DYNAMIC REDUNDANCY FORWARD ERROR CORRECTION MECHANISM FOR THE ENHANCEMENT OF INTERNET-BASED VIDEO STREAMING

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by

OMAR MOHAMMAD DEEB AL-MOMANI

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ABSTRACT

Video streaming applications over the Internet is suffering many challenges and packet loss is one of the main challenges. This is a result of best-effort services provided by existing IP networks, which does not guarantee packet delivery. Therefore, Forward Error Correction (FEC) is a mechanism used to alleviate the effect of packet losses in the Internet by adding fixed extra packets known as parity packets or redundant packets, which are used to reconstruct the original packets in the event of losses. The use of redundant packet resulted in more consumed bandwidth and increased end-to-end delay. This thesis is concerned with the design and evaluation of FEC error control mechanism. We aimed at addressing the problems faced by the existing FEC mechanism. Thus, a performance evaluation methodology via network simulation and a defined set of key evaluation criteria to test the existing FEC mechanisms under different network conditions and scenarios can be established. Having learnt from evaluation and analyses of existing FEC mechanisms, we found that using a fixed number of redundant packets worsens network performance and video quality. Therefore, an innovative FEC mechanism, called Dynamic Redundancy FEC (DRFEC) is proposed. The design goals of the mechanism are to enhance the video streaming quality over existing IP network by reconstructing loss packets and to enhance network performance by minimising delay and consumed bandwidth. The proposed mechanism was implemented in simulation environment using the NS2 network simulation package. After implementation and verification of these codes in NS2, the performance evaluation of the proposed mechanism was performed. The performance analysis and simulation experiments showed that our proposed mechanism of DRFEC performs better in comparison with the other FEC mechanisms. The DRFEC mechanism was tested with the most used queue polices in today's Internet router, which are the Drop Tail and Random Early Detection queue policies, and with different queue sizes. The results showed that, using the DRFEC mechanism can decrease the consumed bandwidth as compared with the other FEC mechanisms and using the DRFEC mechanism can also decrease the delay as compared with the other FEC mechanisms. Therefore, based on the findings of this study, using DRFEC is a potentially viable mechanism of improving the network performance and video quality.

ABSTRAK

Aplikasi penstriman video menerusi internet menghadapi banyak cabaran dan kehilangan bingkisan merupakan salah satu daripada cabaran utamanya. Ini adalah kerana perkhidmatan usaha terbaik tidak memberi jaminan penghantaran bingkisan oleh rangkaian protokol internet (IP). Oleh itu, mekanisme Pembetulan Ralat ke Depan (FEC) digunakan bagi mengurangkan kesan kehilangan bingkisan di Internet dengan menambah bingkisan tambahan yang dikenali sebagai bingkisan pariti atau bingkisan lewah. Bingkisan pariti ini digunakan untuk membina semula bingkisan sekiranya kehilangan bingkisan berlaku. Penggunaan bingkisan lelebihan ini mengakibatkan penggunaan lebih banyak ruang jalur lebar dan meningkatkan lengah masa hujung ke hujung. Tesis ini adalah berkenaan merekabentuk dan menilai mekanisme kawalan ralat FEC. Matlamat utama penyelidikan ini adalah untuk mengatasi masalah yang dihadapi oleh mekanisme FEC sedia ada. Oleh itu, satu metodologi penilaian prestasi terperinci dengan menggunakan simulasi rangkaian dan satu set kriteria penilaian utama telah dikenalpasti bagi menguji mekanisme FEC sedia ada dalam keadaan dan senario rangkaian yang berlainan. Daripada penilaian dan analisis yang dilakukan terhadap mekanisme sedia ada, didapati bahawa penggunaan bingkisan lelebihan telah memburukkan prestasi rangkaian dan kualiti video. Oleh itu, satu mekanisme inovatif dikenali sebagai FEC Lewah Dinamik (DRFEC) telah dicadangkan. Matlamat utama dalam merekabentuk mekanisme ini adalah untuk meningkatkan kualiti penstriman video melalui rangkaian protokol internet dengan membina semula bingkisan yang hilang dan meningkatkan prestasi rangkaian dengan meminimumkan lengah masa dan penggunaan ruang jalur lebar. Mekanisme yang dicadangkan telah dilaksanakan dalam persekitaran simulasi menggunakan pakej simulasi rangkaian NS2. Penilaian prestasi telah dilakukan terhadap mekanisme yang dicadangkan setelah perlaksanaan dan pengesahan kod-kod dilaksanakan dalam NS2. Analisis prestasi dan eksperimen simulasi telah menunjukkan bahawa mekanisme DRFEC yang dicadangkan menunjukkan prestasi yang lebih baik berbanding mekanisme-mekanisme FEC yang lain. Mekanisme DRFEC telah diuji dengan menggunakan polisi-polisi baris gilir yang banyak digunakan oleh penghala internet seperti Drop Tail dan Random Early Detection dengan saiz baris gilir yang berbeza. Keputusan ujian menunjukkan bahawa dengan penggunaan mekanisme DRFEC, penggunaan ruang jalur lebar berkurangan berbanding dengan mekanisme-mekanisme lain. Penggunaan DRFEC juga mengurangkan lengah masa berbanding mekanisme-mekanisme lain. Oleh itu, berdasarkan dapatan kajian ini, DRFEC merupakan mekanisme yang sangat berpotensi dalam mempertingkatkan prestasi rangkaian dan kualiti video.

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DEDICATION

Dedicated to …….

The memory of my father

My mother and stepmother

My brothers Abbas, Hamzah and Abdullah

All of my sisters and their husbands

DECLARATIONS

Some parts of the work presented in this thesis have been published in the following articles and poster presentation:

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Omar Almomani, Osman Ghazali and Suhaidi Hassan, "Performance Study of Large Block Forward Error Correction with Random Early Detection Queue Policy", in the Proceedings of the 2009 IEEE Symposium in Industrial Electronics and Applications, Kuala Lumpur, Malaysia, October 2009. (Indexed by Scopus and IEEExplore).

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ABBREVIATIONS

AFEC	Adaptive Forward Error Correction
AP	Access Point
AQM	Active Queue Management
ARQ	Automatic Repeat Request
ATM	Asynchronous transfer mode
BAFEC	Burst- aware Adaptive Forward Error Correction
CBR	Constant Bit Rate
CONSER	Collaborative Simulation for Education and Research
DARPA	Defence Advanced Research Projects Agency
DRFEC	Dynamic Redundancy Forward Error Correction Mechanism
EAFEC	Enhanced Adaptive Forward Error Correction
ER	Error Resilience
FEC	Forward Error Correction
FTP	File Transport Protocol
GloMoSim	Global Mobile Simulator
GOB	Group of Blocks
GUI	Graphical User Interface
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
ISO	International Organization for Standardization

ITU-T	International Telecommunication Union/ Telecommunication
LDPC	Low Density Parity Check
LPC	Linear Prediction Code
MDC	Multiple Description Coding
MPEG	Moving Picture Experts Group
NACK	Negative Acknowledgement
NAM	Network Animator
NS2	Network Simulator 2
OTcl	Object-oriented Tool Command Language
PCM	Pulse Code Modulation
PLR	Packet Loss Ratio
PSD	Packet Size Distributions
PSNR	Peak Signal-to-Noise Ratio
QoS	Quality of Service
EC	Error Concealment
RD	Rate Distortion
REAL	Realistic And Large
RED	Random Early Detection
RNG	Random Number Generation
R-S	Reed-Solomon
RTCP	Real-time Transport Control Protocol
RTP	Real-time Transport Protocol
RVLC	Reversible Variable-Length Coding

SAMAN	Simulation Augmented by Measurement and Analysis for Networks
SIP	Session Initiation Protocol
Tcl	Tool Command Language
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol / Internet Protocol
TD	Tail Drop
TTL	Time to Live
UDP	User Datagram Protocol
VBR	Variable Bit Rate
VINT	Virtual Inter Network Testbed
VOD	Video-on-Demand
VoIP	Voice over Internet Protocol

CHAPTER ONE

INTRODUCTION

1.0 Introduction

Video streaming application is utilized intensively in recent years in the revolutionary Internet Protocol (IP) as a result of the massive evolution in advanced software and network technology. Real-time video playback is one of the video streaming applications in which stored video content is streamed from a server to a client upon request. The 3rd Generation Partnership Project (3GPP) specifies the definition of video streaming as follows:

> *"the ability of an application to play synchronized media streams like audio and video in a continuous way while those streams are being transmitted to the client over a data network"* [1].

Video streaming application requires isochronous processing from the end-to-end point of view, because the today's Internet with the concept of best-effort does not provide guarantee of a minimum delay for such sensitive application. As a consequence, video streaming over the Internet is facing enormous degradation with regard to packet

The contents of the thesis is for internal user only

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