Availability Analysis on Virtualized Two-Node Cluster System: Ratio of Restoration Rate and Failure Rate

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Abstract

Worldwide, businesses continually increase their dependence on IT systems for routine business processes. The business processes which directly rely on information systems and the supporting IT infrastructure often require high levels of availability and recovery in the case of planned and unplanned outage. High availability has achieved by host per host redundancy, a highly expensive method with hardware and human costs. Virtualization technologies promise cost reduction through resource consolidation. By combining virtualization and HA clustering, it is possible to benefit from increased manageability and saving from server consolidation through virtualization without decreasing uptime of critical services. Using analytical modeling, we analyze multiple design choices when dual physical servers are used to host multiple virtual machines. We use Markov decision process when we are concerned about optimal decision at any arbitrary time. Numerical examples are presented to illustrate the applicability of the model.

Keywords: clustering, High availability, Virtualization, Markov decision process.

1. Introduction

In today's complex environments, providing continuous service for applications is a key component of a successful IT implementation. High availability is one of the components that contribute to providing continuous service for the application clients, by masking or eliminating both planned and unplanned systems and application downtime. The systems configured for high availability are a combination of hardware and software components configured to work together to ensure automated recovery in case of failure with a minimal acceptable downtime.

Clusters are groups of servers that are managed together and participate in workload management. The act of creating clusters is called clustering. Clustering is where you run a single application on many servers. This allows you to take advantages of extra hardware to get better performance. It also gives you the ability to have failover support. If one server goes down, there is another one that will handle the processing. Think of a cluster as a group of servers that all act together as one.

Virtualization[1], [7] is a technology that combines or divides computing resources to present one or many operating environments using methodologies like hardware and software partitioning or aggregation, partial or complete machine simulation, emulation, time-sharing, and others. Virtualization essentially lets one computer so the job of multiple computers by sharing the resources of a single computer across multiple environments.

In [6], S.Loveland et al. discussed how virtualization technologies and techniques can augment and amplify traditional HA approaches while avoiding potential pitfalls. And they also presented about applying HA configurations to virtualized environments.

F. Calzolari et al. described in [3] HA has always been one of the main problems for a data center. This paper presented a new approach to the problem can be offered by virtualization. They also presented 3RC system: Reboot, Restart, and Reinstall.

2. System Architecture

While high availability services are essential for 24×7 mission critical applications, the cost issue has to be carefully evaluated. Because of the high costs and hardware configuration requirements, a five nines availability level often implies a strong negative return on investment [2], [4], [8], [10], and [11].

We describe our proposed system to offer high availability. A high availability clustering system generally provides an active/standby node structure by connecting two servers. The standby node monitors the active node while the active node occupies resources and provides services based on the occupied resources. If failures are generated in the active node, the backup node takes over the resources of the active node and continuously provides a corresponding service based on the resources. Virtualization technologies allow to run multiple virtual servers on a single physical machine. Cluster virtualization enables large pools of servers to act and appear like a single, consistent virtual machine.

A virtual machine can easily be moved from one physical machine and relocated to another, if needed [4]. Typical examples of virtual machines movement are: virtual machine cloning (to copy more instances of the same virtual machine), virtual machine relocation (to free the original machine hosting the virtual machine), in case of maintenance or break [8]. Because of their mobility, virtual machines can be used in high availability and disaster recovery scenarios.

3. Modeling and Analysis

We model the two-component system, one component is considered as active and the other as a standby (spare) unit. The failure rate of active unit λ and those of standby unit λ_s are different, and also the effects of failure of them are different. We use c and c_s, the probabilities of the active and standby unit respectively. We also use μ as a restoration rate and β as a reboot rate for the failed unit.

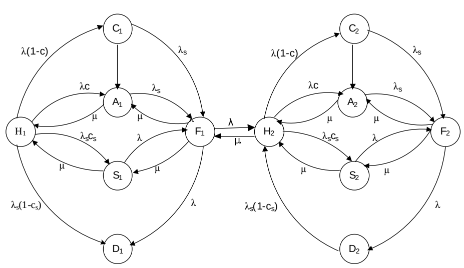

Figure 1: State Transition Diagram

According to the state transition diagram of figure, we denote in table 1.

Table 1. Notation of the System

Notation	Description for States
H_i	Both active and standby VM are working
C_i	Fails to cover the failure of active VM
A_i	If active VM fails, standby unit successfully restores service
S_i	The failure of standby VM while active VM is still working is detecting immediately
D_i	Failure of standby VM is not detected
F_i	System fails

Writing down and solving the steady-state balance equations as follows.

$$\mu P_{A_1} + \mu P_{S_1} = \lambda(1-c)P_{H_1} + \lambda c P_{H_1} + \lambda_s c_s P_{H_1} + \lambda_s(1-c_s)P_{H_1} \quad (1)$$

$$\lambda(1-c)P_{H_1} = \beta P_{C_1} + \lambda_s P_{C_1} \quad (2)$$

$$\lambda c P_{H_1} + \beta P_{C_1} + \mu P_{F_1} = \mu P_{A_1} + \lambda_s P_{A_1} \quad (3)$$

$$\lambda_s c_s P_{H_1} + \mu P_{F_1} = \mu P_{S_1} + \lambda P_{S_1} \quad (4)$$

$$\lambda_s(1-c_s)P_{H_1} = \lambda P_{D_1} \quad (5)$$

$$\lambda_s P_{C_1} + \lambda_s P_{A_1} + \lambda P_{S_1} + \lambda P_{D_1} + \mu P_{H_2} = \mu P_{F_1} + \mu P_{F_1} + \lambda P_{F_1} \quad (6)$$

$$\lambda P_{F_1} + \mu P_{A_2} + \mu P_{S_2} = \mu P_{H_2} + \lambda(1-c)P_{H_2} + \lambda c P_{H_2} + \lambda_s c_s P_{H_2} + \lambda_s(1-c_s)P_{H_2} \quad (7)$$

$$\lambda(1-c)P_{H_2} = \beta P_{C_2} + \lambda_s P_{C_2} \quad (8)$$

$$\lambda c P_{H_2} + \beta P_{C_2} + \mu P_{F_2} = \mu P_{A_2} + \lambda_s P_{A_2} \quad (9)$$

$$\lambda_s c_s P_{H_2} + \mu P_{F_2} = \mu P_{S_2} + \lambda P_{S_2} \quad (10)$$

$$\lambda_s(1-c_s)P_{H_2} = \lambda P_{D_2} \quad (11)$$

$$\lambda_s P_{C_2} + \lambda_s P_{A_2} + \lambda P_{S_2} + \lambda P_{D_2} = \mu P_{F_2} + \mu P_{F_2} \quad (12)$$

The conservation equation of figure 1 is obtained by summing the probabilities of all states in the system and the sum of the equation is 1. Combining the above-mentioned balance equations with the conservation equation, and solving these simultaneous equations, we acquire the closed-form solution for the system.

$$P_{H_1} = \begin{bmatrix} 1 + F + \frac{\lambda(1-c)}{\beta + \lambda_s} + \frac{\lambda(1-c)}{\beta + \lambda_s} F + C + \\ \frac{\mu + \lambda}{\mu + \lambda_s} G + AF + B + G + \frac{\lambda_s(1-c_s)}{\lambda} \\ + \frac{\lambda_s(1-c_s)}{\lambda} F + D + \frac{1}{\mu}\begin{pmatrix} G(\mu+\lambda) \\ -\lambda_s c_s F \end{pmatrix} \end{bmatrix}^{-1} \tag{13}$$

$$P_{C_1} = \frac{\lambda(1-c)}{\beta + \lambda_s} P_{H_1} \tag{14}$$

$$P_{A_1} = C P_{H_1} \tag{15}$$

$$P_{S_1} = B P_{H_1} \tag{16}$$

$$P_{D_1} = \frac{\lambda_s(1-c_s)}{\lambda} P_{H_1} \tag{17}$$

$$P_{F_1} = D P_{H_1} \tag{18}$$

$$P_{H_2} = F P_{H_1} \tag{19}$$

$$P_{C_2} = \frac{\lambda(1-c)}{\beta + \lambda_s} F P_{H_1} \tag{20}$$

$$P_{A_2} = \left(\frac{\mu + \lambda}{\mu + \lambda_s} G + AF\right) P_{H_1} \tag{21}$$

$$P_{S_2} = \frac{F(\mu + \lambda + \lambda_s) - \lambda D - \mu AF}{\frac{\mu(\mu + \lambda)}{\mu + \lambda_s} + \mu} P_{H_1} \tag{22}$$

$$P_{D_2} = \frac{\lambda_s(1-c_s)}{\lambda} F P_{H_1} \tag{23}$$

$$P_{F_2} = \frac{1}{\mu}(G(\mu + \lambda) - \lambda_s c_s F) P_{H_1} \tag{24}$$

$$A = \frac{1}{\mu + \lambda_s}\left(\lambda c + \frac{\lambda(1-c)\beta}{\beta + \lambda_s} - \lambda_s c_s\right) \tag{25}$$

$$B = \frac{\lambda + \lambda_s - \mu A}{\frac{\mu(\mu + \lambda)}{\mu + \lambda_s} + \mu} \tag{26}$$

$$C = \frac{\mu + \lambda}{\mu + \lambda_s} B + A \tag{27}$$

$$D = \frac{\mu + \lambda}{\mu} B - \frac{\lambda_s c_s}{\mu} \tag{28}$$

$$E = \frac{\lambda(1-c)\lambda_s}{\beta + \lambda_s} + \lambda_s(1 - c_s) \tag{29}$$

$$F = \frac{D(2\mu + \lambda) - E - \lambda_s C - \lambda B}{\mu} \tag{30}$$

$$G = \frac{F(\mu + \lambda + \lambda_s) - \lambda D - \mu AF}{\frac{\mu(\mu + \lambda)}{\mu + \lambda_s} + \mu} \tag{31}$$

Availability models capture failure and repair behavior of systems and their components. States of the underlying Markov chain will be classified as up states or down states. Since the system is not available in states C_1, F_1, C_2 and F_2, we obtain an expression for the steady-state availability:

$$\begin{aligned} Availability &= 1 - Unavailablity \\ &= 1 - (P_{C_1} + P_{F_1} + P_{C_2} + P_{F_2}) \end{aligned} \tag{32}$$

4. Experimental Results

To verify the validity of our derivation formulae, we compare the results obtained from the closed-form solution and the result obtained from the numerical solution by SHARPE. For this purpose, the parameters are chosen as follows:

$\lambda_s = \frac{\lambda}{4}$ μ=1 β=12

c= c_s = 0.9.

For the illustration in Figure, we use the values of 10,100,1000,10000 for the ration of μ by λ. We see that the higher the μ/λ ratio, the higher the system availability computed by the model.

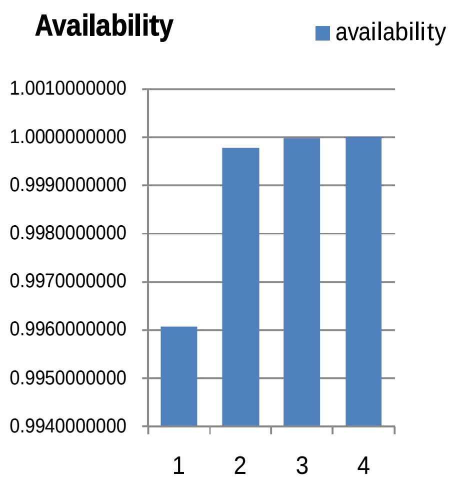

Figure 2:Steady-state Availability with different μ/λ

5. Conclusion

Industries and governments are becoming increasingly accountable for how data is managed, protected, and secured. Policies and regulations vary from industry to industry, and overall landscape of technical requirements continues to grow in complexity. Our virtualized approach is meant to be the less disruptive as possible for the running service and reduce the recovery time and get the users back to work faster. This new approach to high availability allows the running virtual machines to be distributed over a small number of servers. The results show that our approach is able to guarantee a high available system.

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