IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 21, Issue 3, Ser. IV (May - June 2019), PP 56-60
www.iosrjournals.org

Three-Tier LAN Reliability Design Using Constraint-Based Branch-and-Bound Algorithmic Approach

Betselot Yitagesu[1]
[1](*Computer Science, Computing College/ Debre Berhan University, Ethiopia)*
Corresponding Author: Betselot Yitagesu

Abstract: *Reliability is major concern of any system. Network infrastructure design is no exception. While designing and analyzing a Local area network, reliability issue needs to be addressed carefully. Since a LAN constitutes different components, failure of any component could lead to service unavailability for end users. Thus, overall reliability of a given system relies on the reliability of connected devices. However, system reliability cannot be improved to the expected level with components having better reliability only. Having redundant devices at each layer or stage of network infrastructure is fundamental to improve the overall network reliability.*

Therefore, this paper presents the use of branch and bound algorithmic approach with bounding functions to calculate optimal possible reliability of three-tier local area network architecture with a limited amount of budget as a constraint for an organization.

Keywords: *Reliability Design, Reliability problem, branch and bound, three-tier LAN design*

Date of Submission: 02-06-2019 Date of acceptance: 17-06-2019

I. Introduction

To set up a system, its reliability is major concern to deal with. A system reliability with different components connected together depends on the reliability of each device at each stage, and it is the cumulative product of each devices reliability level. Thus overall reliability of a system degrades rapidly as the number of components connecting to set up the system increases. In a three-tier architecture of network design, the overall reliability of the network infrastructure is multiplicative result of each three layers' reliability individually. In this modern society, customer's satisfaction of services provided by any organization mainly depends on its reliability [1].

To calculate total reliability of a system containing devices D1, D2, D3…. Dn, where the reliability of each devices is R_1, R_2, R_3…. R_n, the formula is:

Total Reliability (R)=$\prod_1^n r_i$

This mean, if a system consisting 3 devices each with 0.95 reliability, then the overall reliability of the system will be 0.78. This indicates that thought individual devices or components reliability is good; the overall system reliability is much lower than the individual's reliability. This is because the failure rate of the overall system is the combination of failures rate of each device.

Network infrastructure reliability depends on various factors related to design and exploration of network that are subject to failure of infrastructure components [1].

Therefore, the solution to this problem is either to have a high reliable device at each stage or to have a redundant device at each stage to improve the reliability of each stage, which again leads overall improvement of the system reliability [2]. The later solution requires additional cost and management to accommodate the additional devices price, thus there is a tradeoff between reliability and investment. Enhancing reliability in reliability design problem is to deploy multiple copies of each component at each stage with cost a major constraint [3].

Network components represented as either nodes in the infrastructure having failed or active state [1]. In a network design, making a system available for the user as much as possible is the main principle of the expert. Thus with limited amount of investment, it is important to have a method which suggest the network experts to design the system in a way that the overall reliability is maximized. There are some basic parameters for a network designer to consider; reliability, availability, mean time for failure and repair and the readiness of the system to operate [4]. A structured redundancy schema is expected [4].

II. Problem Description

In three-tier LAN architecture, there are three distinct stages go consider in general. Representing each stages with a single device as follows, we can simplify the problem of reliability design.

The redundancy need to be provided in a way that the user of the network access time is maximum, given the budget constraint of the organization. It is important to understand that at least one device at each stage is necessary for the system to function at all.

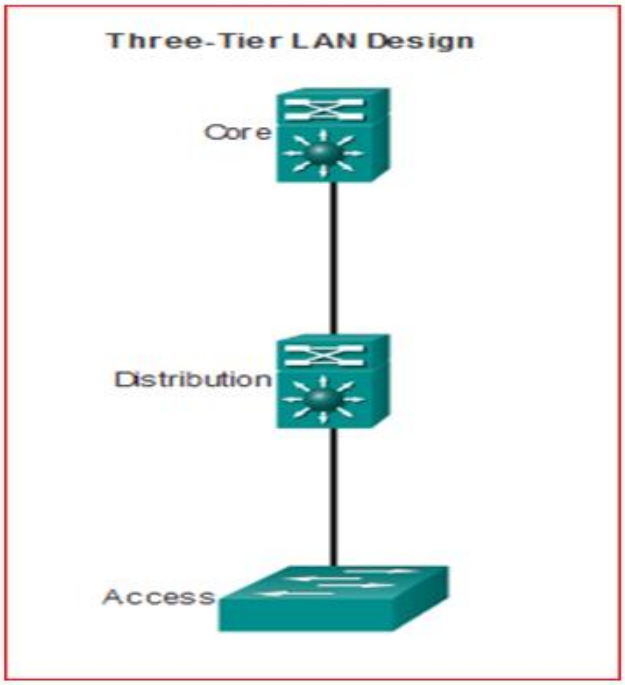

Fig.1 LAN Three-Tier Architecture

The design is to have redundant devices at each layer of the network architecture, which can improve the overall reliability and efficiency of the system. Each stages reliability need to be considered, because the effect of the core layer reflected on both distribution and access layer, and effect of distribution layer is reflected on the access layer. In the actual network design there will be more that distribution and access infrastructure, which creates a separate string of device chain starting from the core to specific access group. Thus, a different sequence of reliability design needs to execute to generate to whole topology design. Layout of each device at each stage depicted in the picture below.

Stage1 Core	Stage2 Distribution	Stage3 Access
D1	D2	D3
D1	D2	D3
D1	D2	D3
…..	…..	…..

Table 1: Devices distribution within a stage and in series across the system

III. Problem Formulation

The problem is now given set of devices with reliability and cost for each device, then to design a system comprising of all those devices in series with the maximum possible reliability using branch and bound algorithmic approach. Each stage reliability will be calculated using the formula:

Reliability of stage= 1- $\prod_1^n (1 - r_i)$

First, we need to determine the maximum number of devices possible to purchase with total budget allotted to setup the system. For the system to start working at least one copy of each device required. Assuming the total budget given is cost(C), and then we have:

- ✓ C is total budget
- ✓ $\sum_{1i=1}^{n} c_i$; is the amount of money that is necessary to purchase one device from each kind

- ✓ C-$\sum_{1i=1}^{n} c_i$; gives the amount of cash remaining for redundant devices to be added at each stage
- ✓ Upper limit (Ui)= 1+ int($\frac{C-\sum_{1i=1}^{n} c_i}{ci}$) is the maximum possible number of a device to be purchased

Using the above given computation, it is possible to generate the following table as a summary and an input for the branch and bounding algorithm. The table contains a more general form in which a given system may require more than three type of devices. However, for three-tier LAN architecture, only single type of device at each stage considered for simplicity.

Device	Cost	Reliability	Upper limit
D1	C1	R1	U1
D2	C2	R2	U2
D3	C3	R3	U3
…..	…..	…..	…..
Dn	Cn	Rn	Un

Table 2: Devices distribution within a stage and in series across the system along with Upper limit of each device

IV. Branch-and-Bound Approach To Solve The Problem

Branch and bound algorithmic approach follows breadth first search (BFS) approach in generating an optimal solution. BFS along with bounding function looks for more promising solutions ignoring impossible solutions [6]. It uses to solve optimization problem considering all possible solution to select the optimal one, overlooking the obvious impossible candidate solution in the process. Mostly, these kind of problems are exponential in terms of time complexity. However, branch and bound approach can solve such problem quicker, if certain bounding condition applied properly. In this LAN design reliability design the main bounding condition is the amount of money allotted for the system.

In three-tier LAN architecture, devices starting from the first layer (Core), will be considered level by level. At each level constraints or blocking conditions to consider are:

- ✓ At least one copy of each layer's device is necessary
- ✓ Devices traversed or considered only in sequence (D1-> D2-> D3)
- ✓ Upper limit value of each device cannot exceed
- ✓ Previously considered device won't be considered again.

The following graph depicts the basic traversal sequence using branch and bound in three-tier LAN architecture. D1 is a device used at core layer, D2 at distribution layer and D3 operates at access layer.

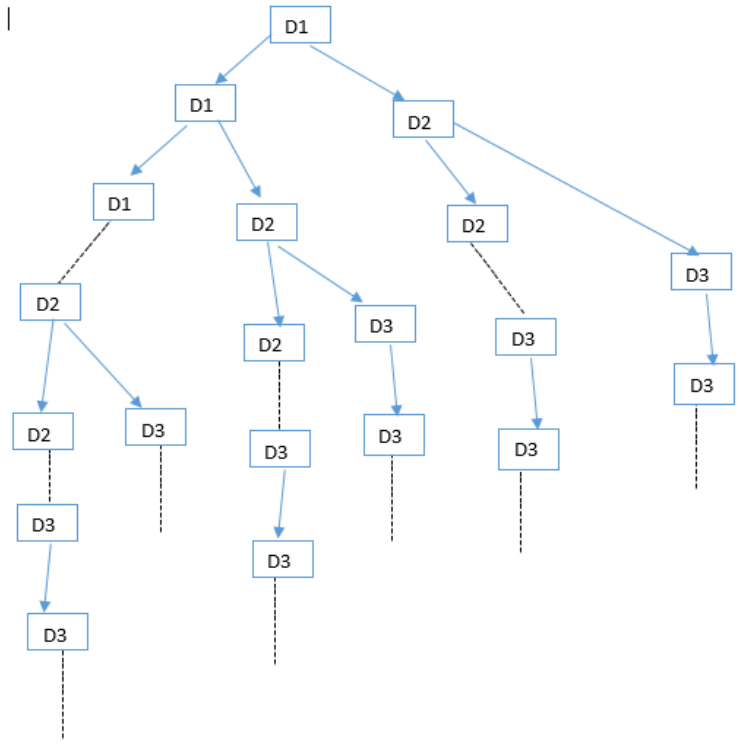

Fig 2: Branch and bound with bounding function to design reliability of LAN

In the graph above, initially a single copy of the first device assumed and network reliability computed which is equal to r1 and current cost =c1. Then, either a redundant device of the first device added or the second device considered, if the value C-$\sum_{1i=1}^{n} c_i$ is greater than Redundancy cost (RC), a cost spent for redundant devices so far. If the two copy of D1 added, then stage 1 (Core layer) reliability will compute using the formula given above, in which stage reliability will increase.

Current System Reliability= 1- (1-r1)2

However, if the second device D2 added to the system then system reliability will be product of the reliabilities of each stage.

Current System reliability = r1*r2

At the 3rd level there are three possible considerations: -

- ✓ Add device D1 to the system to increase the redundancy of the first stage, but if only C-$\sum_{1i=1}^{n} c_i$ is greater than RC. Then Current System Reliability would be 1- (1-r1)3
- ✓ Two copy of D2 added to the system, such that reliability of the system becomes: r1* 1- (1-r2)2
- ✓ Or one copy of third device D3 added to the system, such that system reliability becomes: r1*r2*r3

At each stage, the total remaining cash should not be less than amount $\sum_{i,i=j+1}^{n} c_i$, where j is the current device considered. This assure the acquisition of at least one copy of each devices in the system. However, if the amount remaining is less than required amount of cash as mentioned, then the node is considered as dead and traversing will stop. A dead node can be a candidate solution if at least one device from each stages traversed so far. Otherwise, it is an obvious impossible solution and eliminated. Branching will not cut optimal solution [5], because all candidate solution except the impossible once traversed and assigned at leaf node.

V. Time Complexity Analysis

Brach and bound approach contains branching and bounding processes. In branching process all possible solutions discovered. This makes the problem complex because traversing all possible combination is vast. Usually such problems are NP-complete or even NP-hard type of problems. However, the second part of the approach, bounding limits the traversal process using certain constraints or bounding function such that it can solve problem more efficiently than other approaches.

Branch and bound approach used DFS algorithm which has O(n2) worst-case scenario time complexity in general. However, DFS for reliability design problem, in which the problem is exponential time and Non-Deterministic, NP-hard problem type. Worst-case time complexity of such a problem is expected to be exponential. However, using a bounding function and not listing all possible combination of device with maximum possible redundancy, estimated time complexity of reliability design can reduce greatly. Thought there is no proven time complexity for NP-hard problem in general and branch bad bound algorithmic approach specifically, it is mainly preferred for such more complex category of problems [7]. Considering three-tiers in the LAN architecture and budget as main constraints, which mainly limits the redundant devices number to the minimum, a more efficient computational time can be achieved for reliability of LAN design with the use of branch-and-bound algorithmic approach.

VI. Conclusion

In this paper, using branch and bound algorithm approach to solve a reliability design problem of three-tier LAN discussed, such that an optimum solution achieved. Reliability of the network and failure to the services provided mainly depends on components failure rate at each stage. Having redundant components at each stage greatly improves the overall network reliability.

Brach and bound approach to solve this reliability problem generates the targeted results quickly compared to dynamic programming approach. Such approach can be used in a situation where space is scared. In addition to this this approach advantage is that its simplicity and presentable, especially along with depict the LAN physical topology.

Therefore, solving network reliability design problem using branch and bound approach has the advantage of efficiency and simplicity.

For future, there are additional considerations to be addresses about the detail physical topology of a given LAN. In this, each major layers were represented with a single stage. However, more than one stages at each layer is expected and the algorithm needs to expand to cover all possible stages.

References

[1]. M.O. Ball et al., Eds., *Handbooks in OR & MS*, 4 (Elsevier Science B.V, 1995). (7)

[2]. Hsieh, Yi-Chih, Ta-Cheng Chen, and Dennis L. Bricker. Genetic algorithms for reliability design problems, *Elsevier Microelectronics Reliability, 38.10* (1998): 1599-1605.

[3]. Dr. R. Mohanty, *Design and Analysis of Algorithms*, (VEER SURENDRA SAI UNIVERSITY OF TECHNOLOGY, BURLA SAMBALPUR, ODISHA, INDIA – 768018

[4]. Lad, Bhupesh K., Makarand S. Kulkarni, and Krishna B. Misra, Optimal reliability design of a system, *Handbook of Performability Engineering. Springer*, London, 2008. 499-519.

[5]. Luedtke, James, A branch-and-cut decomposition algorithm for solving chance-constrained mathematical programs with finite support, Mathematical *Programming-Springer 146.1-2* (2014): 219-244.

[6]. T. Carneiro, A.E.Muritiba, M.Negreiros, G.A.L. Campos,A New Parallel Schema for Branch-and-Bound Algorithms Using GPGPU: *23rd International Symposium on Computer Architecture and High Performance Computing*, 41-47, 2011

[7]. Chung-Yang (Ric) Huang, ... Kwang-Ting (Tim) Cheng, *Electronic Design Automation* (Elsevier Inc., 2009)

IOSR Journal of Computer Engineering (IOSR-JCE) is UGC approved Journal with Sl. No. 5019, Journal no. 49102.

Betselot Yitagesu. "Three-Tier LAN Reliability Design Using Constraint-Based Branch-and-Bound Algorithmic Approach." IOSR Journal of Computer Engineering (IOSR-JCE) 21.3 (2019): 56-60.