

# ENTERPRISE NETWORK REDESIGN THROUGH SERVER CONSOLIDATION

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**Abstract:** In this paper, we have explored the utilization of existing servers within an enterprise information network (EIN), and we have proposed redesign operations on servers to identify and remove the low-utilized servers. The low-utilized servers consume unnecessary power and increase the operational and maintenance cost. The removal of low-utilized server is viewed as an EIN redesign problem, which removes the low-utilized servers within the EIN and re-distributes the clients of the purged servers to the remaining servers, thereby reducing a portion of expenditure on maintenance and operation. We have proposed three approaches on distributing the clients of removed servers and the approaches are; single server pure random distribution, selective distribution and multiple servers pure random distribution. We have employed Simulated Annealing to search for best possible random server/servers in order to distribute the workload of the removed server, thereby improving the utilization of the remaining servers. The simulation results for a given EIN with 10 servers and 25 clusters show that our proposed server consolidation approaches improve the initial average server utilization of around 25% to 60%, 68.5%, and 90% respectively in the proposed three methods.

## 1 INTRODUCTION

An enterprise information network (EIN) is a medium scale computer network, designed to support the activities of an enterprise such as bank or scientific institution. Typically, an EIN is comprised of several servers offering specific services to a number of clusters containing clients; Moreover, it offers high quality service and enables enterprises to coordinate their processes across all functional and management levels. Many enterprises install separate servers to house new applications mainly to prevent the risk of negative effects of one application on another, when both the applications are installed on the same server. Commonly, enterprise data centers use to have many servers to handle their operations in various departments, as the installation of a new application on an existing server with several applications running on it, sometimes leads to degrade the server performance. Moreover, the servers purchased by different decision makers over a period of time to offer specific services to a group of clients may also increase the number of servers. As years pass by, the added servers within the enterprise network have

lead to a situation known as ‘server sprawl’, whereby too-many servers are running at very low utilization, consuming physical space and power, as well as wasting the internal resources of servers such as CPU, memory, and storage devices. On net result, server sprawl increases the operational and maintenance cost of the EIN.

The present economic crisis forces the enterprise networks to cut unnecessary operational and maintenance costs. In this paper, we have examined the utilization of installed servers in an enterprise network and apply server consolidation techniques to remove the under-utilized servers and redistribute the clients of the removed servers to the selected server from the remaining servers. We have extended the work of Abdulgafer et al (2010), whereby the authors redesign a grid-based enterprise information network through servers consolidation. We have proposed three different approaches to distribute the workload of the removed low utilized server; single server pure random distribution, selective distribution and multiple servers pure random distribution. We have employed Simulated Annealing to search for the best server to distribute the clients of the removed server that improves the

utilization of the existing servers. We have compared the utilization of the servers present in the EIN before and after the application of the redesign process, whereby it shows a maximum increase of 65.2% in the average utilization.

This paper is organized as follows: Section 2, discusses the related work and Section 3 describes the server sprawl problem. The server consolidation methods are presented in Section 4. Section 5 elaborates on Simulated Annealing approach and Section 6 presents the experimental results and analysis, and Section 7 concludes our work.

## 2 RELATED WORK

Several studies were carried out by various researchers to devise techniques to reduce the costs of enterprise network by improving the utilization of installed servers. A decision model for server consolidation in data centers was presented by Speitkamp and Bichler (2010) in order to minimize the costs of servers in terms of hardware costs (e.g., CPU and memory bandwidth). By optimally allocating virtual servers to physical servers, the authors reduced the hardware cost.

Spellmann, et al. (2003) applied a performance modelling and stepwise refinement to analyze the consolidation alternatives before making any physical changes. They defined three consolidation alternatives, which were centralization, physical consolidation, and, data and application integration. Servers were moved from different geographic data centers to a common location (centralization), several small servers were replaced with fewer large servers to achieve storage consolidation (physical consolidation) and data was consolidated into a single server, and similar applications were merged into a single server (data and application integration).

Gupta et al. (2008) discussed the problem of server sprawl. The authors modelled the problem of server consolidation as a variant of the bin packing problem, where the items to be packed were the servers being consolidated and bins were the target servers. The authors developed a new heuristic algorithm for determining the number of destination servers in the presence of the incompatibility constraints including bin-item incompatibilities.

The problem of data-centers consolidation was formulated as a minimization problem (Anselmi, Cremonesi and Amaldi, 2009). The weighted sum of server costs comprised of cost of energy consumption, and maintenance, subject to satisfying

performance constraints on utilizations and data-center response times was studied. Server costs were minimized by reducing the number of servers used in the data-center, which was achieved through installing a given software application on a number of servers, while maintaining a maximum utilization thresholds.

Uddin and Abdul Rahman (2010) presented a server consolidation solution to reduce the energy consumption from underutilized servers and reach energy efficient data centers using virtualization. They defined virtualization as a technology that combines multiple virtual servers on a single server, and thus, increased the utilization of server. The utilization of a server was estimated by measuring its performed workloads and executed applications.

Dhyani et al. (2010) presented a constraint programming approach for the service consolidation problem in data-centers. The problem was to find an allocation of applications to servers while minimizing the data-center costs and satisfying constraints on the resource utilizations. The authors developed a constraint programming approach using the Comet programming language to assess the impact of the rule-based constraints in reducing the problem search space and to improve the solution quality and scalability.

Cardosa et al. (2009) presented a suite of techniques for placement and power consolidation of virtual machines in data centers taking advantage of the min-max and shared features inherent in virtualization technologies. The objective was to place virtual machines among a set of physical servers in the data center and estimated the shares that should be given to each VM.

The behavior of server consolidation workloads was studied by Jerger, Vantrease and Lipasti (2007), which focused particularly on sharing of caches across a variety of configurations. The authors presented a study of a variety of last level cache sharing arrangements to illuminate some of the pressures felt by the cache hierarchy, and showed that both performance and fairness were affected. They presented a simulation methodology which was designed to mimic a dynamically partitioned system running a hypervisor or virtual machine.

Our work focuses on redesign of an existing EIN through the removal of underutilized servers and the distribution of their clients' to the remaining servers.

## 3 PROBLEM FORMULATION

The server consolidation problem is formulated as

an optimization problem, where the objective function is to maximize the servers' utilization as shown in Equation (1). The term  $U_i$  represents the utilization for server  $j$ , and  $S$  is the total number of servers in the system

$$\text{Utilization of Servers} = \max \sum_{j=1}^S U_j \quad (1)$$

Here, we highlight the core constraints, which facilitate the uniform distribution of clients to the existing servers. Constraint (2) states that each cluster of clients is attached to only one server, thereby ensuring that each client is served by one server.

$$\sum_{j=1}^S \alpha_{ij} \beta_j = 1, \quad \forall j = 1, 2, \dots, C \quad (2)$$

In constraint (2),  $\alpha_{ij}$  represents the binding of  $i$ th cluster to  $j$ th server.  $\beta_j$  represents the allocation of server  $j$  in the EIN.

Constraint (3) ensures that an installed server serves more than one cluster. Moreover, it ensures that the number of connected clusters is less than the total number of clusters in the system so that the server will not be over-utilized. The term  $C$  represents the total number of clusters within EIN.

$$1 < \sum_{j=1}^C \alpha_{ij} \beta_i < C \quad \forall i = 1, 2, 3, \dots, S \quad (3)$$

## 4 REDESIGN THROUGH SERVER CONSOLIDATION

### 4.1 Server Utilization

The server utilization is calculated by taking the average CPU usage over a period of time (during one hour) (Abdulgafer et al., 2010), which includes the number of file requests received by each server and time taken by each server to process the file requests. The performance of each server is estimated based on its utilization and higher server utilization leads to higher server performance.

We have defined the server utilization ( $U$ ) as the amount of time the server is busy during a period of time, (for example; duration of one hour) as in Equation (4).

$$U = (\text{amount of time the server is busy during one hour} / 3600 \text{ seconds}) * 100 \quad (4)$$

With known server capacity, which is the

maximum number of files the server can handle during one hour, the amount of time ( $T$ ) the server is busy during one hour can be calculated using Equation (5). The average file size is measured in Megabytes and server capacity is measured in Megabytes/hour.

$$T = (\text{average file size} * \text{average number of requested files per one hour}) / \text{server capacity} \quad (5)$$

### 4.2 Load Redistribution Approaches

We have proposed three approaches on distributing the clients of the removed servers; single server pure random distribution, selective distribution into the second lowest utilized server and multiple servers pure random distribution as shown in Figure 1. In all the three methods, the utilization of each server is computed and the server with lowest utilization is selected for removal from the EIN. The single server pure random distribution method selects a server randomly from the remaining servers list and it distributes the clients of the removed server. The second approach allocates the clients of the removed server to the second lowest utilized server in the EIN. The third approach distributes the clients of the removed server to two servers selected randomly from the remaining servers in the EIN. Since the first approach distributes the workload to only one server, the probability of the randomly selected server to become over utilized may occur more frequently than the other methods. But the overloading of server is decreased in the second approach as it adds the clients to the second lowest utilized server. However, the third approach balances the workload by distributing the clients over two servers, which result in overall improvement in the servers' utilizations.

## 5 ROLE OF SIMULATED ANNEALING IN EIN REDESIGN

Simulated Annealing (SA) is used widely to solve different optimization problems. SA starts with an initial solution  $S_0$ , and then, it generates a new solution using a function called neighbor in the optimization process (Kirkpatrick et al., 1983). The neighbor function is defined with a function known as the Metropolis, which accepts a new solution based on the dominance of cost of new solution or based on a probabilistic function. We have employed SA in our consolidation algorithm to

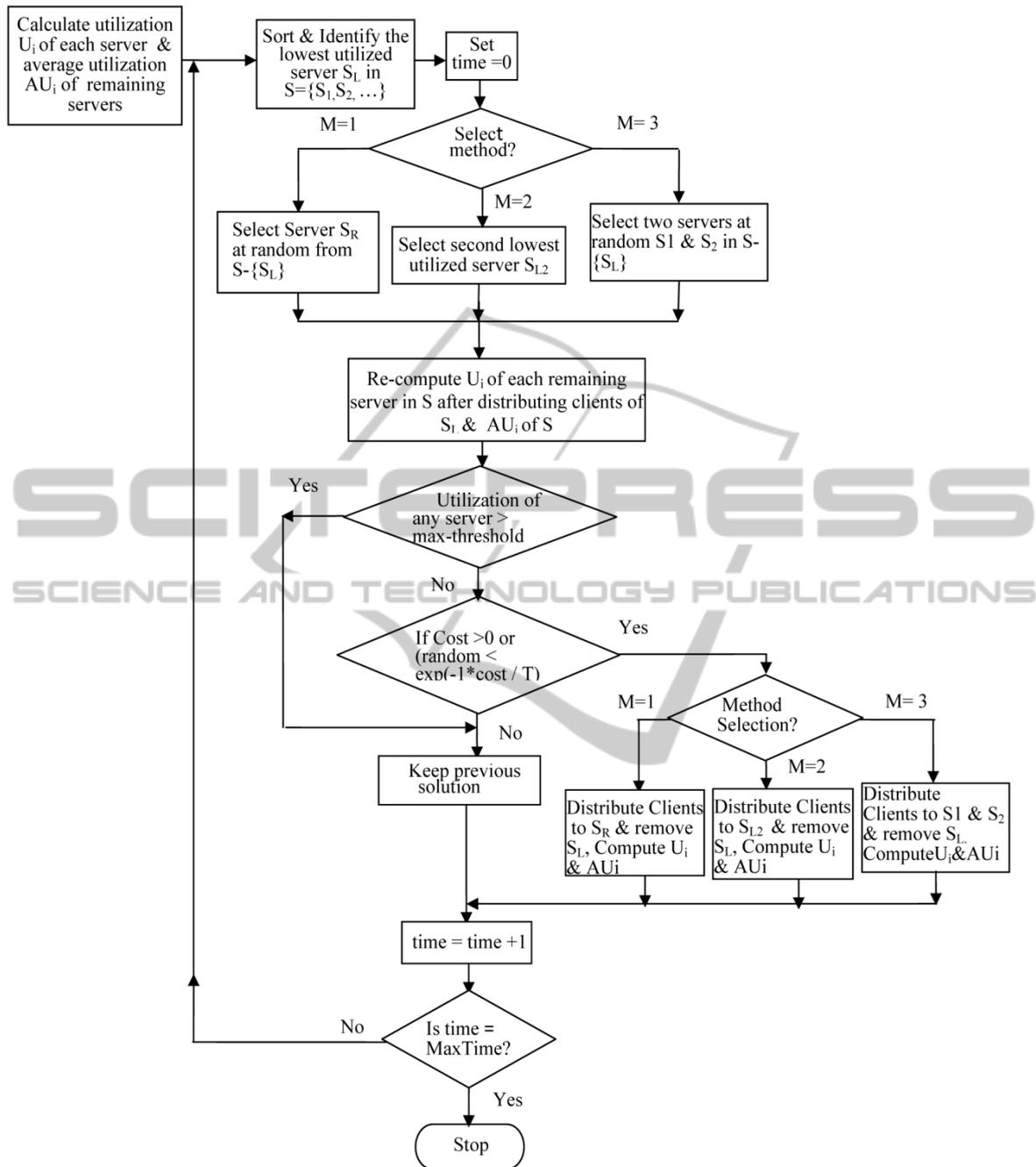


Figure 1: Load redistribution techniques utilized by neighborhood functions within SA.

optimize the utilizations of servers in the given EIS. If the cost of the computed solution is positive, then, the new solution gives a higher average utilization and it is accepted. Otherwise, if the random number in the Metropolis satisfies the given condition, then the new solution is accepted. Metropolis consolidation function is considered as the solution modification function, which

generates new solution and passes it to a function called neighbor in all the iterations. The neighbor function tests the new solution and computes the average utilizations of all servers for the new solution without removing a server from EIN. Metropolis algorithm accepts the new solution if the cost of the new solution is greater than the previous solution.

## 6 RESULTS AND DISCUSSION

We have experimented with an enterprise information network using all the three clients' distribution approaches. EIN comprises of 10 servers and 25 clusters. Figure 2 shows the distribution of servers' utilization within the initial EIN. The average server utilization of the initial network is of 25.8%. The Simulated Annealing parameters are set to the following values; initial temperature = 1000° C,  $\alpha = 0.8$ ,  $\beta = 1$ , and maximum-time = 100 time units. We have coded all the three experiments within Simulated Annealing in C++.

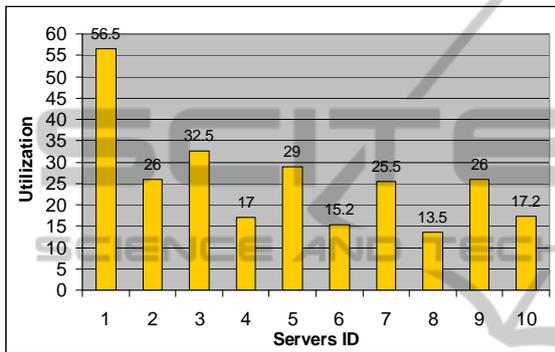


Figure 2: Server utilization in initial EIN network.

According to the first approach, the average utilization of the remaining servers is computed for an optimization period as in Figure 3, and it is equal to 68.25%. In each of the iteration, the algorithm removes one underutilized server and distributes their clients' randomly to the remaining servers that exist in the system.

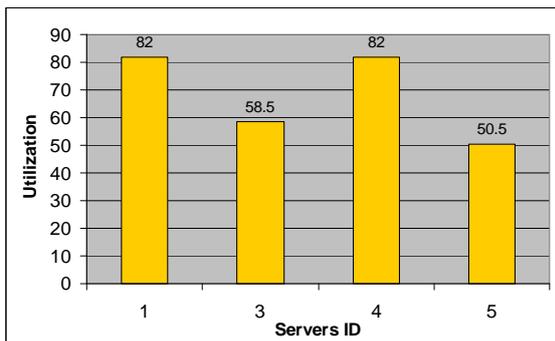


Figure 3: Utilization of remaining servers in first approach.

The second approach increases the server utilization by 34.55% from 25.8 to 60.35% as shown in Figure 4. In each of the iteration, the algorithm removes one underutilized server and distributes

their clients' clusters to the lowest utilized server selected from the remaining servers. For the similar EIN, the third approach ends with a final redesign solution consisting of 3 servers and with the average utilizations of 91% as shown in Figure 5.

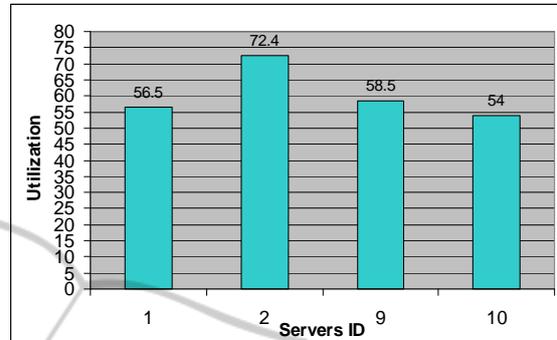


Figure 4: Utilization of remaining servers in second approach.

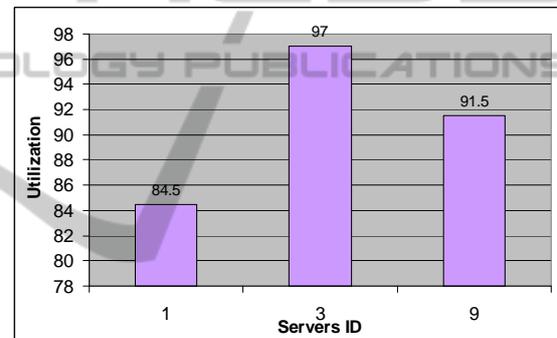


Figure 5: Utilization of remaining servers in third approach.

The first and second approaches reduce the servers from 10 servers to 4 servers where it represents a 60% reduction after consolidation, whereas the third approach reduced the servers to 3, where it represents a 70% consolidation.

## 7 CONCLUSIONS

In this paper, we have proposed three server consolidation approaches namely, single server pure random distribution, selective distribution and multiple servers pure random distribution to distribute the clients of a low-utilized server in an existing enterprise information network (EIN). The three methods are tested on EIN with 10 servers and 25 clusters, and the utilization of the EIN improves by 42.45%, 34.55% and 65.2% respectively. The experimental results show that the redesign

algorithm reduces total number of servers from 10 servers to 4 servers, by eliminating most of the under-utilized servers, and thereby reduces the EIN operational and maintenance costs with acceptable performance.

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