Wide Area Network's Reliability Redundancy Design Using Simulation

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***Abstract*—Reliability is the main characteristic to evaluate the performance of WAN's. The devices used in the network and their availability in the market make the network to give services without interruptions. Redundant network components are installed for continuous functioning of network and to reduce the service interruptions. A designer has to consider the economic views of the organization in designing a system with high reliability. To optimize the number of redundant components in WAN environment cost and material resources are utilized for optimum use and for maximum reliability. Though the component reliabilities at various stages of the system are estimated, reliabilities of the server and routers are assumed to be reliable in nature but the circuit continuously changes due to active redundancy and components follow stochastic distributions. A software package is developed with stochastic redundancy technique for "Reliability Optimization using Monte-Carlo simulation".**

Keywords-Wide area networks, Monte-carlo simulation, Stochastic programming, Network Reliability

I. INTRODUCTION

Reliability of computer networks is very essential in critical areas like military. Redundancy is the provision of alternative means or parallel paths in a system for accomplishing a given task that all means must fail before causing the system failure. Application of redundancy in the system design is found in almost all types of systems due to numerous advantages over other methods of improving system reliability. The important ones are: 1) Any desired level of reliability can be achieved. 2) Design through redundancy needs comparatively less skill on the part of the designer. 3) It provides quick solution before establishing the network connection. 4) This method can be employed in the event of failure of all other methods.

If a quick Google search is any indication, then security and cost are the top concerns regarding LAN purchases, and reliability is an afterthought. Searching "Wireless network" and "security" garners 4,740,000 hits. "Wireless network" and "cost" – 4,150,000 hits. But Goggling "wireless network" and "reliability" results in a comparatively paltry 931,000 hits – approximately 80% fewer. This would seem to indicate that while IT managers are considering Wireless LANs as a feasible alternative networking option, unfortunately, many don't seems to be considering the reliability of network. Network security is extremely important, as evidenced by myriad headlines about hackers stealing credit card numbers. And yes, of course the price of network equipment should be of vital concern, especially in the current economy. But nothing is more important than making sure the network actually runs! And so when a company is considering a new LAN, the first question should be, "Is it reliable?" and the second question should be, "How can I make sure it's ALWAYS reliable?".

There exists Various forms of redundancy – active(hot) redundancy, standby (cold) redundancy, warm redundancy, component redundancy, system redundancy, hierarchical redundancy etc. and can be employed in a system, depending on the feasibility. One has to select a suitable form considering such factors as the type of components, type of systems, reliability requirements, resources Optimization is an act of obtaining the best results under given circumstances. In design, construction and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decisions is to either minimize the effort required or to maximize the required benefit.

A. Cost

Ethernet cables, hubs or switches are very inexpensive. Some connection sharing software packages, like ICS, are free; some costs a nominal burden. Broadband routers and Servers cost more, but these are optional components of a wired LAN, and their higher cost is offset by the benefit of easier installation and built-in security features.

B. Reliability

Ethernet cables, hubs or switches are extremely reliable, mainly because manufacturers have been continually improving Ethernet technology over several decades. Loose cables likely remain the single most common and annoying source of failure in a wired network. When installing a wired LAN or moving any of the components later, be sure to carefully check the cable connections.

II. NETWORK DESCRIPTION

The WAN comprises of two networks namely LAN1 and LAN2. LAN1 comprises of 16 systems (only 3 are shown in fig1.) connected to SW0. The SW0 is connected to Router R1 and then to the Internet Server. LAN1 also consists of another switch SW1 to which 16 systems can be connected (only 3 are shown in fig.1). LAN2 is also connected in the similar configuration. The following network assumptions are made before the system is reliability is calculated.

As the reliabilities of switches are very high as well as doesn't cost much ten switches are assumed to be connected in parallel with fixed reliability of 0.7 for every switch at each point in the network. The reliabilities of routers and servers are subjected to stochastic distributions.

A. Budget

The maximum budget allocated for the network under consideration is Rs. 10,00,000/-. The estimated cost of the server is Rs. 1, 50,000/-, each of the router costs Rs. 1, 00,000/-, cost of each switch is Rs. 3,000/-.

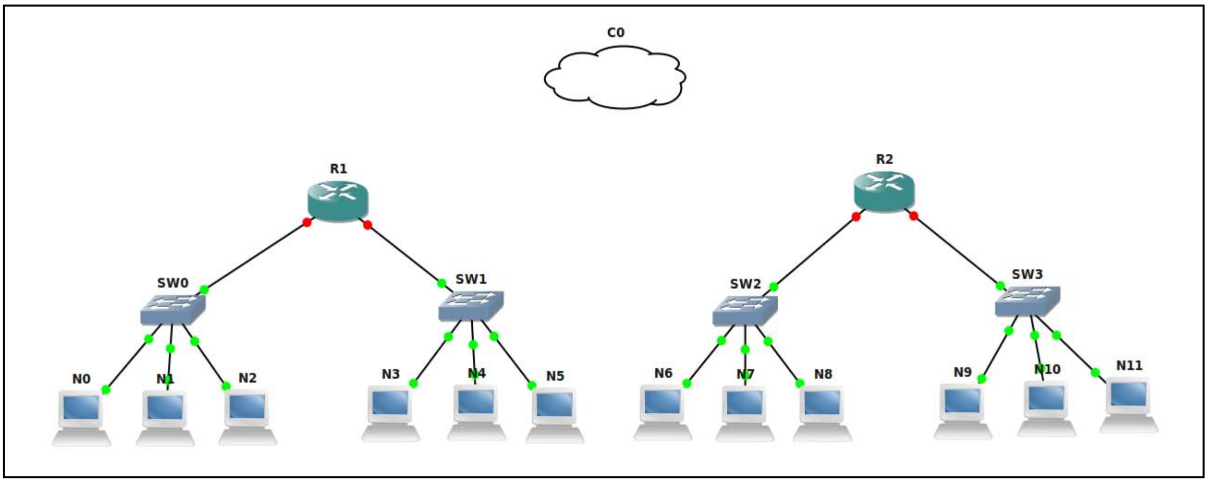

Figure 1. Wide Area Network considered for simulation

B. 2.2 Notations & Equations

R1 = Server

R2 = Router 1

R3 = Router 2

R4 = Switch 1

R5 = Switch 2

R6 = Switch 3

R7 = Switch 4

This process is repeated for different component combinations of the system. If there are ‘n’ stage Simulationsand maximum of ‘m’ components in each stage, the total number of component combinations achieved is m^n. So totally **n**x(**m x n**) random numbers are generated. The cost constraint is also taken into consideration. The component combination of the system with highest reliability and satisfying the cost constraint is considered as the optimal solution after first simulation run

C. Equivalent Network

The network under consideration can be converted into an equivalent network for easy understanding of the network function using the redundancy block diagram reduction technique is shown in fig 2.

After thorough inquiries made the following costs are assumed for the components used in the network

Cost of Internet server - Rs. 1, 50,000/-

Cost of Router - Rs. 1, 00,000/-

Cost of Switch - Rs. 3,000/ -

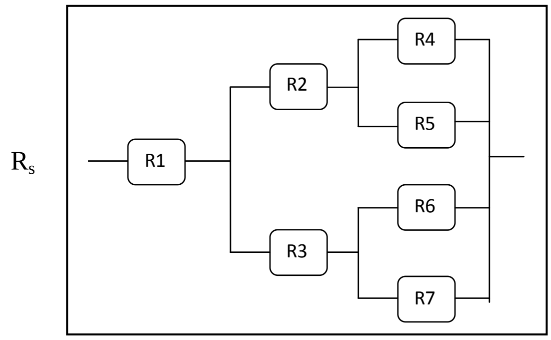

Figure 2. Equivalent Network of the network under consideration

$$R_i = 1 - (1 - r_i)^{n_i} \quad (1)$$

Where R_i – Reliability of i^{th} stage with n_i redundant components and r_i – reliability of each component at i^{th} stage. Reliability of the branch 1 consisting of components R_4, R_5, and R_2 is calculated by

$$B_1 = [1 - (1 - R_4)(1 - R_5)]R_2$$

Similarly for branch 2 comprising of components of R6, R7 and R3 is calculated by

$$B_2 = [1 - (1 - R_6)(1 - R_7)]R_3 \quad (3)$$

The reliability of the network is thus evaluated to be

$$R_s = [1 - (1 - B_1)(1 - B_2)]R_1 \quad (4)$$

Max. Reliability of the system

$$R_s = N_1C_1 + N_2C_2 + N_3C_3 + 10(C_4 + C_5 + C_6 + C_7) \leq 1000000 \quad (5)$$

$$R_s = N_4 + N_5 + N_6 + N_7 \quad (6)$$

$$N_i \geq 1 \quad (7)$$

III. SIMULATION

- "Simulation is a quantitative technique developed for studying alternative courses of action by building a model of that system and then conducting a series of repeated trial and error experiments to predict the behavior of the system over a period of time."
- In situations where the mathematical formulation of the problem is not feasible, simulation technique is used by representing reality through a model that will respond in the same manner as in a real-life situation. In simulation, a certain type of mathematical model is formulated which describes the real system's operation. The WAN is divided into various segments and their inter-relationships with some predictable behavior in terms of probability distributions for each of the possible stages of the system are studied. The simulation experiment is then performed on the model of the system.
- The following are the reasons for adopting simulation in place of other known mathematical techniques
- It can handle complex systems that require the modeling of interacting stochastic variants. These are the means for modeling empirical or theoretical distribution of real-world parameters.
- Simulation may be the only method available because it is difficult to observe the actual environment.

- Actual observations of a system may be too expensive.
- There may not be sufficient time to allow the system to operate extensively.
- Simulation enables one to study dynamically systems either in real time, compressed time or expanded time.
- Simulation can be used to experiment with new situations about which we have little or no information, so as to prepare for what may happen.

TABLE I. THE FIRST AND LAST TWENTY RESULTS OF THE SIMULLATION

S.No	**R1**		**R2**		**R3**		**R4**	**R5**	**R6**	**R7**	**N1**	**N2**	**N3**	**N4**	**N5**	**N6**	**N7**	**System Cost**	**System Reliability**
1	69	0.96	98	0.95	53	0.92	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9612986293223212
2	63	0.96	49	0.92	55	0.92	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9538559999950728
3	5	0.95	40	0.92	4	0.9	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9423999999945676
4	98	0.97	94	0.95	12	0.9	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9651499999952649
5	33	0.95	46	0.92	29	0.9	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9423999999945676
6	56	0.96	14	0.9	70	0.92	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9523199999945103
7	19	0.95	80	0.92	22	0.9	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9423999999945676
8	7	0.95	64	0.92	78	0.92	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9439199999951241
9	13	0.95	13	0.9	13	0.9	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9404999999940375
10	67	0.96	2	0.9	99	0.95	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9551999999953137
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90	63	0.96	45	0.92	74	0.92	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9538559999950728
91	56	0.96	75	0.92	92	0.95	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9561599999959162
92	3	0.95	16	0.9	74	0.92	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9423999999945676
93	10	0.95	22	0.9	29	0.9	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9404999999940375
94	28	0.95	47	0.92	40	0.92	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9439199999951241
95	4	0.95	67	0.92	93	0.95	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9461999999959587
96	70	0.96	22	0.9	79	0.92	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9523199999945103
97	87	0.96	61	0.92	58	0.92	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9538559999950728
98	96	0.97	8	0.9	67	0.92	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9622399999944532
99	89	0.96	53	0.92	6	0.9	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9523199999945103
100	32	0.95	84	0.92	23	0.9	0.7	0.7	0.7	0.7	1	1	1	10	10	10	10	470000.0	0.9423999999945676

IV. SOLUTION THROUGH SIMULATION APPROACH

This process starts with assigning 100 random numbers (0.00 to 0.99) to each of these probability distributions. This is done in tabular column shown below. The cumulative probabilities and range of random numbers allotted are calculated from the input data. Then a random number between 0.00 and 0.99 is generated for each stage each component, it is compared with each range of random numbers specified for each stage and reliability, corresponding to the appropriate range of random numbers in which the random number falls, is assigned to the stage as its reliability. Generation of random numbers is done through a probabilistic mechanism. Most computer facilities include a generator of this kind in their software libraries. If there is 'n' number of stages in the system, 'n' random numbers are to be generated and stage reliability of stages R_1, R_2, R_3, ... R_n is calculated.

With the discussion made earlier as the switches failure rate is very much less and as they are more reliable and of less cost, 10 units of redundancy is maintained at 4^{th}, 5^{th}, 6^{th} and 7^{th} components. Costing much 10 units was assumed to be placed in parallel to each component in the network. As we are not required to replace the components as and when they fail we will place all of them initially in the network.

The routers no. of components that can be placed in parallel assuming each of other components in the network is 6 this assumption holds even for the other router too. Coming to the servers components the minimum no. that can be placed in parallel are 4 maintaining the min. at each of the components.

Conducting simulation at once may not yield optimal solution, since each simulation run is like a single experiment conducted under a given set of conditions,. So for effectiveness, the component combination that has occurred as the optimal solution for more number of times is taken as the final optimal solution after finite simulation runs. Hence the simulation was run 100 times of which the first and last twenty results were shown in table

For all the possible combinations within the specified budget constraints the average system reliabilities are shown in table 2. Finally the most economical and reliable combination can be selected from table 2.

TABLE II. AVERAGE SYSTEM RELIABILITIES FOR ALL POSSIBLE COMBINATIONS OF COMPONENTS

Combination	N1	N2	N3	System Cost	Average System Reliability for the combination through simulation
1	1	1	1	470000	0.9407069799949817
2	1	1	2	570000	0.9465848373971455
3	1	1	3	670000	0.9477523054892673
4	1	1	4	770000	0.9477951910270778
5	1	1	5	870000	0.9471996404710227
6	1	1	6	970000	0.9461999674423198
7	1	2	1	570000	0.9459628789971438
8	1	2	2	670000	0.9466546932355472
9	1	2	3	770000	0.9476962264788633
10	1	2	4	870000	0.9477996518973555
11	1	2	5	970000	0.9467999681544745
12	1	3	1	670000	0.9465498634252261
13	1	3	2	770000	0.9475959550070736
14	1	3	3	870000	0.947599664783093
15	1	3	4	970000	0.9468999686542897
16	1	4	1	770000	0.9470954659645563
17	1	4	2	870000	0.9480996139899383
18	1	4	3	970000	0.9481999686668543
19	1	5	1	870000	0.947999639849529
20	1	5	2	970000	0.946899964241348
21	1	6	1	970000	0.946699961165481
22	2	1	1	620000	0.9812958350947294
23	2	1	2	720000	0.9876053312549752
24	2	1	3	820000	0.9881141183482326
25	2	1	4	920000	0.9881073474874789
26	2	2	1	720000	0.987581438615
27	2	2	2	820000	0.9880784813145845
28	2	2	3	920000	0.9881604047235665
29	2	3	1	820000	0.9880904506512209
30	2	3	2	920000	0.9880820815920711
31	2	4	1	920000	0.9880946323925892
32	3	1	1	770000	0.9831148038197565
33	3	1	2	870000	0.9893381975144827
34	3	1	3	970000	0.9898638560320281
35	3	2	1	870000	0.9893050621031633
36	3	2	2	970000	0.9898780525710668
37	3	3	1	970000	0.9898681323759462
38	4	1	1	920000	0.9830801532830274

We can find the optimum reliability from the table for the network under consideration with the max. Number of permissible components in each of the stage with in the allocated budget is equal to 0.9898780525710668.

Optimum reliable combination is found in the iteration number 36 with 3 servers, 2 routers in branch A and 2 routers in branch B. The total cost of the system is equal to .970000/-

For the best reliability of the network the cost of Server components in the network is equal to cost of the server X 3, Cost of router1 components in branch A is equal to cost of the router X 2 and cost of router2 components in branch B is equal to cost of the router X 2.

It is assumed that, the Total No. of redundant components of switch type at each of the switch location in stage 4 equal to 10. Because these components are fixed at the time of designing the circuit itself whose reliabilities are assumed to be known (deterministic).

Total cost of the system with the maximum reliability for all the possible combinations is calculated by substituting the number of components and their costs values will evaluate to 3 * 1,50,000 + 2 * 1,00,000 + 2 * 1,00,000 + (10 * 3000) * 4, which is equal to Rs. 9, 70,000/-.

From the simulation results it is found that the best reliable combination is found to be the combinational occurring at the 36th instance within the assumed budget limit.

V. CONCLUSION

The reliability is evaluated with the Monte Carlo simulation technique under the assumed constraints as components costs and no of components. After running the simulation for each of the possible combinations for 100 times the best network reliable combination is found to be 3 Servers, 2 routers in branch A and 2 routers in branch B. The cost of system for the best reliable components setup is 9, 70,000/- The developed software package is very flexible to adapt to any WAN environment.In the WAN environment such that cost and material resources are utilized for optimum use and for maximum reliability. For the stochastic redundancy problem formulated the simulation technique is employed to arrive at the solution. For the WAN under Monte-Carlo simulation technique the optimized number of redundant network components the optimal no. of redundant components at each stage is evaluated!

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