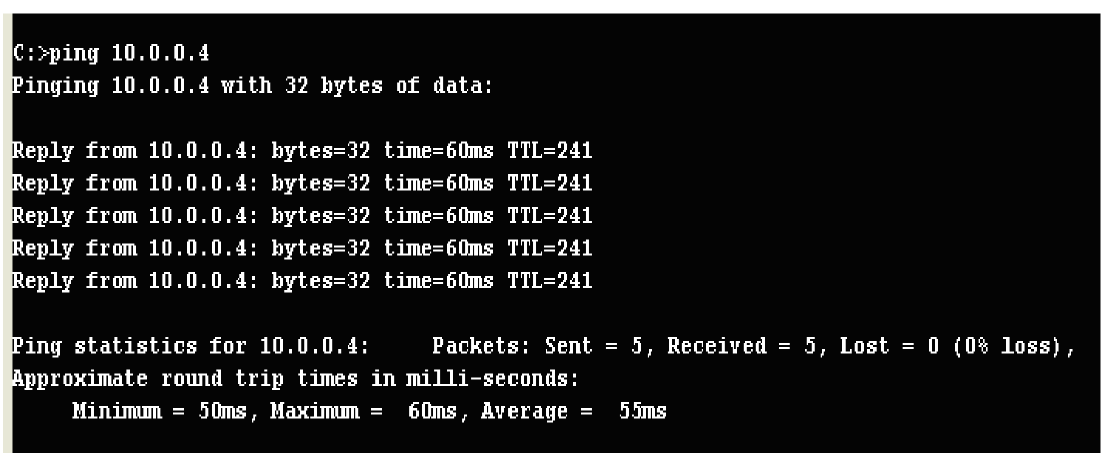
4.2. Phase 2:

Followed by the phase 1 of the algorithm, the routing information protocol is fired in between the routers. As soon as the IP addresses have been assigned within two consecutive routers, the RIP is fired. The process repeats itself till all the routers have been configured.

4.3. Phase 3: Configuring the distributed processors:

Processor	IP Address	Subnet Mask	Default Gateway
PC 1	10.0.0.2	255.0.0.0	10.0.0.1
PC 2	10.0.0.3	255.0.0.0	10.0.0.1
PC 3	10.0.0.4	255.0.0.0	10.0.0.1
PC 4	10.0.0.5	255.0.0.0	10.0.0.1
PC 5	12.0.0.2	255.0.0.0	12.0.0.1
PC 6	14.0.0.2	255.0.0.0	14.0.0.1
PC 7	14.0.0.3	255.0.0.0	14.0.0.1
PC 8	14.0.0.4	255.0.0.0	14.0.0.1
PC 9	17.0.0.2	255.0.0.0	17.0.0.1
PC 10	19.0.0.2	255.0.0.0	19.0.0.1
PC 11	19.0.0.3	255.0.0.0	19.0.0.1
PC 12	19.0.0.4	255.0.0.0	19.0.0.1
PC 13	21.0.0.2	255.0.0.0	21.0.0.1
PC 14	23.0.0.2	255.0.0.0	23.0.0.1
PC 15	25.0.0.2	255.0.0.0	25.0.0.1
PC 16	25.0.0.3	255.0.0.0	25.0.0.1
PC 17	25.0.0.4	255.0.0.0	25.0.0.1
PC 18	27.0.0.2	255.0.0.0	27.0.0.1

After successful completion of the three phases, the output that we have is a reliable distributed system. To verify the deploy ability of the algorithm, one can ping any processor from any other one in the complete distributed system, its output put be as follows (Fig. 2):



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C:>ping 10.0.0.4
Pinging 10.0.0.4 with 32 bytes of data:

Reply from 10.0.0.4: bytes=32 time=60ms TTL=241
Reply from 10.0.0.4: bytes=32 time=60ms TTL=241
Reply from 10.0.0.4: bytes=32 time=60ms TTL=241
Reply from 10.0.0.4: bytes=32 time=60ms TTL=241
Reply from 10.0.0.4: bytes=32 time=60ms TTL=241

Ping statistics for 10.0.0.4:     Packets: Sent = 5, Received = 5, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
     Minimum = 50ms, Maximum =  60ms, Average =  55ms
```

Fig. 2: Reply from PC16 to PC3

[V] FAULT TREE ANALYSIS

Risk can be analyzed in one of two basic ways: inductively or deductively, that is either bottom-up or top-down. In a deductive analysis a system failure is postulated. The analyst then works backwards to deduce what combinations of events could have occurred for the failure to have taken place (a detective solving a crime is thinking deductively). Fault tree analysis is deductive. An inductive analysis works in the other direction. A single failure, such as a pump stopping or a valve closing at the wrong time, is postulated. The inductive analysis then determines what impact the item failure could have on the overall system performance. Event tree analysis is inductive [14].

When a system is formed from elements and units connected in parallel, series or mixed configurations, a suitable method of calculating its reliability becomes necessary[15]. Fault tree analysis is unique ways to identify how a system may fail to function a specified task and how will it reflect to the reliability of a system.

The fault tree can easily be constructed of the above-distributed system as all the nodes are connected in series. (Fig. 3)

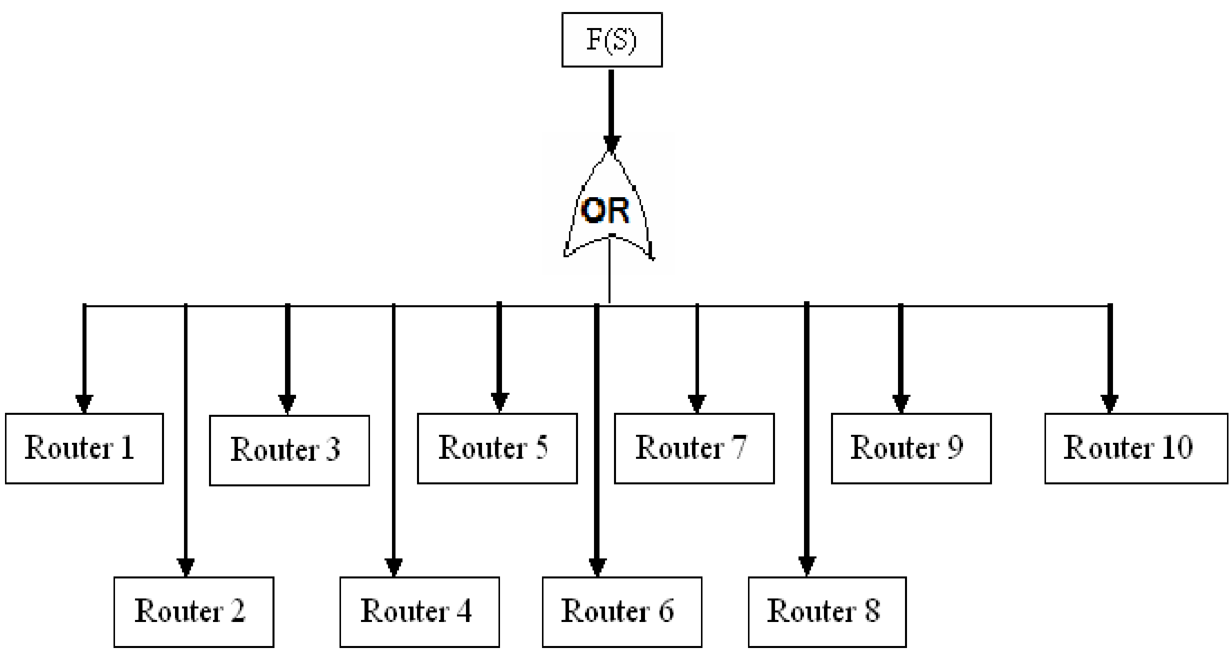

Fig. 3 Fault Tree of Distributed Systems

After having constructed a fault tree for the given distributed system, the next step is calculation of reliability of the system. To do this, let us first assume the probability of failure of the components i.e. routers. Suppose the failure probability of different routers is given as:

Router 1 P(F1)	= 0.001
Router 2 P(F2)	= 0.005
Router 3 P(F3)	= 0.007
Router 4 P(F4)	= 0.002
Router 5 P(F5)	= 0.006
Router 6 P(F6)	= 0.004
Router 7 P(F7)	= 0.009
Router 8 P(F8)	= 0.003

Router 9 P(F9) = 0.008
Router 10 P(F10) = 0.006

Now, if failure of the complete distributed system is given by F(S), then,

F(S) =P [(F1) OR (F2) OR F(3) OR F(4) OR F(5) OR F(6) OR F(7) OR F(8) OR F(9) OR F(10)]
= P[(F1 OR F2)] OR P[F(3) OR F(4) OR F(5) OR F(6) OR F(7) OR F(8) OR F(9) OR F(10)]
= [P(F1) + P(F2) – P(F1F2)] OR P[F(3) OR F(4) OR F(5) OR F(6) OR F(7) OR F(8) OR F(9) OR F(10)]
= [P(F1) + P(F2) – P(F1F2)] OR [P(F3) + P(F4) – P(F3F4)] OR [P(F5) + P(F6) – P(F5F6)] OR [P(F7) + P(F8) – P(F7F8)] OR [P(F9) + P(F10) – P(F9F10)]
= (0.04161)

Now, as per the definition of Reliability [13], Reliability of the distributed System R(S) is,

R(S) = 1 – F(S)
= 1 – 0.04161
R(S) = 0.09584

Hence, the reliability of the configured Distributed System comes out to be 0.958.

[VI] CONCLUSION

A distributed computing environment has become necessary for all sort of distant communications, but from experience, we learned that it is not so easy to create, setup and manage even a small area network. It requires a lot of efforts to keep a distributed system up and running in reliable manner. Simulation has become a very useful tool in many fields of everyday life and it plays a very important role in education and science. It is not possible to actually design and implement an actual distributed system or even a small project of building such a system, since it requires a huge infrastructure to involve. Simulations provide us with the capability to understand and get a good feel about the things without actual risk involved in the given situation. Our paper ends up with discussing all these details regarding how to establish a reliable connection amongst loosely coupled distributed processors.

Further, different categories of routers and switches can be used in the establishment of different categories of distributed systems, depending upon the user requirements. Also, different routing protocols such as IGRP, EIGRP, OSPF, BGP etc. can be applied between the connections of the routers depending upon the requirements.

Once, the distributed system is configured, we assumed it to be comprised of sub components i.e. routes & decomposed the above system in the form of a fault tree. Assuming the probability of failure of the routers, we then calculated the probability of failure of the routers based on the concept of Fault tree analysis and finally we succeed in finding out the reliability of the Distributed System that comes out to be 0.9584.

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