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as of 29-Mar-2023

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Final Report for Period Beginning 17-Aug-2018 and Ending 16-Aug-2019

Title: Parametrics Sensitivity Analysis of Systems: Studying cloud computing impacts

Begin Performance Period: 17-Aug-2018

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Major Goals: The goals of this project were to develop methods for accurate identification of performance, reliability and availability bottlenecks, especially for designers and administrators of complex systems, such as virtualized data centers and Infrastructure as a Service (IaaS) cloud computing environments. Such an approach should employ hierarchical modeling strategy and combine specific sensitivity analysis indices for distinct models. Decision-making processes may be guided by the hierarchical analytical models and their sensitivity analysis, providing robust and precise information about the points of optimization in the analyzed system.

This proposition suggests methods for evaluation and detection of bottlenecks of cloud computing systems and a methodology for sensitivity analysis (Matos). The methodology is based on hierarchical modeling and parametric sensitivity analysis techniques tailored for such a scenario. This piece of research should introduce methods to build unified sensitivity rankings when distinct modeling formalisms are combined. These methods should be embedded in the Mercury software tool for providing an automated sensitivity analysis framework for supporting the process. The whole project is planned for being executed in three years. Nevertheless, as advised by the ARO staff, this specific plan is a one-year project that concentrates only on the first specific goal and partially on the second.

The specific goals of the research are:

1. Build and validate performance and availability models for cloud computing architectures found in corporate environments.
2. Develop composition methods for sensitivity metrics of analytical models commonly used in the areas of performance and dependability evaluation.
3. Automate the computation of sensitivity metrics for hierarchical models in the Mercury tool.
4. Recommend improvements to some existing cloud computing architectures through the proposed methodology and its sensitivity analysis results.

Accomplishments: The accomplishments of this project are summarized in the papers submitted to peer-reviewed journals and conferences. These papers are depicted in the following.

Journal Articles:

Under review

Title: Estimating Capacity-Oriented Availability in Cloud Systems

Journal: International Journal of Computational Science and Engineering

Abstract: Over the years, many companies have employed cloud computing to support their services and optimize their infrastructure utilization. The provisioning of high availability and high processing capacity is a significant

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challenge when planning a cloud computing infrastructure. Even when the system is available, a part of the resources may not be offered due to partial failures in just a few of the many components in an IaaS cloud. The dynamic behavior of virtualized resources requires special attention to the suitable amount of capacity that is available to users so that the system can be correctly sized. Therefore, estimating capacity-oriented availability (COA) is an essential asset for cloud infrastructure providers to analyze the cost-benefit tradeoff among distinct architectures and deployment sizes. This paper presents a strategy to evaluate the capacity-oriented availability of virtual machines on a private cloud infrastructure. The proposed strategy aims to provide efficient and accurate computation of COA through closed-form equations. We compare our approach to the use of models such as Continuous Time Markov Chains, considering execution time and values of metrics obtained with both approaches.

Under review

Title: Sensitivity Analysis of Smart Building IoT System: An Availability Modeling Approach

Journal: International Journal of Network Management

Abstract: The Internet has been undergoing significant transformations and changing the world around it. We can also see the Internet being used in many areas and innumerable purposes, even by objects. This evolution takes the name Internet of Things (IoT). It is a system composed of storage resources, sensor devices, controllers, applications and network infrastructure, in order to provide some service to its users. Since IoT comprises various components, the creation of these systems, as well as the communication and maintenance of their components, becomes a complex task. There are growing interest and efforts of academia and industry in areas such as smart cities, smart homes, and industry 4.0, that may be seen as IoT-related concepts. This paper presents a sensitivity analysis of a system of IoT considering distinct infrastructures. A case study was carried out based on a specific scenario considering a smart building. The proposed models enable to estimate measures such as steady-state availability, with its behavior represented through a Stochastic Petri Net. Thus it was possible to notice a gain of availability in the system when it was considered redundancy in a local management infrastructure. As well as, there was a gain of availability in the system when considering more one building in a cloud computing infrastructure. However, sensitivity analyze revealed that the device manager and database are the components that most affect the availability. Cost analysis also was performed between local and cloud computing infrastructures.

Under review

Title: Bottleneck detection in cloud computing performance and dependability: Sensitivity rankings for hierarchical models

Journal: Journal of Grid Computing

Abstract: Cloud computing became widespread in the IT industry, saving costs of acquisition and maintenance for companies of all sizes, and enabling appropriate management of resources according to the demand. Stochastic models can enable performance and dependability evaluation of cloud computing systems efficiently, what is needed for proper capacity planning. Distinct models may be combined in a hierarchy to address the massive number of components and levels of interaction among the system parts. Identification of bottlenecks in such composite models might be hard yet, due to the vast amount of input factors and variables which may interfere with the results. This paper proposes a method for bottleneck detection of computational systems represented with hierarchical models, that is remarkably applied in cloud computing systems. This is achieved through the computation of sensitivity indices for each model and subsequent composition of indices from lower-level models in equations and solution methods of higher-level models. An overall sensitivity ranking, comprising the composite indices, indicates the parameters with the highest impact on output metrics.

A case study supports the accuracy and benefits supported by the proposed methodology. The study addresses a web service running on a private cloud with autoscaling mechanisms. The methods and algorithms presented here are helpful for decision-making when designing and managing cloud computing infrastructures regarding incremental and architectural improvements.

Under review

Title: A Dependability and Cost Optimization Method for Private Cloud Infrastructures

Journal: International Journal of Web and Grid Services

Abstract: Creating a cost-effective and highly available private cloud infrastructure from scratch is challenging. In order to improve availability, system administrators commonly employ redundant hardware, which incurs increased acquisition cost. One question that arises is: among all possible ways to arrange the servers, and considering a set of requirements (e.g., the minimum number of available workers, minimum availability), which configurations can sustain a minimal availability level (steady-state and capacity oriented)? In this work, we propose an optimization model for private clouds planning supported by analytical modeling for computing the cost of solutions. By combining the optimization model with the bisection method, we can minimize the acquisition cost while

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maintaining the high availability of the cloud. The proposed method can also be applied to another parallel/distributed systems with the same properties as the private clouds used in our study.

Final accepted

Title: Models for Hyper-convergent Cloud Computing Infrastructures Planning

Journal: International Journal of Grid and Utility Computing

Abstract: The data center concept has evolved, mainly due to the need to reduce expenses with the required physical space to store, provide, and maintain large computational infrastructures. The software-defined data center (SDDC) is a result of this evolution. Through SDDC, any service can be hosted by virtualizing more reliable and easier-to-keep hardware resources. Nowadays, many services and resources can be provided in a single rack, or even a single machine, with similar availability, considering the deployment costs of silo-based environments. One of the ways to apply the SDDC into a data center is through hyper-convergence. Among the main contributions of this paper are the behavioral models developed for availability and capacity-oriented availability evaluation of silo-based, converged, and hyper-converged cloud computing infrastructures. The obtained results may help stakeholders to select between converged and hyper-converged environments, owing to their similar availability but with the particularity of having lower deployment costs.

Conference Articles:

Final Accepted

Title: Dependability Evaluation of an IoT System: A Hierarchical Modelling Approach

Conference: IEEE International Conference on Systems, Man, and Cybernetics

Title: Dependability Evaluation in a Convergent Network Service using BGP and BFD Protocols

Conference: IEEE International Conference on Systems, Man, and Cybernetics

Book Chapter

Final Accepted

Title: Reliability Engineering: Methods and Applications

Chapter Title: Markov Chains and Stochastic Petri Nets for Availability and Reliability Modeling

Publisher: CRC Press- A Taylor & Francis Group

Training Opportunities: The proposed solutions have also been shared with our graduate and undergraduate students.

Results Dissemination: Besides the published and under review papers, the results obtained have also been shared with graduate and undergraduate students of our center and collaborations.

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: Co PD/PI

Participant: Paulo Romero Martins Maciel

Person Months Worked: 12.00

Project Contribution:

National Academy Member: N

Funding Support:

Participant Type: Postdoctoral (scholar, fellow or other postdoctoral position)

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Participant: Rubens de Souza Matos Júnior

Person Months Worked: 12.00

Project Contribution:

National Academy Member: N

Funding Support:

Participant Type: Postdoctoral (scholar, fellow or other postdoctoral position)

Participant: Jamilson Ramalho Dantas

Person Months Worked: 12.00

Project Contribution:

National Academy Member: N

Funding Support:

CONFERENCE PAPERS:

Publication Type: Conference Paper or Presentation

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Conference Name: IEEE International Conference on Systems, Man, and Cybernetics

Date Received:

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Date Published:

Conference Location: Bari, ITALY

Paper Title: Dependability Evaluation in a Convergent Network Service using BGP and BFD Protocols

Authors: Diogo, Thiago Pinheiro, Jamilson Dantas and Paulo Maciel

Acknowledged Federal Support: **Y**

Publication Type: Conference Paper or Presentation

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Paper Title: Dependability Evaluation of an IoT System: A Hierarchical Modelling Approach

Authors: Eltton Tullyo, Jamilson Dantas, Rubens Matos, Paulo Pereira, Paulo Maciel

Acknowledged Federal Support: **Y**

Partners

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I certify that the information in the report is complete and accurate:

Signature:

Signature Date:

Nothing to report in the uploaded pdf (see accomplishments)