FLEXPOP: A POPULARITY-BASED CACHING STRATEGY FOR MULTIMEDIA APPLICATIONS IN INFORMATION-CENTRIC NETWORKING

IKRAM UD DIN

DOCTOR OF PHILOSOPHY
UNIVERSITI UTARA MALAYSIA
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Abstrak

Perangkaian Bertumpuan Maklumat (ICN) adalah senibina Internet masa hadapan yang dominan. Dalam ICN, item kandungan disimpan seketika oleh nod-nod rangkaian seperti penghala. Apabila memori penghala penuh dan tiada lagi ruang untuk kandungan yang baharu tiba, kandungan yang disimpan akan dikeluarkan untuk menangani saiz ruang simpanan penghala yang terhad. Oleh yang demikian, adalah penting untuk membangunkan satu strategi penyimpanan yang berkesan bagi menyimpan kandungan popular untuk jangka masa yang lebih lama. Kajian ini mencadangkan satu strategi penyimpanan yang baharu, dinamakan Penyimpanan Lentur Berdasarkan Popularity (*FlexPop*) bagi penyimpanan kandungan popular. FlexPop mengandungi dua mekanisme iaitu Mekanisme Penempatan Kandungan (CPM) yang bertanggungjawab untuk penyimpanan kandungan dan Mekanisme Pengusiran Kandungan (CEM) yang menangani pengusiran kandungan apabila simpanan penghala penuh dan tiada lagi ruang untuk kandungan yang baharu tiba. Kedua-dua mekanisme ini disahkan melalui Teori Set Kabur, mengikut Kaedah Penyelidikan Reka Bentuk (DRM) yang digunakan dalam penyelidikan ini bagi memastikan kerapian kerja serta keboleh-ulangan di bawah keadaan setanding. Prestasi FlexPop dinilai menggunakan simulasi dan kemudiannya dibandingkan dengan keputusan bagi strategi-strategi Tinggalan Salinan Merata (LCE), ProbCache serta strategi Kandungan Paling Popular (MPC). Keputusan kajian menunjukkan bahawa strategi FlexPop melebihi jangkuan strategi LCE, *ProbCache* dan MPC dari segi kadar sasar simpan, kelewahan, kelengahan perolehan semula kandungan, penggunaan memori dan regangan, yang merupakan metrik-metrik penting (dalam kebanyakan kajian) untuk tujuan penilaian penyimpanan ICN. Hasil yang dipamerkan dalam kajian ini adalah penting untuk membolehkan *FlexPop* diterima oleh pengguna kerana dengannya mereka mampu menentusahkan prestasi ICN sebelum memilih strategi penyimpanan yang sesuai. Justeru, *FlexPop* berpotensi dalam penggunaan ICN untuk Internet masa hadapan umpamanya bagi pengerahan teknologi IoT.

Kata kunci: Perangkaian bertumpuan maklumat, Internet masa hadapan, *FlexPop*, Penempatan kandungan, Pengusiran kandungan

Abstract

Information-Centric Networking (ICN) is the dominant architecture for the future Internet. In ICN, the content items are stored temporarily in network nodes such as routers. When the memory of routers becomes full and there is no room for a new arriving content, the stored contents are evicted to cope with the limited cache size of the routers. Therefore, it is crucial to develop an effective caching strategy for keeping popular contents for a longer period of time. This study proposes a new caching strategy, named Flexible Popularity-based Caching (FlexPop) for storing popular contents. The FlexPop comprises two mechanisms, i.e., Content Placement Mechanism (CPM), which is responsible for content caching, and Content Eviction Mechanism (CEM) that deals with content eviction when the router cache is full and there is no space for the new incoming content. Both mechanisms are validated using Fuzzy Set Theory, following the Design Research Methodology (DRM) to manifest that the research is rigorous and repeatable under comparable conditions. The performance of FlexPop is evaluated through simulations and the results are compared with those of the Leave Copy Everywhere (LCE), ProbCache, and Most Popular Content (MPC) strategies. The results show that the FlexPop strategy outperforms LCE, ProbCache, and MPC with respect to cache hit rate, redundancy, content retrieval delay, memory utilization, and stretch ratio, which are regarded as extremely important metrics (in various studies) for the evaluation of ICN caching. The outcomes exhibited in this study are noteworthy in terms of making FlexPop acceptable to users as they can verify the performance of ICN before selecting the right caching strategy. Thus FlexPop has potential in the use of ICN for the future Internet such as in deployment of the IoT technology.

Keywords: Information-centric networking, Future Internet, FlexPop, Content placement, Content eviction

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

"*As for those who strive hard in Us (Our Cause), We will surely guide them to Our Paths. And verily Allah is with the good doers.*"

(Al-Quran - 29:69)

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Dedication

Dedicated to my whole family . . .

List of Abbreviations

AS	-	Autonomous System
CCN	-	Content-Centric Network
CDN	-	Content Delivery Network
CEM	-	Content Eviction Mechanism
CLS	-	Chunk Caching Location and Searching Scheme
COMET	-	Content Mediator Architecture for Content Aware Network
CPM	-	Content Placement Mechanism
CR	-	Content Router
CS	-	Content Store
CT	-	Comparison Table
DHT	-	Distributed Hash Table
DONA	-	Data Oriented Network Architecture
DoS	-	Denial of Service
DRM	-	Design Research Methodology
DS	-	Descriptive Study
FGPC	-	Fine-Grained Popularity-based Caching
FIB	-	Forwarding Information Base
FIFO	-	First-In-First-Out
FlexPop	-	Flexible Popularity-based Caching
ICN	-	Information-Centric Network
IP	-	Internet Protocol
LAN	-	Local Area Network
LCD	-	Leave Copy Down
LCE	-	Leave Copy Everywhere
LFU	-	Least Frequently Used
LNC	-	Linear Network Coding
LRU	-	Least Recently Used
MADM	-	Multiple Attribute Decision Making
MAUT	-	Multiple Attribute Utility Theory

MCD	-	Move Copy Down
MPC	-	Most Popular Content
NAT	-	Network Address Translation
NCCM	-	Network Coding based Cache Management
NDN	-	Named Data Network
NDO	-	Named Data Object
NetInf	-	Network of Information
PIT	-	Pending Interest Table
PS	-	Prescriptive Study
PSIRP	-	Publish-Subscribe Internet Routing Paradigm
PT	-	Popularity Table
PURSUIT	-	Publisher Subscriber Internet Technology
P2P	-	Peer-to-Peer
RC	-	Research Clarification
SAIL	-	Scalable Adaptive Internet Solution
SAW	-	Simple Additive Weighting
TLRU	-	Time Aware Least Recently Used
TOPSIS	-	Technique for Order Preference by Similarity to Ideal Solution
TSB	-	Time Since Birth
TSI	-	Time Since Inception
VoD	-	Video on Demand
WAN	-	Wide Area Network

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CHAPTER ONE
INTRODUCTION

The existing Internet was intended to address the correspondence demands of a period when a communication network was required to share expensive and rare resources, such as long distance communication links, peripherals, and mainframe computers [1]. The main design rules of the Internet made it possible to connect new systems to the Internet and allowed a remarkable development in its size. However, the inspiring growth of the Internet has offered ascend to new requirements from the design, for example, content dissemination, storage resources, quality of service, mobility, security, scalability, and economics [2]. Moreover, due to its particular implementation and end-to-end approach, the current Internet architecture has many limitations. For example, a variety of add-on patches, such as Point-to-Point (P2P) overlays, Content Delivery Networks (CDNs), Mobile IP, and Network Address Translation (NAT), that were not part of the original design, all violate, in different manners, various features of the initial Internet architecture [3].

Furthermore, the initial protocols and Internet architecture were designed expecting a cooperative and acceptable environment, which is far away from practicality, where lack of privacy and security threats, for example, phishing, Denial of Service (DoS) attacks, and malware, have turned out to be progressively predominant [4]. It has been recently perceived that information-centric usage of the Internet has gained popularity as revealed by the majority being associated with it [5]. This usage brings up a range of design challenges, several of which were not successfully handled by the existing architecture [6]. These challenges include information scarcity, security and liability through controlled information distribution, tussle mediation through information governance, and medium-independent information access.

The contents of the thesis is for internal user only

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