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AN EFFICIENT PENDING INTEREST TABLE CONTROL MANAGEMENT IN NAMED DATA NETWORK

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Abstrak

Perangkaian Data Dinamakan (NDN) adalah seni bina Internet memuncul yang menggunakan model rangkaian komunikasi baharu berdasarkan identiti kandungan Internet. Komponen utamanya iaitu Jadual Minat Tertunda (PIT) menyediakan peranan penting dalam merekodkan maklumat paket Minat yang sedia dihantar tetapi masih menunggu padanan paket Data. Dalam pengurusan PIT, isu pensaizan aliran PIT adalah sangat mencabar kerana penggunaan hayat Minat yang panjang secara meluas terutamanya apabila tiada dasar penggantian yang fleksibel sehingga mempengaruhi prestasi PIT. Matlamat penyelidikan ini adalah untuk mencadangkan satu pendekatan Pengurusan Kawalan PIT (PITCM) yang cekap untuk menangani paket Minat yang mendatang bagi mengurangkan limpahan PIT seterusnya meningkatkan penggunaan dan prestasi PIT. PITCM mengandungi mekanisme PIT Maya Mudah Suai (AVPIT), mekanisme Hayat Minat Ambang Pintar (STIL) dan Polisi Hayat Tertinggi Permintaan Terkecil (HLLR). AVPIT bertanggungjawab mendapatkan ramalan awal limpahan PIT berserta tindakan balasnya. STIL adalah untuk menyesuaikan nilai hayat paket Minat yang mendatang manakala HLLR digunakan untuk menguruskan kemasukan PIT secara cekap. Metodologi penyelidikan khusus diikuti untuk memastikan kerapian kerja bagi mencapai matlamat kajian ini. Perisian simulasi rangkaian digunakan dalam merekabentuk dan menilai PITCM. Keputusan kajian menunjukkan bahawa PITCM mengatasi prestasi PIT NDN piawai dengan 45% lebih tinggi kadar kepuasan Minat, 78% lebih rendah kadar penghantaran semula Minat dan 65% penurunan kadar keguguran Minat. Di samping itu, lengahan kepuasan Minat dan panjang PIT dikurangkan dengan ketara masing-masing kepada 33% dan 46%. Sumbangan kajian ini adalah penting dalam pengurusan paket Minat bagi sistem penghalaan dan penghantaran NDN. Mekanisme AVPIT dan STIL serta polisi HLLR boleh digunakan dalam memantau, mengawal dan menguruskan kandungan PIT untuk seni bina Internet masa hadapan.

Kata kunci: Internet Masa Hadapan, Perangkaian Bertumpuan Maklumat, Penghalaan NDN, Pengurusan Giliran Aktif, Simulasi rangkaian.

Abstract

Named Data Networking (NDN) is an emerging Internet architecture that employs a new network communication model based on the identity of Internet content. Its core component, the Pending Interest Table (PIT) serves a significant role of recording Interest packet information which is ready to be sent but in waiting for matching Data packet. In managing PIT, the issue of flow PIT sizing has been very challenging due to massive use of long Interest lifetime particularly when there is no flexible replacement policy, hence affecting PIT performance. The aim of this study is to propose an efficient PIT Control Management (PITCM) approach to be used in handling incoming Interest packets in order to mitigate PIT overflow thus enhancing PIT utilization and performance. PITCM consists of Adaptive Virtual PIT (AVPIT) mechanism, Smart Threshold Interest Lifetime (STIL) mechanism and Highest Lifetime Least Request (HLLR) policy. The AVPIT is responsible for obtaining early PIT overflow prediction and reaction. STIL is meant for adjusting lifetime value for incoming Interest packet while HLLR is utilized for managing PIT entries in efficient manner. A specific research methodology is followed to ensure that the work is rigorous in achieving the aim of the study. The network simulation tool is used to design and evaluate PITCM. The results of study show that PITCM outperforms the performance of standard NDN PIT with 45% higher Interest satisfaction rate, 78% less Interest retransmission rate and 65% less Interest drop rate. In addition, Interest satisfaction delay and PIT length is reduced significantly to 33% and 46%, respectively. The contribution of this study is important for Interest packet management in NDN routing and forwarding systems. The AVPIT and STIL mechanisms as well as the HLLR policy can be used in monitoring, controlling and managing the PIT contents for Internet architecture of the future.

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Keywords: Future Internet, Information-Centric Networking, NDN routing, Active Queue Management, Network simulation.

Declaration Associated with This Thesis

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

[1] **Raaid Alubady**, Suhaidi Hassan and Adib Habbal, "A Taxonomy of Pending Interest Table Implementation Approaches in Named Data Networking", Journal of Theoretical & Applied Information Technology (JATIT), Vol 91, No.2, pp 411-423, (30 September 2016), ISSN: 1992-8645. [Indexed by SCOPUS]

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[3] Suhaidi Hassan, **Raaid Alubady**, and Adib Habbal, "Performance Evaluation of the Replacement Policies for Pending Interest Table", Journal of Telecommunication Electronic and Computer Engineering , Vol. (8), No. (10), pp 125-131, (2016), ISSN: 2180-1843. [Indexed by SCOPUS]

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[5] **Raaid Alubady**, Suhaidi Hassan and Adib Habbal, "Performance Analysis of Reactive and Proactive Routing Protocols in MANET", Journal of Engineering and Applied Sciences (ARPN), Vol.10, No.3, pp. 1468-1478, (2015), ISSN: 1819-6608. [Indexed by SCOPUS]

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Dedication

For my family . . .

my father;

my mother ; and

my brothers and sisters

my wife Rana; and

our children Ali and Retij

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List of Abbreviations

AIMD	Additive Increase Multiplicative Decrease
AQM	Active Queue Management
AVQ	Adaptive Virtual Queue
API	Application Program Interface
AsiaFI	Asia Future Internet BF
AVPIT	Adaptive Virtual Pending Interest Table
AVQ	Adaptive Virtual Queue
BF	Bloom Filter
BGP	Border Gateway Protocol
CBCB	Combined Broadcast and Content-Based
CBF	Counting Bloom Filter
CBN	Content-Based Network
CBR	Constant Bit Rate
CCN	Content Centric Networking
CCNPL-Sim	Content Centric Networking Packet Level Simulator
ccnSim	Content Centric Networking Simulator
CCNx-DCE	Content Centric Networking_x-Direct Code Execution
CDN	Content Delivery Network
CDT	C/C++ Development Tool
CodAn	Code Analysis
COMET	COntent Mediator architecture for content-aware nETworks
CONET	Content-Centric Inter-Network
CRC-32	Cyclic Redundancy Check 32
CS	Content Store
CSMA	Carrier Sense Multiple Access
DDoS	Distributed Denial of Service
DHT	Distributed Hash Table
DiPIT	Distributed Bloom Filter based Pending Interest Table
DNS	Domain Name Service

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DONA	Data-Oriented Network Architecture
DPEL	Dynamic Pending Interest Table Entry Lifetime
DRM	Design Research Methodology
E2E	End to End
ECN	Explicit Congestion Notification
ENPT	Encoded Name Prefix Trie
EU FIA	European Future Internet Assembly
FCFS	First Come First Serve
FIB	Forwarding Information Base
FIE	Forwarding Information Entries
FTP	File Transfer Protocol
GCC	GNU C Compiler
GENI	Global Environment for Network Innovations
GPLv2	General Public License, version 2
GUI	Graphical User Interface
HEP	High Energy and unclear Physics
HLLR	Highest Lifetime Least Request
ICN	Information-Centric Networking
IDE	Integrate Development Environment
ICP	Interest Control Protocol
IDR	Interest Drop Rate
INET	Internet NETtworking
IoT	Internet of Things
ISD	Interest Satisfaction Delay
IP	Internet Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
IRR	Interest Retransmission Rate
ISR	Interest Satisfaction Rate
IT	Index Table
LPM	Longest Prefix Matching

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LRU	Least Recently Used
LSPSIN	Line Speed Publish/Subscribe Inter-Networking
LTI	Long-Term Interest
MA	Mapping Array
MBF	Mapping Bloom Filter
NACK	Negative ACKnowledgment
NAT	Network Address Translation
NCE	Name Component Encoding
NDN	Named Data Networking
ndnSIM	Named Data Networking Simulator
NetInf	Network of Information
NOD	Named DataObject
NPHT	Name Prefix Hash Table
NPT	Name Prefix Trie
NS 2	Network Simulation 2
NS 3	Network Simulation 3
NSF	National Science Foundation
OMNeT++	Objective Modular Network Testbed in C++
OPNET	Optimized Network Engineering Tool
P2P	Point to Point
PARC	Palo Alto Research Center
PEs	Propagation Entries
PEL	Pending Interest Table Entry Lifetime
PHT	Propagating Hash Table
PIT	Pending Interest Table
PITCM	Pending Interest Table Control Management
PQ	Priority Queuing
PS	Packet Store
PSIRP	Publish-Subscribe Internet Routing Paradigm
PURSUIT	Publish-Subscribe Internet Technologies
QoS	Quality of Service

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RED	Random Early Detection
REM	Random Exponential Marking
RLDRAM	Reduced Latency Dynamic Random Access Memory
RTO	Retransmission TimeOut
RTT	Round-TripTime
SAIL	Scalable and Adaptive Internet Solutions
SAVQ	Stabilized Adaptive Virtual Queue
SRED	Stabilized Random Early Drop
SRAM	Static Random Access Memory
STIL	Smart Threshold Interest Lifetime
SVB	Stabilized Virtual Buffer
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
UBF	United Bloom Filter
UGC	User-Generated Content
UPD	User Datagram Protocol
URL	Uniform Resource Locator
V&V	Verification and Validation
VoD	Video on Demand
VPIT	Virtual Pending Interest Table
WSN	Wireless Sensor Networking

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CHAPTER ONE
INTRODUCTION

At the beginning, when the Internet was developed, users were academic in nature; they were merely interested in file transfers, for example, mail exchange [1]. After that, with the develop of new technology, especially the advent of computing devices that have the ability to connect to the Internet, people have more access to the Internet than ever. The old dream of having information at one's fingertips, any place, and any time' is no longer a dream at all. Thus, the generated data traffic has increased at an inconceivable speed and is exhausting network resources, such as available bandwidth and Internet Protocol (IP) address [2]. The popularity of the Internet has caused the data traffic on the Internet to grow dramatically every year during the last several years [3]. The main cause of the Internet growth is to share and distribute information, e.g., academic, social, commercial, mobile video, and cloud computing over the Internet [4].

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In the other words, nowadays, users of networks have evolved significantly to be dominated by content distribution and retrieval, while still the basic infrastructure is dependent on the connection between the End-to-End (E2E) of their IP addresses. Access to content and services requires naming methods since methods include the Uniform Resource Locator (URL), which links content to the Internet hosts [5]. On the other hand, the emergence of new applications, such as social networking [6, 7, 8], Video on Demand (VoD) [9, 10], sensor networking [11], Interactive on-line gaming [12, 13] and Internet of Things (IoT) [14, 15, 16], have led the Internet communication to become named content objects rather than on host-location [17].

In brief, the question is to figure out whether the current architecture and its properties will turn into the restricting component of the Internet development and a new

The contents of the thesis is for internal user only

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