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**ENHANCED IPFIX FLOW PROCESSING MECHANISM
FOR OVERLAY NETWORK MONITORING**



**DOCTOR OF PHILOSOPHY
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2019**



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Abstrak

Pengkomputeran awan adalah teknologi yang baru muncul. Masyarakat menggunakan teknologi ini pada kadar yang lebih pantas, kerana trafik rangkaian awan ini berkembang pada kadar yang sukar untuk dikendalikan. Alat pemantauan adalah aspek penting dalam pengkomputeran awan dan menjadi lebih menyerlah dengan penggunaan perkhidmatan awan. Rangkaian tindanan menyediakan laluan baru untuk menumpu rangkaian dan bekerja sebagai rangkaian maya bebas di atas rangkaian fizikal. Pada masa kini, teknologi rangkaian tindanan awan dalam infrastruktur awan mempunyai jurang kebolehlihatan, yang bermaksud pembekal awan dan pengguna terlepas isu prestasi utama untuk mengatasi masalah trafik rangkaian tindanan. Justeru, untuk memastikan pengawasan rangkaian dan mengenalpasti potensi masalah, alat pemantauan rangkaian diperlukan untuk mengesan dan melaporkan lebih mendalam bukan sahaja untuk melihat trafik yang tersembunyi tetapi juga menyediakan maklumat berkaitan teknologi rangkaian tindanan awan yang khusus sesuai dengan pusat data skala besar moden. Oleh itu, kajian ini mencadangkan mekanisme peningkatan Eksport Maklumat Aliran IP (IPFIX), mengikuti Kaedah Penyelidikan Reka Bentuk untuk pengawasan rangkaian tindanan awan dengan mengadopsi teknik berasaskan aliran yang fleksibel. Tambahan pula, penyelesaian yang disediakan dalam penyelidikan ini terdiri daripada pelbagai mekanisme: mekanisme penapisan paket yang lebih baik melalui teknik penapisan perbandingan sifat dan teknik penapisan hash-based. Mekanisme klasifikasi aliran berasaskan Virtual Extensible Local Area Network (VXLAN), menggunakan bentuk aliran 6-tupel dan bentuk aliran yang diterima pakai. Mekanisma templat mesej IPFIX yang terdiri daripada kumpulan ruangan merekod data dalam sistem pemproses aliran IPFIX. Penemuan menunjukkan bahawa pendekatan yang dicadangkan dapat menganalisa trafik rangkaian tindanan *multi-tenant* untuk mengenal pasti, menjejaki, menganalisis dan terus memantau prestasi perkhidmatan rangkaian tindanan awan. Selain itu, mekanisme yang dicadangkan adalah sumber yang cekap di mana gabungan Mesej VFMM+6tuple+VXLAN menggunakan 4.63% kurang CPU, manakala gabungan Mesej VHFMM+AFCM+AFCM menggunakan 11.45% kurang CPU daripada IPFIX Standard. Sumbangan kajian ini akan membantu pengendali rangkaian awan dan pengguna akhir untuk menyelesaikan masalah prestasi berasaskan rangkaian tindanan dengan cepat dan secara proaktif dengan kebolehlihatan secara akhir-ke-akhir dan wawasan yang boleh dilakukan.

Kata kunci: Pengkomputeran awan, Rangkaian tindanan, Virtual Extensible Local Area Network, Pemantauan aliran paket.

Abstract

Cloud computing is an emerging technology. People are adopting cloud at a faster rate, due to this cloud network traffic is increasing at a pace which is challenging to manage. Monitoring tool is an essential aspect of cloud computing and becomes more apparent with the acquired of cloud services. Overlay network provides new path to converge network and run as an independent virtual network on top of physical network. Currently, cloud overlay network technologies in cloud infrastructure have visibility gaps, which mean cloud provider and consumers miss out the major performance issues for troubleshooting of overlay network traffic. Hence, to keep a close watch on network and catch potential problems, a network monitoring tool required, to track and report more in-depth for not only see the hidden traffic but also presents the related information of cloud overlay network technologies specifically suited to the modern cloud-scale data center. Therefore, this study proposes an enhanced IP Flow Information Export (IPFIX) mechanism for cloud overlay network monitoring by adopting flexible flow based technique. Furthermore, the solution provided in this research consist of diverse mechanisms: enhanced packet filtering mechanisms using property match filtering technique and hash-based filtering technique. Virtual Extensible Local Area Network (VXLAN) based flow classification mechanisms using 6-tuple flow pattern and adoptable flow patterns. IPFIX message template mechanisms, which is comprise set of fields for data records within the IPFIX flow processing system. The findings demonstrate that the proposed mechanism can capture multi-tenant overlay network traffic to identify, track, analyze and continuously monitor the performance of cloud overlay network services. The proposed mechanisms are resource efficient where the combination of VFMFM+6tuple+VXLAN Message consume 4.63% less CPU, while the combination of VHFM+AFCM+AFCM Message consume 11.45% less CPU than Standard IPFIX. The contributions of this study would help cloud network operators and end-users to quickly and proactively resolve any overlay network based on performance issues with end-to-end visibility and actionable insights.

Keywords: Cloud computing, Overlay networks, Virtual Extensible Local Area Network, Packet flow monitoring

Declaration

Some of the works presented in this thesis have been published or submitted as listed below.

[1] **S. Khurram**, O. Ghazali, F. Shahzad, A. S. Osman “A Survey of Cloud Monitoring: High Level, Low Level, Underlay and Overlay,” in *4th International Conference on Internet Applications Protocols and Services (NETAPPS2015)*, December 1-3, 2015, Cyberjaya, Malaysia.

[2] **S. Khurram** and O. Ghazali, “Design and Development of VXLAN Based Cloud Overlay Network Monitoring System and Environment”, *Information Technology – New Generations. Advances in Intelligent Systems and Computing*, pp. 141-147, vol 738, Springer Nature America, 2018.

[3] **S. Khurram** and O. Ghazali, “A Comprehensive Survey of Cloud Monitoring”, *European Journal of Computer Science and Information Technology (EJCSIT)*, pp. 51-65, vol 6, Issue 5, 2018.

[4] O. Ghazali and **S. Khurram**, “Enhanced IPFIX Flow Monitoring for VXLAN based Cloud Overlay Networks”, *Conference on Mathematics, Informatics and Statistics (CMIS2018)*, October 29-31, 2018, Terengganu, Malaysia.

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Dedication

This dissertation is nicely dedicated to my father the late Rana Shaukat Ali Khan, my mother the late. Shahida Perveen, may Allah reward you with Jannah!

To my beloved wife Saiqa Sadiq and my kids Muhammad Ahyan Khurram and Hibba Khurram your love, patience, words of encouragement and prayers were the best tonic that continued to soothe the fatigue that was always felt.

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List of Abbreviations

API	Application Programming Interface
IaaS	Infrastructure as a Service
IP	Internet Protocol
IPFIX	IP Flow Information Export
LAN	Local Area Network
MAC	Media Access Control
MIB	Management Information Database
NMS	Network Management System
NVGRE	Network Virtualization with Generic Routing Encapsulation
PaaS	Platform as a Service
QoS	Quality of Service
SaaS	Software as a Service
SLA	Service Level Agreement
SNMP	Simple Network Management Protocol
STT	Stateless Transport Tunneling Protocol
UDP	User Datagram Protocol
VLAN	Virtual Local Area Network
VM	Virtual Machine
VNI	Virtual Network Identifier
VTEP	Virtual Terminal End Point
VXLAN	Virtual eXtensible Local Area Network
WAN	Wide Area Network
VHFM	VXLAN based Hash Filtering Mechanism
VFMM	VXLAN Field Match Filtering Mechanism
AFCM	Adaptable Flow Classification Mechanism

CHAPTER ONE

OVERVIEW

This chapter presents a brief introduction to the proposed research. This chapter also presents the general background information of cloud computing along with cloud monitoring and brief overview of cloud overlay networks. The chapter also outlines the problem statement and research questions, research motivation, research objectives, research scope and the significance of the research along with the expected contribution. Finally, the outline of the proposal is presented at the end.

1.1 Background

Cloud computing provide the various computing resources as a service. It is the current iteration of utility computing and returns to the model of resource sharing. The terms “cloud computing” and “cloud” have previously been contentious. According to National Institute of Standards and Technology (NIST)’s definition: “Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction” [1]. Cloud terminology has largely become standardized and has entered the academic lexicon. Today, cloud computing underpins a significant

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