Pós-Graduação em Ciência da Computação

"Discriminative Sensing Based on Signal Processing"

By

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M.Sc. Dissertation

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"Discriminative Sensing Based on Signal Processing"

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Ficha Catalográfica

Signatures

Dedicatory.

Agradecimentos

First and foremost, I would like to thank God for giving me the life, strength, knowledge and opportunity to undertake this research study and to ..

(...)

Thank You!!!

Wherever you go, go with all your heart!

—CONFUCIUS

Resumo

Sistemas distribuídos têm sido utilizados na construção de modernos serviços da Internet e infraestrutura de computação em núvem, com o intuito de obter serviços com alto desempenho, escalabilidade e confiabilidade. Os acordos de níves de serviço adotados pela computação na núvem requerem um reduzido tempo para identificar, diagnosticar e solucionar problemas em sua infraestrutura, de modo a evitar que problemas gerem impactos negativos na qualidade dos serviços prestados aos seus clientes. Então, a detecção de causas de erros, diagnóstico e reprodução de erros provenientes de sistemas distribuídos são desafios que motivam esforços para o desenvolvimento de mecanismos menos intrusivos e mais eficientes, para o monitoramento e depuração de aplicações distribuídas em tempo de execução.

A análise de tráfego de rede é uma opção para a medição de sistemas distribuídos, embora haja limitações na capacidade de processar grande quantidade de tráfego de rede em curto tempo, e na escalabilidade para processar tráfego de rede sob variação de demanda de recursos.

O objetivo desta dissertação é analisar o problema da capacidade de processamento para mensurar sistemas distribuídos através da análise de tráfego de rede, com o intuito de avaliar o desempenho de sistemas distribuídos de um data center, usando hardware não especializado e serviços de computação em núvem, de uma forma minimamente intrusiva.

Nós propusemos uma nova abordagem baseada em MapReduce para profundamente inspecionar tráfego de rede de aplicações distribuídas, com o objetivo de avaliar o desempenho de sistemas distribuídos em tempo de execução, usando hardware não especializado. Nesta dissertação nós avaliamos a eficácia do MapReduce para um algoritimo de avaliação profunda de pacotes, sua capacidade de processamento, o ganho no tempo de conclusão de tarefas, a escalabilidade na capacidade de processamento, e o comportamento seguido pelas fases do MapReduce, quando aplicado à inspeção profunda de pacotes, para extrair indicadores de aplicações distribuídas.

Palavras-chave: Medição de Aplicações Distribuídas, Depuração, MapReduce, Análise de Tráfego de Rede, Análise em Nível de Pacotes, Análise Profunda de Pacotes

Abstract

Distributed systems has been adopted for building modern Internet services and cloud computing infrastructures, in order to obtain services with high performance, scalability, and reliability. Cloud computing SLAs require low time to identify, diagnose and solve problems in a cloud computing production infrastructure, in order to avoid negative impacts into the quality of service provided for its clients. Thus, the detection of error causes, diagnose and reproduction of errors are challenges that motivate efforts to the development of less intrusive mechanisms for monitoring and debugging distributed applications at runtime.

Network traffic analysis is one option to the distributed systems measurement, although there are limitations on capacity to process large amounts of network traffic in short time, and on scalability to process network traffic where there is variation of resource demand.

The goal of this dissertation is to analyse the processing capacity problem for measuring distributed systems through network traffic analysis, in order to evaluate the performance of distributed systems at a data center, using commodity hardware and cloud computing services, in a minimally intrusive way.

We propose a new approach based on MapReduce, for deep inspection of distributed application traffic, in order to evaluate the performance of distributed systems at runtime, using commodity hardware. In this dissertation we evaluated the effectiveness of MapReduce for a deep packet inspection algorithm, its processing capacity, completion time speedup, processing capacity scalability, and the behavior followed by MapReduce phases, when applied to deep packet inspection for extracting indicators of distributed applications.

Keywords: Distributed Application Measurement, Profiling, MapReduce, Network Traffic Analysis, Packet Level Analysis, Deep Packet Inspection

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List of Acronyms

DPI Deep Packet Inspection

EC2 Elastic Compute Cloud

GQM Goal Question Metric

HDFS Hadoop Distributed File System

IP Internet Protocol

I/O Input/Output

JVM Java Virtual Machine

MBFS Message Based Per Flow State

MBPS Message Based Per Protocol State

PBFS Packet Based Per Flow State

PBNS Packet Based No State

PCAP Packet Capture

PDU Protocol Data Unit

POSIX Portable Operating System Interface

RTT Roud-Trip Time

SLA Service Level Agreement

TCP Transmission Control Protocol

UDP User Datagram Protocol

1 Introduction

Though nobody can go back and make a new beginning, anyone can start over and make a new ending.

—CHICO XAVIER

1.1 Motivation

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1.2 Problem Statement

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1.3 Contributions

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1.4 Thesis Organization

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Conclusion and Future Work

The softest things in the world overcome the hardest things in the world.

—LAO TZU

Distributed systems has been adopted for building modern Internet services and cloud computing infrastructure. The detection of error causes, diagnose and reproduction of errors of distributed systems are challenges that motivate efforts to develop less intrusive mechanisms for monitoring and debugging distributed applications at runtime.

Network traffic analysis is one option for distributed systems measurement, although there are limitations on capacity to process large amounts of network traffic in short time, and on scalability to process network traffic where there is variation of resource demand.

In this dissertation we proposed an approach to perform deep inspection in distributed applications network traffic, in order to evaluate distributed systems at a data center through network traffic analysis, using commodity hardware and cloud computing services, in a minimally intrusive way. Thus we developed an approach based on MapReduce, to evaluate the behavior of a JXTA-based distributed system through DPI.

We evaluated the effectiveness of MapReduce to implement a DPI algorithm and its completion time scalability to measure a JXTA-based application, using virtual machines of a cloud computing provider. Also, was deeply evaluated the performance of MapReduce for packet-level analysis and DPI, characterizing the behavior followed by MapReduce phases, its processing capacity scalability and speed-up, over variations of

input size, block size and cluster size.

2.1 Conclusion

With our proposed approach, it is possible to measure the network traffic behavior of distributed applications with intensive network traffic generation, through the offline evaluation of information from the production environment of a distributed system, making it possible to use the information from the evaluated indicators, to diagnose problems and analyse performance of distributed systems.

We showed that MapReduce programming model can express algorithms for DPI, as the Algorithm **??**, implemented to extract application indicators from the network traffic of a JXTA-based distributed application. We analysed the completion time scalability achieved for different number of nodes in a Hadoop cluster composed of virtual machines, with different size of network traffic used as input. We showed the processing capacity and the completion time scalability achieved, and also was showed the influence of the number of nodes and the data input size in the processing capacity for DPI using virtual machines of Amazon EC2, for a selected scenario.

We evaluated the performance of MapReduce for packet level analysis and DPI of applications traffic, using commodity hardware, and showed how data input size, block size and cluster size cause relevant impacts into MapReduce phases, job completion time, processing capacity scalability and in the speedup achieved in comparison against the same execution by a non distributed implementation.

The results showed that although MapReduce presents a good processing capacity using cloud services or commodity computers for dealing with massive application traffic analysis, but it is necessary to evaluate the behaviour of MapReduce to process specifics data type, in order to understand its relation with the available resources and the configuration of MapReduce parameters, and to obtain an optimal performance for specific environments.

We showed that MapReduce processing capacity scalability is not proportional to number of allocated nodes, and the relative processing capacity decreases with node addition. We showed that input size, block size and cluster size are important factors to be considered to achieve better job completion time and to explore MapReduce scalability, due to the observed variation in completion time provided by different block size adopted. Also, in some cases, the processing capacity does not scale with node addition into the cluster, what highlights the importance of allocating resources according with the workload and input data, in order to avoid wasting resources.

We verified that packet level analysis and DPI are Map-intensive jobs, due to Map phase consumes more than 70% of the total job completion time, and shuffle phase is the second predominant phase. We also showed that using whole block as input for Map functions, it was achieved a poor completion time than the approach which splits the block into records.

2.2 Contributions

We attempt to analyse the processing capacity problem of measurement of distributed systems through network traffic analysis, the results of the work presented in this dissertation provide the contributions below:

1. We proposed **an approach to implements DPI algorithms through MapReduce**, using whole blocks as input for Map functions. It was **shown the effectiveness of MapReduce for a DPI algorithm** to extract indicators from a distributed application traffic, also it was **shown the completion time scalability of MapReduce for DPI**, using virtual machines of a cloud provider;

2. We developed *JNetPCAP-JXTA* (**?**), an open source **parser to extract JXTA messages from network traffic traces**;

3. We developed *Hadoop-Analyzer* (**?**), an open source **tool to extract indicators from Hadoop logs and generate graphs** of specified metrics.

4. We **characterized the behavior followed by MapReduce phases for packet level analysis and DPI**, showing that this kind of job is intense in Map phase and highlighting points that can be improved;

5. We **described the processing capacity scalability of MapReduce for packet level analysis and DPI**, evaluating the **impact caused by variations in input size, cluster size and block size**;

6. We **showed the speed-up obtained with MapReduce for DPI**, with variations in input size, cluster size and block size;

7. We **published two papers** reporting our results, as follows:

   (a) Vieira, T., Soares, P., Machado, M., Assad, R., and Garcia, V. *Evaluating Performance of Distributed Systems with MapReduce and Network Traffic*

Analysis. In ICSEA 2012, The Seventh International Conference on Software Engineering Advances. Xpert Publishing Services.

(b) Vieira, T., Soares, P., Machado, M., Assad, R., and Garcia, V. *Measuring Distributed Applications Through MapReduce and Traffic Analysis*. In Parallel and Distributed Systems (ICPADS), 2012 IEEE 18th International Conference on, pages 704 - 705.

2.2.1 Lessons Learned

The contributions cited are of scientific and academic scope, with implementations and evaluations little explored in the literature. However, with the development of this work, some important lessons were learned.

During this research, different approaches for evaluating distributed systems of cloud computing providers were studied. In this period, we could see the importance of the performance evaluation in a cloud computing environment, and the recent efforts to diagnose and evaluate system at production environment of a data center. Also, the growth of the Internet and resource utilization make necessary solutions to be able to evaluate large amounts of data in short time, with low performance degradation of the evaluated system.

MapReduce has grown as a general purpose solution for big data processing, but it is not a solution for all kind of problems, and its performance is dependent of several parameters. Some researches has been done in order to improve MapReduce performance, through analytical modelling, simulation and measurement, but the most relevant contributions in this direction was guided by realistic workload evaluations, from large MapReduce clusters.

We learned that although the facilities provided by the MapReduce for distributed processing, its performance is influenced by the environment, network topology, workload, data type and by several specific parameter configurations. Therefore, an evaluation of the MapReduce behavior using data of a realistic environment will provide more accurate and wide results, while in controlled experiments the results are more restricted and limited to the evaluated metrics and factors.

2.3 Future Work

Because of time constraints imposed on the master degree, this dissertation addresses some problems, but some problems are still open and others are emerging from current results. Thus, the following issues should be investigated as future work:

- **Evaluating of all components of the proposed approach**. This dissertation evaluated the *JNetPCAP-JXTA*, the *AppAnalyzer* and its implementation to evaluate a JXTA-based distributed application, it is necessary to evaluate the *SnifferServer*, *Manager* and the whole system working together, analysing their impact into the measured distributed system and the scalability achieved;

- Development of a **technique for the efficient evaluation of distributed systems through information extracted from network traffic**. This dissertation addressed the problem of processing capacity for measuring distributed systems through network traffic analysis, but it is necessary an efficient approach to diagnose problems of distributed systems, using information of flows, connections, throughput and response time obtained from network traffic analysis;

- Development of a **analytic model and simulations**, using information of MapReduce behavior for network traffic analysis, measured by this dissertation, to reproduce its characteristics and enable the evaluation and prediction of some cases of MapReduce for network traffic analysis;

Bibliography