FAST CONGESTION NOTIFICATION MECHANISM FOR NEXT GENERATION ROUTERS

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ABSTRAK (BAHASA MALAYSIA)

Matlamat utama tesis ini adalah untuk mengemukakan mekanisma baru kawalan kesesakan proaktif yang dinamakan "Notifikasi Pantas Kesesakan (FN)" untuk penghala TCP/IP berkemampuan ECN. FN telah dibangunkan dan dilaksanakan menggunakan Network Simulator versi 2 (ns-2). Ia menggunakan panjang baris gilir serta merta (semasa) dan kadar purata ketibaan bingkisan untuk membuat keputusan. FN menggugurkan bingkisan yang sampai (jika bukan ECN) dan menandakan bingkisan (jika ECN) pada permulaan baris gilir sebelum limpahan penimbal berlaku. Ini dilakukan bagi mengawal panjang baris gilir semasa (Q_{cur}) agar berada di bawah keperluan panjang baris gilir optimum (Q_{opt}) bagi mengurangkan lengah dan menghindari limpahan penimbal. Ianya juga digunakan untuk mengekalkan kadar purata ketibaan bingkisan (R) sekitar keupayaan kesesakan dan panjang baris gilir. Pada masa ini, mekanisma pengesanan awal rawak (RED) digunakan dalam Internet. RED menggunakan purata panjang baris gilir untuk membuat keputusan kawalan. Pengunaan purata panjang baris gilir membuatkan RED lambat bertindak balas terhadap kesesakan mengakibatkan kelainan dalam saiz baris gilir yang besar serta pengesanan dan pemberitahuan kesesakan yang tidak kena pada masanya menyebabkan penurunan prestasi akibat daripada lengah baris gilir serta merta (semasa) dan kadar purata ketibaan bingkisan yang tinggi. Kombinasi panjang baris gilir serta merta (semasa) dan kadar purata ketibaan bingkisan yang digunakan oleh FN menunjukkan prestasi yang lebih tinggi berbanding RED dalam pengesanan dan pemberitahuan kesesakan yang pantas. Kekangan FN adalah ianya berkesan hanya dengan perhubungan responsif yang memainkan peranan yang besar dalam menghindari dan mengawal kesesakan. Sumbangan utama tesis ini adalah memperkenalkan mekanisma baru pengurusan baris gilir proaktif yang responsif pada kesesakan dengan lebih pantas, memberikan pemberitahuan tepat pada waktinya, dan mengawal panjang baris gilir secara terus yang secara langsung meminimumkan kelainan panjang baris gilir. Kesemua ini dapat membantu meningkatkan prestasi Internet.

ABSTRACT (ENGLISH)

The aim of this thesis is to present a new proactive congestion control mechanism, namely "Fast Congestion Notification (FN)" for TCP/IP ECN-capable routers. FN has been developed and implemented in Network Simulator 2 (ns-2). It uses the instantaneous (current) queue length and the average packet arrival rate to make its control decisions. The new mechanism drops the arriving packets (if non-ECN) and marks packets (if ECN) at the head of the queue before the buffer overflows, to effectively control the current queue length (Q_{cur}) below the required optimal queue length (Q_{opt}) in order to reduce the queuing delay and avoid the buffer overflows; and to maintain the average packet arrival rate (R) about the outgoing transmission link capacity (μ) in order to enable the congestion and queue length control. Currently, Random Early Detection (RED) mechanism is used in the Internet. RED uses the average queue length for making the control decisions. The use of average queue length makes RED reacts to congestion slowly. This results in large queue length variation and untimely congestion detection and notification which would cause performance degradation due to high queuing delays and high packet loss. The combination of the instantaneous (current) queue length and the average packet arrival rate used by FN showed superior performance to that of RED in term of fast congestion detection and notification. The limitation of the new mechanism is that it works only with responsive connections which play a big role in avoiding and controlling the congestion. Since this thesis considers the necessity for modern queue management mechanisms that can control the Internet traffic efficiently and improve the Internet performance, the major contribution of this thesis is to provide a new pro-active queue management mechanism that responds to congestion more quickly, delivers congestion notification timely, and controls queue length directly to congestion which results in minimizing queue length variation. All these would help improve the Internet performance.

DECLARATION

Some of the work presented in this thesis have been published as listed below.

[1] M. M. Kadhum and S. Hassan, "The Effect of ECN on Short TCP Sessions," in *IEEE International Conference on Telecommunications and Malaysia International Conference on Communications (ICT-MICC)*, Malaysia, pp. 708-712, 2007.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ACKs	Acknowledgements
AQM	Active Queue Management
avg	Average Queue Length
AVQ	Adaptive Virtual Queue
B_c	Physical Buffer Capacity
BDP	Bandwidth Delay Product
CBR	Continuous Bit Rate
cwnd	Congestion Window Size
DRED	Dynamic Random Early Detection
$E(X)$	Expected Average of n Numbers
ECN	Explicit Congestion Notification
ERD	Early Random Drop
EWMA	Exponentially Weighted Moving Average
FD	Front-Drop
FN	Fast Congestion Notification
FRED	Flow Random Early Detection
FTP	File Transfer Protocol
IETF	Internet Engineering Task Force
IP	Internet Protocol
ISP	Internet Service Provider
J-Sim	Java-Based Simulation
L	Packet Loss
LPF	Low Pass Filter
LPF/ODA	Low Pass Filter/Over Drop Avoidance

LSE	Least Square Error
Max_{drop}	Maximum Packet Drop Probability
Max_{th}	Maximum Threshold
Min_{th}	Minimum Threshold
MSS	Maximum Segment Size
ns-2	Network Simulator 2
P_f	Final Dropping/Marking Probability
PQM	Passive Queue Management
P_{ini}	Initial Packet Drop/Mark Probability
Q_{cur}	Current Queue Length
Q_{opt}	Optimal Queue Length
QoS	Quality Of Service
$\bar{Q}$	Expected Average Queue Length
R	Average Packet Arrival Rate
RARED	Refined Adaptive RED
RD	Random Drop
REAL	REalistic And Large Network Simulator
RED	Random Early Detection
$\bar{R}$	Mean of Average Packet Arrival Rate
SFB	Stochastic Fair Blue
SMTP	Simple Mail Transfer Protocol
SRED	Stabilize Random Early Detection
T	Time Constant
TCP/IP	Transmission Control Protocol / Internet Protocol
TD	Tail-Drop
thr	Throughput
U	Transmission Link Utilization
$\overline{U}$	Average Transmission Link Utilization
UDP	User Datagram Protocol
VBR	Variable Bit Rate
W	Weight Parameter
W_s	Packet Sliding Window Size
WWW	World Wide Web

CHAPTER ONE

INTRODUCTION

This thesis is about creating a new congestion management mechanism for TCP/IP networks' routers to help control and avoid congestion. The aim of this chapter is to place the thesis in its context. In this chapter, an introduction to computer network congestion issues, the importance of congestion management, and signalling the congestion information are provided in Sections 1.1, 1.2, and 1.3, respectively. Sections 1.4, 1.5, and 1.6 of this chapter, respectively, include the motivation, scope, and objectives of the research presented in this thesis. The contributions of the work done in this thesis are stated in Section 1.7 while the thesis organization is presented in Section 1.8 of this chapter.

1.1 Congestion Issues in Computer Networks

A computer network is a collection of resources which has a finite capacity that causes users to compete for the network resources such as buffers, transmission bandwidth and processing time. As stated by Agnew [1], the limitation of capacity can result in a degradation of performance of the system to the point that the throughput of the system goes to zero. If the network is overloaded, the throughput degradation becomes unavoidable. Networks cannot afford to accept all the traffic that is offered, unless there

The contents of the thesis is for internal user only

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