A NEW COORDINATED CACHING PLACEMENT MECHANISM FOR VOD IN NAMED DATA NETWORKING

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DOCTOR OF PHILOSOPHY
UNIVERSITI UTARA MALAYSIA
2025

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Abstrak

Walaupun terdapat kemajuan ketara dalam Rangkaian Data Dinamakan (NDN), pengendalian trafik Video atas Permintaan (VoD) yang cekap masih menjadi cabaran akibat strategi caching yang tidak optimum. Hal ini menyebabkan peningkatan kelewatan hujung ke hujung (E2EDelay) dan beban pelayan yang tinggi. Mekanisme sedia ada sering gagal mengurus permintaan video dalam talian serentak, terutamanya dalam persekitaran rangkaian yang dinamik. Kajian ini menangani ketidakefisienan tersebut dengan mencadangkan satu mekanisme penempatan caching terkoordinasi baharu yang direka khas untuk perkhidmatan VoD dalam persekitaran NDN. Objektif pertama kajian ini adalah menilai ciri fungsian tujuh mekanisme penempatan caching sedia ada melalui simulasi, bagi mengenal pasti keperluan fungsi penting untuk penghantaran kandungan VoD yang optimum. Berdasarkan dapatan ini, mekanisme baharu iaitu Coordination Caching Placement by Video Partitioning (CPVP), diperkenalkan. CPVP bertujuan meningkatkan kecekapan caching, mengurangkan kependaman, dan menambah baik pengalaman pengguna. CPVP menggunakan teori hipergraph untuk memodelkan tingkah laku caching koperatif dalam rangkaian. Ia membahagikan kandungan video secara dinamik dan menyimpan segmen video di sepanjang laluan ke klien melalui tiga penghala yang berdekatan. Mekanisme ini merangkumi tiga skema utama: Video Aggregation Scheme (VAS) untuk mengenal pasti video penuh dan menentukan penghala yang boleh digunakan untuk caching; Video Cache Decision Scheme (VCDS) yang mengurangkan redundansi dan kependaman; serta Video Partitioning Scheme (VPS) yang membahagikan video kepada tiga blok untuk disimpan secara teragih. Simulasi dijalankan menggunakan ndnSIM 2.0 ke atas empat topologi rangkaian, menilai empat metrik prestasi utama. Hasil kajian menunjukkan bahawa CPVP mengatasi mekanisme sedia ada seperti Leave Copy Everywhere (LCE), Leave Copy Down (LCD), dan caching secara kebarangkalian (Prob). Secara khususnya, CPVP mencatatkan pengurangan 22.3% dalam E2EDelay purata dan peningkatan 56.5% dalam nisbah hit cache pada topologi GEANT. Kajian ini menyumbang kepada pembangunan strategi caching yang lebih cekap dalam NDN dan menawarkan peningkatan ketara dalam kualiti penstriman VoD dan prestasi rangkaian.

Kata Kunci: Skim Pengagregatan Video (VAS), Skim Keputusan Cache Video (VCDS), Skim Pembahagian Video (VPS), Hipergraf, Penempatan Cache Penyelarasan oleh Pemisahan Video (CPVP).

Abstract

Despite significant advancements in Named Data Networking (NDN), the efficient handling of Video on Demand (VoD) traffic remains a challenge due to suboptimal caching strategies, resulting in increased End-to-End Delay (E2EDelay) and elevated server load. Existing mechanisms often fail to manage simultaneous online video requests effectively, particularly under dynamic network conditions. This study addresses these inefficiencies by proposing a novel coordinated caching placement mechanism tailored for VoD services in NDN environments. The first objective of the research is to evaluate the functional characteristics of seven existing caching placement mechanisms through simulation, identifying the features essential for optimal VoD content delivery. Building on these insights, a new mechanism, Coordination Caching Placement by Video Partitioning (CPVP), is introduced. CPVP aims to enhance caching efficiency, reduce latency, and improve user experience. CPVP utilises hypergraph theory to model cooperative caching behaviour across the network. It dynamically partitions video content and strategically stores segments along the path to clients using three neighbouring routers. The mechanism incorporates three integrated schemes: the Video Aggregation Scheme (VAS), which identifies the full video and determines cacheable routers; the Video Cache Decision Scheme (VCDS), which minimises redundancy and latency; and the Video Partitioning Scheme (VPS), which divides the video into three blocks for distributed caching. Simulations are conducted using ndnSIM 2.0 across four network topologies, evaluating four key performance metrics. Results demonstrate that CPVP outperforms existing mechanisms such as Leave Copy Everywhere (LCE), Leave Copy Down (LCD), and probabilistic caching (Prob). Specifically, CPVP achieves a 22.3% reduction in average E2EDelay and a 56.5% improvement in cache hit ratio on the GEANT topology. This research contributes to the development of efficient caching strategies in NDN and offers practical improvements in VoD streaming quality and network performance.

Keywords: Video Aggregation Scheme (VAS), Video Cache Decision Scheme (VCDS), Video Partitioning Scheme (VPS), Hypergraph, Coordination Caching Placement by Video Partitioning (CPVP).

Acknowledgements

In the name of ALLAH, Most Gracious, Most Merciful:

"*Work so that Allah will see your work and (so will) his messenger and the believers*;"

(The Holy Quran – AtTawbah 9:105)

Conducting this research marks the end of an exciting and eventful journey. The completion of this dissertation signifies the fulfilment of a long-awaited goal. Without the professional, academic, and personal support of the following excellent and talented people, I could not have achieved this. I will start by extending my deep and sincere gratitude to my two supervisors, AP. Ts Dr. Shahrudin Awang Nor, and Dr. Amran Ahmad (School of Computing, Universiti Utara Malaysia), for their tireless encouragement, wisdom, and experience, who provided me with constant guidance and constructive criticism throughout my research. May Allah give them their reward and make them happy. In addition to my never-ending dedication to my work, I must say a huge thanks to the current and past members of InterNetWorks Research Lab, with whom I enjoyed working. I would like to thank the Internet Society's Next Generation Leaders (NGL) programme while serving as an ISOC fellow for the Internet Engineering Task Force (IETF). Finally, my heartiest gratitude goes to my family... to my late father... and my mother... to my beloved husband Sadaq for his understanding, support, and love... to my clever and loyal sons Jaafer, Osamah, and Abhaj... and my fantastic and lovely daughter Tabarek... and to my dearest and soul sister who always has faith in me and prays for my success.

Declaration Associated with This Thesis

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

[1] Rasha Saleem Abbas, Shahrudin Awang Nor, and Amran Ahmad.“Coordination and Non-coordination Caching Placement Algorithms in Named Data Network for Video on Demand Services,” Journal of Computer Engineering (IOSR-JCE),24(2), pp. 14–21, Sept. 2022.

[2] Rasha Saleem Abbas, Shahrudin Awang Nor, and Amran Ahmad. “A Review of Cache Placement Algorithms for Video on Demand in Named Data Networking,” Journal of Advanced Research in Dynamical and Control Systems (JARDCS), pp. 1322–1332, Sept. 2018.

[3] Rasha Saleem Abbas, Shahrudin Awang Nor, and Amran Ahmad.“A Study of Cache Placement Algorithms for Video on Demand in Named Data Networking, Technical Report, InterNetWorks Research Laboratory, School of Computing, Universiti Utara Malaysia, 2017

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List of Abbreviations

ANDaNA	Anonymous Named Data Networking Application
AODV	Ad-hoc On-Demand Destance Vector
AWS	Amazon Web Services
BAS	Building Automation System
CBEWT	Cache Placement Mechanism Based on Entropy Weighting Method and TOPSIS
CBR	Constant Bit Rate
CBCP	Cache Placement Based on Compound Popularity Mechanism
CCFS	Controller-based Caching and Forwarding Scheme
CCN	Content-Centric Network
CCS	Cooperative Content Store Table
CDC	Cooperative Data Chunk Table
CDN	Content Delivery Network
Centrality	Centrality-based mechanism
CIC	Cooperative Interest Chunk Table
CL4M	Cache Less for More
COBRA	COntentdriven Bloom filter-based intra-domain Routing Algorithm
COMET	COntent Mediator architecture for content-aware nET-works
CONET	COntent centric inter-NETworking architecture
CoRC	Coordinated Routing and Caching
CPIT	Cooperative Pending Interest Table
CPM	Content Placement Mechanism
CPVP	Coordination Placement by Video Partitioning Mechanism
CR	Content Router
Cross	Hybrid caching
CS	Content Store
DASH	Dynamic Adaptive Streaming over HTTP
DONA	Data Oriented Network Architecture
E2EDelay	End-to-End Delay
EgoNet	Egocentric Network study software

FIB	Forwarding Information Base
GB	Giga Byte
HTTP	Hypertext Transfer Protocol
HVAC	Heating, Ventilation, and Air Conditioning
ICN	Information-Centric Network
INFORM	INterest FORwarding Mechanism for Information-Centric Networking
IoE	Internet of Everything
IoT	Internet of Thing
IP	Internet Protocol
ISP	Internet Service Provider
Kb	Kilo bit
LCD	Leave Copy Down
LCE	Leave Copy Everywhere
LFU	Least Frequently Used
LRU	Least Recently Used
MZipf	Maldelbrot-Zipf
Mb	Mega bit
MPD	Media Presentation Description
MPEG-DASH	MPEG-Dynamic Adaptive Streaming
NDN	Named Data Networking
ndn-cxx	NDN C++ library with eXperimental eXtentions
ndnSIM2.0	NDN Simulator version 2.0
NetInf	Network Information
NFD	NDN Forwarding Daemon
non-CBR	Non-Constant Bit Rate
NRENs	Europe's Research & Education Networks
NS3	Network Simulation version 3
NSCC	Not So Cooperative Cache
OTT	Over-The-Top (OTT) media service
PARC	Palo Alto Research Center
PIT	Pending Interest Table

PProb	Path Probabilistic cache
Prob	Probabilistic cache
ProbCache	Content-Aware Caching
PSIRP	Publish and Subscribe Internet Routing Paradigm
PT	Popularity Table
PURSUIT	PUblish Routing SUbscribe Internet Technology
QoE	Quality of Experience
QoS	Quality of Service
QSOD	Questions-Steps-Objectives-Diagram
Rand	Random choice caching
RSA	Rivest Shamir Adleman
RTT	Round Trip Time
SAIL	Scalable and Adaptive Internet Solutions
SD	Standard-Definition
SSD	Smart System Development
SSH	Secure SHell
STEM	Science, Technology, Engineering, and Mathematics
SVC-DASH	Scalable Video Coding-Dynamic Adaptive Streaming over HTTP
SVoD	Subscriptions Video on Demand
TB	Tera Byte
TCP	Transmission Control Protocol
TelNet	Teletype Network
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
TV	TeleVision
UCLA	University of California in Los Angeles
UHD	Ultra-High Definition
VoD	Video on Demand
VoIP	Voice over Internet Protocol

CHAPTER ONE
INTRODUCTION

Over the past decades, the Internet has become one of the most popular tools that are utilised in our everyday lives. With its development being based on Transmission Control Protocol/Internet Protocol (TCP/IP), the Internet has flourished dramatically. This progress is actualised not just because the Internet has many applications, but also because of the different media types that have access to it. However, with this expansive growth and diversification, the network exposes several significant challenges, such as delay, data redundancy, and unexpected interruption. Hence, the focus is on developing and growing future network research [1, 2]. Furthermore, coordinated caching within Named Data Networking (NDN) for Video-on-Demand (VoD) is crucial for enhancing performance, scalability, and user experience. Coordinated caching is a strategic and cooperative approach where caches at different network nodes work together, rather than operating independently, to manage what content is stored, replicated, or evicted.

The initial target of the Internet was to share data between two point-to-point endpoints and offer channels of communication between them. This concept follows the traditional telecommunication network idea. In this process, the function of the identifier and locator of the data holders is handled by the IP address, which is the most essential element for the transmission of packets. For consumers to access data, they need to be initially informed about the location of the data and also be provided with the IP address of the holder. However, many consumers are only concerned about what they can subscribe to and less about where they can obtain the content [3, 4].

To enhance serving the consumer, the development of future networks is needed, such as NDN, which is a new architecture developed by the Palo Alto Research Center

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