UNIVERSITI PUTRA MALAYSIA

PERFORMANCE EVALUATION OF ADAPTIVE FORWARDING STRATEGY USING STOCHASTIC ADAPTIVE FORWARDING (SAF) IN NAMED DATA NETWORKING

NOR FAIZAH BT JEMANGIN

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By

NOR FAIZAH BT JEMANGIN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Master of Computer Science

June 2018

DEDICATIONS

To my beloved husband, Abd. Rashid Ahmad.
Thank you for the support, encouragement and constant love.

Also, to my supervisor, YM Raja Azlina Raja Mahmood
Your encouragement, support, advice and guidance are outline to my achievement.

Finally, thank you to all my family and friends,
Thank you for the support and encouragement.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Master of Computer Science

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Supervisor : YM Raja Azlina Raja Mahmood
Faculty : Computer Science and Information Technology

In current IP-based network, loop is avoided by routing which have an authority in determining forwarding decision but it prevent efficiency of content dissemination. As future Internet architecture, NDN gives forwarding plane more authority by using forwarding strategy to improved Interest satisfaction ratio and cache hit ratio even in unexpected network status such as link failures. However, there are increased delay whenever simulation times, link failures or number of clients are increased. A number of technologies have been deployed in the current Internet infrastructure to accommodate the new demands for access to content such as Content Distribution Networks (CDN), Load Balancers, and Cloud Services. Although a lot of effort has been made to improved IP-based forwarding plane but it is confined to the data transmission in client-to-server mode or end-to-end. Thus, limiting the adaptability in the forwarding plane function. Unique characteristic of NDN over IP is the adaptability of its forwarding plane on choosing the potential outgoing face or forwarding link when it discovers link failure to achieve quick recovery and manage congestion by load balancing in multiple links. SAF has been introduced by Posch, Rainer & Hellwagner in 2017 as new forwarding strategy in NDN to increase the throughput by using adaptive ability in it. Thus, it gains my interest to study different

perspective of performance such as delay and Interest retransmission in SAF using ndnSIM simulator. The result shows that Stochastic Adaptive Forwarding (SAF) is better than BestRoute in Interest satisfaction ratio by 17.8%, cache hit ratio by 1.8%, delay by 10.5 seconds and Interest retransmission by 22%. Result also shows BestRoute outperforms SAF in hop count by 3.2 hops because its aim is to find the shortest route to the cache or server without evaluating the link performance.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Sarjana Sains Komputer

PENILAIAN PRESTASI STRATEGI MUDAH SUAI PENGHANTARAN MENGGUNAKAN PENGHANTARAN MUDAH SUAI STOKASTIK (SAF) DALAM RANGKAIAN DATA YANG DINAMAKAN

Oleh

NOR FAIZAH BT JEMANGIN

Jun 2018

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Dalam rangkaian semasa yang berasaskan IP, putaran berulang dielakkan oleh penghalaan yang mempunyai kuasa dalam menentukan keputusan penghantaran tetapi ia menghalang kecekapan penyebaran kandungan. Sebagai seni bina Internet untuk masa akan datang, NDN memberi pemproses penghantaran lebih kuasa dengan menggunakan strategi penghantaran bagi mencapai nisbah kepuasan Minat dengan lebih baik dan nisbah jumpa simpanan walau dalam keadaan rangkaian yang tidak diduga seperti kegagalan tautan. Walau bagaimanapun, terdapat kenaikan kelewatan apabila masa simulasi, kegagalan tautan atau bilangan pelanggan dinaikkan. Sebilangan teknologi telah dilaksanakan di dalam infrastruktur Internet semasa untuk menampung permintaan yang baru bagi capaian kepada kandungan di rangkaian pengedaran kandungan (CDN), pengimbang beban dan perkhidmatan awan. Walaupun banyak usaha telah dibuat untuk menambahbaik penghantaran berasaskan IP tetapi ia terhad kepada penghantaran data pelanggan-pelayan atau hujung-ke-hujung. Oleh itu, menghadkan keupayaan penyesuaian diri di dalam fungsi tersebut. Ciri-ciri unik NDN berbanding IP adalah keupayaan menyesuaikan diri dengan menggunakan pemproses penghantaran untuk memilih antaramuka keluar atau laluan penghantaran yang berpotensi apabila ia bertemu laluan yang gagal bagi mencapai

pemulihan yang cepat dan menguruskan kesesakan dengan mengimbangi beban di beberapa laluan keluar. SAF telah diperkenalkan oleh Posch, Rainer & Hellwagner pada 2017 sebagai strategi penghantaran yang baru dalam NDN untuk meningkatkan daya pemprosesan dengan menggunakan keupayaan adaptif di dalamnya. Justeru, saya berminat untuk belajar berkenaan prestasi dari sudut perspektif lain seperti kelewatan dan penghantaran semula Minat dalam SAF menggunakan pensimulasi ndnSIM. Keputusan menunjukkan yang Penghantaran Adaptif Stokastik (SAF) lebih baik daripada LaluanTerbaik dalam nisbah kepuasan Minat sebanyak 17.8%, nisbah jumpa simpanan sebanyak 1.8%, kelewatan sebanyak 10.5 saat dan penghantaran semula Minat sebanyak 22%. Keputusan juga menunjukkan LaluanTerbaik mengatasi SAF dalam bilangan lompatan sebanyak 3.2 lompatan kerana kaedahnya hanya memilih jalan terpendek kepada tempat simpanan atau pelayan tanpa menilai prestasi talian.

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I would like to thank the author of SAF, Mr. Daniel Posch who had provided the simulation program in https://github.com/danposch/ for me to explore and completed this project. He also responses my email even though we never know each other before.

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May Allah blessed all of you. Ameen.

APPROVAL

This thesis submitted to the Faculty of Computer Science and Information Technology of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Master of Computer Science (Distributed Computing).

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Date:

DECLARATION BY GRADUATE STUDENT

I hereby confirm that:

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LIST OF ABBREVIATIONS

Abbreviations	Meaning
AS	Autonomous System
CDN	Content Delivery Network
CS	Content Store
FIB	Forwarding Information Base
ICN	Information Centric Network
IP	Internet Protocol
ISP	Internet Service Provider
LAN	Local Area Network
LFU	Least Frequently Used
FIFO	First In First Out
LRU	Least Recently Used
NDN	Named Data Networking
PIT	Pending Interest Table
RAM	Random-Access Memory
TCP/IP	Transmission Control Protocol/Internet Protocol
WAN	Wide Area Network

CHAPTER 1

INTRODUCTION

1.1 Background

It is all started when Van Jacobson presenting "A New Way to look at Networking" in Google Tech Talk in 2006. This talk introduce a new paradigm of moving the Internet toward a content distribution architecture ("NDN Frequently Asked Questions (FAQ) - Named Data Networking (NDN)," n.d.). In this event, Jacobson had defined ICN as to remove IP address which currently used in Internet communication.

In short, IP is end to end host communication and centred around host address while NDN is focusing on data content names instead of end to end host. This requirement has translated from "where is the server hosting my data?" to "where is my data?" (Aloulou, Ayari, Zhani, Saidane, & Pujolle, 2017) as in Figure 1 taken from http://comnet.ieee.tn/wp-content/uploads/2017/05/Comnet2017_Final.pdf

Figure 1: IP vs NDN
Retrieved from http://comnet.ieee.tn/wp-content/uploads/2017/05/Comnet2017_Final.pdf
(Source: Aloulou, Ayari, Zhani, Saidane, & Pujolle, 2017)

In the same reference as above, a lot of effort has been made to improve the content delivery performance in current IP infrastructure such as using Content Delivery Network (CDN). Although CDN is an effective solution to date but it is not able to optimized the bandwidth usage in local area network (LAN) or in wide area network (WAN), as the data is located in the region data centre. Thus, it has the potential to increase the risk of bottleneck in the network gateways. That is all nodes need to go to the endpoint of the CDN if they want to access the same content. Figure 2 and Figure 3 illustrate how data gets distributed over the IP-based (CDN) and NDN architectures respectively.

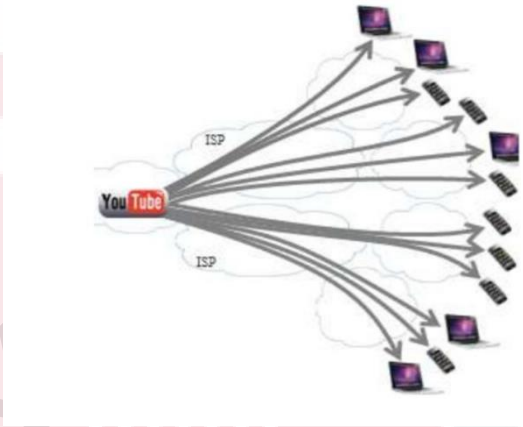

Figure 2: How Data Gets Distributed Over IP-CDN Architectures
Retrieved from http://mustafacanturk.com/named-data-networking/
(Source: Mustafacanturk, 2015)

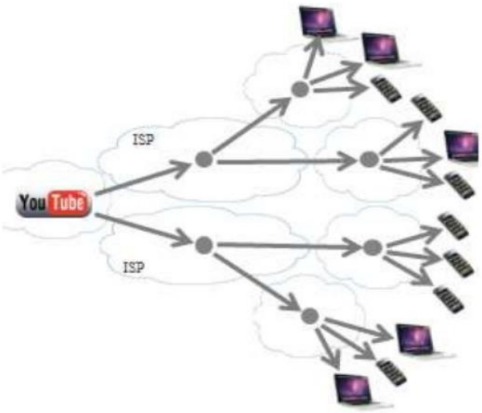

Figure 3: How Data Gets Distributed Over NDN Architectures.
Retrieved from http://mustafacanturk.com/named-data-networking/
(Source: Mustafacanturk, 2015)

Further, the role of Internet is increasing with the demand of Internet of Things (IoT). According to Shang, Yu, Droms and Zhang (2016) the TCP/IP is not suitable to handle IoT environment because it is not effective and efficient as compared to NDN architecture. Cisco forecasted that global IP traffic in 2021 will be equivalent to 127 times the volume of the entire global IP traffic in 2005 ("Cisco Visual Networking Index: Forecast and Methodology, 2016–2021 - Cisco," 2017). Content Delivery Network (CDN) traffic will carry 71 percent of all Internet traffic by 2021 in the same forecast report. Named data networking (NDN) is a promising approach to address the needs of improving content delivery, handling IoT environment and increasing volume of Internet traffic as it is expected to be future of Internet architecture. Instead of sending packets between client and server devices identified by numeric IP addresses in IP network, in NDN the network will send Interest in the form of desired data name without specifying where the data may be located. Routers may satisfy the Interests from router caches, other nodes or original data producer. This will increase user experience in using Internet and lowering cost of service provider who owned the original data producer by reducing number of servers and the amount of bandwidth needed at their datacentre.

According to Yi, Abraham, Afanasyev, Wang, Zhang & Zhang (2014), IP networks make routing as a brain of activity, such as spreads policy information and topology, discovers and recovers from network failures, calculate route meanwhile the data plane only forwards packets based on the Forward Information Based (FIB). However, NDN forwarding react differently which it has adaptive forwarding to handle further changes in network once the above activities have been implemented

without the need to refer back to the routing information. Routing information in NDN only used during first time and for any long-term network changes.

Although a lot of effort has been made to improved IP-based forwarding plane but it is confined to the data transmission in end-to-end or client-to-server mode. Thus, limiting the adaptability in the forwarding plane (Cao et al., 2016).

The forwarding strategy is crucial to the robustness and effectiveness of Named Data Networking (NDN) (Lei, Wang, & Yuan, 2015) and (Cao et al., 2016). The spread of NDN's local caching is an advantage in decreasing duplication of content transmission. However, the behaviour of cached items which can volatile in certain condition calls for an effective and efficient forwarding strategy to significantly improved the performance of data delivery (Yao, Yin, Tan, & Jiang, 2017).

There are two types of forwarding strategies. An adaptive forwarding strategy learns current network status through it face(s) or interfaces to improve future decisions. A static forwarding strategy only relies on the decisions made by the routing protocol and unable to adapt with network changes unless it removes the unperformed face in forwarding information base (FIB) (Ben Abraham, Crowley, & Abraham, 2016).

I have chosen an anchor paper wrote by Posch, Rainer & Hellwagner (2017) about Stochastic Adaptive Forwarding (SAF) in Named Data Networking. It has been published in IEEE Transaction on Networking in April 2017. SAF is focuses to

improved throughput or Interest satisfaction ratio by evaluating the interface performance and diverting Interest to another reliable interface if the current interface become unreliable.

1.2 Problem Statement

In current IP-based network, loop-free can be achieved by routing which have an authority in determining forwarding decision but it prevent efficiency of content dissemination. As future Internet architecture, there have been several researches effort pertaining forwarding strategies in NDN to increase any relevant performance. These include SAF that studied such as Interest satisfaction ratio, cache hit ratio and hop count (Posch, Rainer, & Hellwagner, 2017). However, their work does not evaluate delay and Interest retransmission in different simulation time, different link failures, different number of clients and different number of servers.

1.3 Research Objectives

The aim of this project is to evaluate the performance of stochastic adaptive forwarding (SAF) and comparing it with the BestRoute algorithm in terms of delay and Interest retransmission in different simulation time, different link failures, different number of clients and different number of servers. The project will also evaluate and verify the performance of the two algorithms in terms of Interest satisfaction ratio, cache hit ratio and hop count in the said scenarios.

1.4 Research Scope

This project focuses on evaluating the performance of SAF approach as compared to the current forwarding strategy available in ndnSIM such as BestRoute in NDN. The studied performance parameters are delay, Interest retransmission, Interest satisfaction ratio, cache hit ratio and hop count.

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