Availability Model for Virtualized Platforms

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Abstract. *Network virtualization is a method of providing virtual instances of physical networks. Virtualized networks are widely used with virtualized servers, forming a powerful dynamically reconfigurable platform. In this paper we discuss the impact of network virtualization on the overall system availability. We describe a system reflecting the network architecture usually deployed in today's data centres. The proposed system is modelled using Markov chains and fault trees. We compare the availability of virtualized system using standard physique network with the availability of virtualized system using virtualized network. Network virtualization introduces a new software layer to the network architecture. The proposed availability model integrates software failures in addition to the hardware failures. Based on the estimated numerical failure rates, we analyse system's availability.*

Keywords

Availability model, continuous-time Markov chains, network virtualization, server virtualization.

1. Introduction

Network virtualization [1] is a complementary technology to server virtualization. It is a software layer decoupling virtual logical networks from the network hardware. Main advantages of network virtualization are efficient use of network resources and simplification of configuration tasks by offering a unified user interface to heterogeneous network components. The hardware network infrastructure configuration and services are one of difficulties faced in today's data centres. Network virtualization significantly simplifies tasks such as network hardware configuration, dynamic adaptation of network configuration or deployment of new services.

In this paper we compare the availability of conventional non-virtualized network and a virtualized one. Additionally, we evaluate the impact of network virtualization on the overall system availability. We use a two-level model using a fault tree for the system level modelling and a homogeneous continuous time Markov chain to model components' availability. Our model is proposed regarding network infrastructures deployed in nowadays data centres. We perform a numerical analysis allowing a comparison of the system availability values for the considered system.

The rest of this paper is organized as follows. In Section 2, we discuss related works. In Section 3, we detail the architecture of the considered system. Section 4 describes used modelling techniques. Results of numerical simulations are presented in Section 5. Finally, conclusions and future work are given in Section 6.

2. Related Work

In [2], D. S. Kim et al. compare the availability of highly available virtualized system with a non-virtualized one. The considered models are designed using a hierarchical model based on fault trees and homogeneous continuous time Markov chains. Authors show that as long as the availability of data storage system is high enough and the impact of the virtual machine monitor on the operating system's availability stays low, the steady-state availability of virtualized system is higher compared to the non-virtualized system. However, authors do not address the network virtualization process itself.

A typical enterprise server configuration is studied by L. H. S. Bomfim in [3]. The focus is on a server set hosting basic network services such as mail server and web server. A hierarchical model similar to the one proposed in [2] is considered. The impact of server virtualization on the availability is detailed. Authors show that the virtualization negatively impacts system's availability but the impact stays as low as 0,06 % of annual downtime.

A methodology to assess dependability attributes in virtualized networks is presented by S. Fernandes et al. in [4]. The result is intended as input for resource allocation techniques in virtual networks.

In [5], B. Silva et al. introduce a tool for dependability evaluation of data centre power infrastructures called ASTRO. This tool enables a hierarchical modelling of data centre systems by using reliability block diagrams and stochastic Petri nets.

Our work focuses on the impact of network virtualization on system availability. We evaluate the availability of standard network system and compare it with a system relying on a virtualized network.

3. Considered System

This section describes the analysed system. The network architecture is based on recent knowledge of data centre architecture. Considered servers are standard virtualized servers with integrated virtual network layer software.

3.1. Network Architecture

Following conclusions in [6], we take into account a switch-centric centre network architecture that is employed in majority today's data centres. Other architectures like server-centric or irregular network architecture are not considered as their practical application is marginal. The overall network architecture is depicted in Fig. 1. It is based on a recent survey of network virtualization in data centres that is presented in [7].

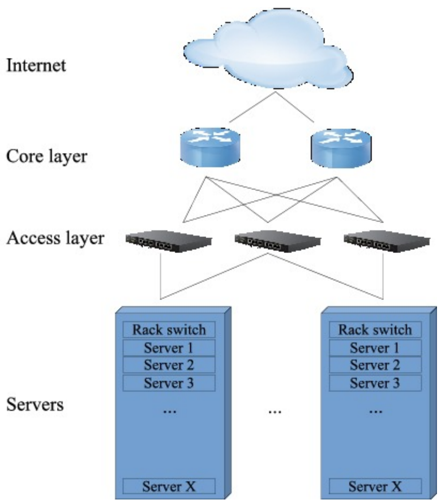

Fig. 1: Data centre network infrastructure.

The proposed architecture is composed of three parts: i) servers, ii) access layer, and iii) core layer. Each server cabinet is equipped with a top-of-rack switch at the access level. The access level distributes data flows between different racks and the core layer. The core layer connects the data centre to the Internet and other external networks. The core level and the access level are fully redundant.

3.2. Network Virtualization

The network virtualization mechanism is based on a logical layer that is built on the top of hardware infrastructure. User data is separated by different tunnelling techniques (for more details see for example [8]). The network architecture shown in Fig. 1 doesn't address network virtualization. The virtualization layer has no impact on the physical network architecture. However, the network border equipments have to support network virtualization [9] that must be reflected in the availability model. In our configuration, the main impact is on the server's network connection and on the access router. A server connected to the virtual network runs a software component that enable connecting server's network interface to the virtual network. The access router providing outside network connectivity to the virtual network integrates an adaptation layer that ensure virtual network functions and has to run specialized software supporting virtual network capabilities. The impact of these components on the availability model is discussed in the next section. A virtual network is usually managed by an external management server. This server is not considered in our study as the server is not placed in the data flow path and its failure does not influence user's experience.

3.3. Server Configuration

There are two types of servers: i) servers hosting user's applications and ii) servers hosting virtual network access router functions.

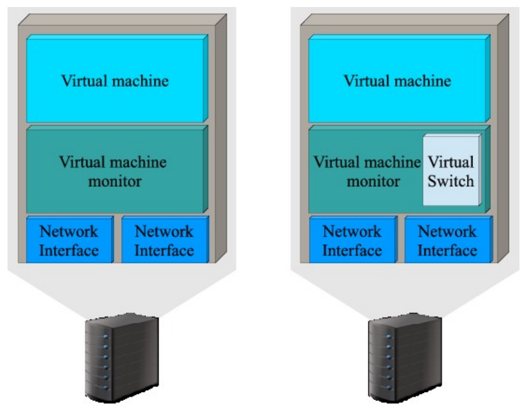

Fig. 2: Server using standard network (left) and virtualized network (right) modelling components.

Figure 2 illustrates models of two server's configurations that we design in our availability models. The first model represents a virtualized server without the network virtualization, whereas the second one includes the network virtualization layer. The network virtualization is ensured by the software package that is part of hypervisor [10]. Therefore, the virtual switch is positioned at the hypervisor level.

In our study we consider same server's architecture for both types of servers. The configuration consists of Quad-core CPU, 2 RAM modules, power supply, cooling system, motherboard, and network card. The access router server critical components (containing power supply, cooling and network cards) are redundant and therefore require specific component models.

4. System Modelling

In this section we detail the investigated system. The general system model is represented by a fault tree in the upper level. In the lower level, we use homogeneous continuous time Markov chains to model each component.

4.1. System Availability Model

The overall system model is adapted conforming to the objective of our work, i.e. to analyse the difference of system availability between non-virtualised and virtualised network.

The proposed fault tree is depicted in Fig. 3. Servers are composed of hardware (detailed in Fig. 4), virtual machine monitor and virtual machine operating system. A specific component called virtual switch is added when the server uses a virtualized network. This component is run by the virtual machine monitor as a kernel module [11]. Data storage is ensured by the Storage Area Network (SAN) component. As stated above, border network equipments host virtualized network components, which are included in the proposed model as well. Virtual network components are virtual switches depicted as Virtual Network Adaptors in Fig. 3. There's one on the server's side and one on the network access router's side. The access router is acting as access gateway for virtual networks. Network virtualization components are highlighted by a yellow background. These components are not considered for the non-virtualized network model. Figure 4 depicts server's hardware fault tree that we show in Fig. 3. All components in the considered system are repairable.

4.2. Component Model

To model components, the Continuous Time Markov Models (CTMM) are used. As shown in [12] by A. Wood, these models are useful to model components availability once the burn-in period is over. Redundancy of critical components is taken into account by the component models. Used models are not presented for the sake of brevity.

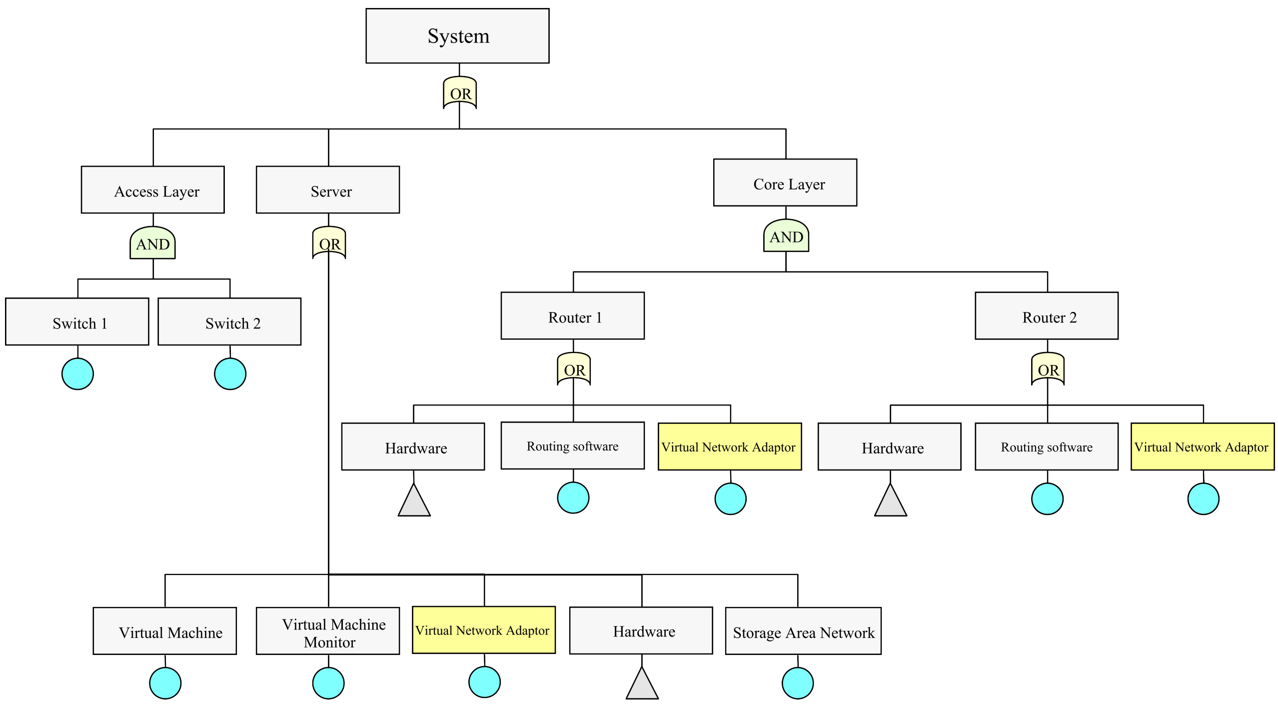

Fig. 3: System fault tree.

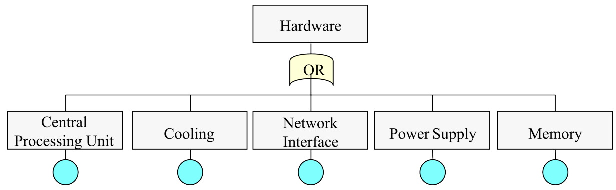

Fig. 4: System fault tree.

4.3. Numerical Results

We calculate numerical results by using a software tool called RAM Commander [13]. In the first step, we evaluate Markov chains in the steady-state to obtain the Mean Time To Failure (MTTF) and Mean Time To Repair (MTTR) values for each component model (e.g. memory component). Markov chains input data are MTTF and MTTR values of each model part (e.g. RAM module). These values are provided in manufacturer's technical documents for the given hardware components. The MTTF and MTTR of software components are much harder to obtain as there are many use scenarios and testing process would be too long. We used values found in [2] and [14]. To our best knowledge, we haven't found any values for the virtualization software layer. The MTTF and MTTR values of virtual network adaptor are estimated as follows. The estimation is based on the software's complexity, size and maturity. Virtual network adaptor is network processing software, therefore it's quite complex. It is small compared to the operating system and it's quite a new technology. Used values are described in Tab. 1.

Tab. 1: Used mean time to failure; mean time to repair values.

Component	**Mean Time to Failure [hours]**	**Mean Time to Repair [hours]**
Central Processing Unit	25 000 000	0,5
Memory	4 800 000	0,5
Network Interface Card	62 000 000	0,5
Power Supply	670 000	0,5
Cooling	3 100 000	1
Storage Area Network	20 000 000	2
Operating System	1 440	1
Linux Operating System	38 520	2
Virtual Network Adapter	2 160	0,5
Virtual Machine Monitor	2 880	1
Virtual Machine	2 880	1
Router	220 000	1
Switch	220 000	1

Outputs from Markov models serve as input values for the fault tree that is employed to calculate the overall system availability. The obtained values are given in Tab. 2. The simulations show a major impact of the network virtualization on the long-term steady-state average availability. The system built on standard network reaches four nines availability whereas the system with network virtualization only three nines availability. The network virtualization causes the system to be down almost 8 hours per year more than the standard network one.

Tab. 2: Avaliability values.

System Type	**Avaliability**
Standard Network Based System	0,9999104446
Virtualized Network Based System	0,999021907

The sensitivity analysis points out that the most critical components are software ones. These are not redundant and their mean time to failure is low. The impact of the network virtualization layer is reduced by redundant core network routers at the core network layer. The impact can be further reduced using a redundant server implementing the network virtualization adaptation at the access layer. However, this approach would degrade the network virtualization capabilities themselves.

5. Conclusion

In this paper we compare the availability of standard network based system with a virtual network based one. To evaluate the availability, we propose a fault tree models for these two systems. The fault tree model with continuous time Markov chain models are used to calculate the impact of network virtualization on the steady-state system availability. The results obtained via simulations show that the network virtualization based system availability is one nine lower than the system availability of standard network infrastructure. The network virtualization brings many advantages but also a perceptible impact on the system's availability. This drawback needs to be taken into account when deploying the network virtualization and defining the Service Level Agreement definition. In future work, we plan to investigate the redundant virtual network access layer in order to reduce the network virtualization's impact.

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