

CHAPTER ONE

INTRODUCTION

1.1 Overview

As a result of the development of the Internet, many applications can now be used to transmit audio and video data traffic; these applications require high-speed router buffers for the quick transmission of data to potential recipients (Braden et al., 1998; Mehta et al., 2017). Network users compete for available network resources, such as bandwidth and buffer space. A crucial problem associated with the performance of Internet applications is congestion, which occurs at a particular router buffer when the demand for network resources exceeds the available capacity of the buffer (Welzl, 2005; Baklizi et al., 2013). Congestion ultimately causes a decline in the overall performance of the network. Congestion in a network is an incident in which network resources are unable to serve the number of transmitted packets (Ryu et al., 2003). Congestion affects network performance by decreasing throughput and increasing packet loss (PL) rate and queuing delay. It may also induce uneven bandwidth sharing among network sources.

The router plays a significant role in controlling the congestion phenomenon using packet management mechanisms. Packet management mechanisms are typically categorized into two types: queue management (Ryu et al., 2003; Zhang et al., 2011) and scheduling (Malhotra & Sharma, 2012). The former handles the queue length (q_l) in the buffer and controls this length by dropping packets (Joshi et al., 2005). The latter determines the order of packets that will be sent subsequently and is used to allocate bandwidth among flows. In the current research,

we focus on the queue management mechanism in a router. Queue management methods are essential for congestion control because network load changes quickly (Lefelhocz et al., 1996).

Several pre-congestion methods, called active queue management (AQM), have been proposed to control congestion and thereby achieve high quality of services (QoS) for traffic loads. Furthermore, AQM techniques establish a fair share among network sources and provide enhanced control over congestion; examples of AQM techniques include Random Early Detection (RED) (Floyd & Jacobson, 1993), BLUE (Feng et al., 2002), and Stabilized Random Early Drop (SRED) (Ott et al., 1999).

Congestion indicators are at the core of AQM techniques. They provide a clue to the status of congestion to enable optimal reactions. Some AQM methods, such as RED, use average queue length (aql) and ql as congestion indicators to detect congestion at an early stage. These methods react to stabilize the number of packets at a specific level (medium level) using a dropping probability (DP) mechanism.

Although numerous AQM methods have been proposed to maintain the number of queuing packets at a specific value, particularly when traffic changes suddenly, this issue remains a major problem for routers. This problem leads to other consequences, namely, (1) increased average waiting time at the router buffer, (2) increased PL probability (Welzl, 2005; Ahammed & Banu, 2010), and (3) dependence on parameter settings to detect and control congestion.

1.2 Problem Statement

Many AQM methods have been proposed to tune parameters to particular values, and thus, ensure satisfactory performance measure results. Existing pre-congestion control methods do not adapt well when network traffic changes over time.

This leads to waste of network resources in general and increase in probable packet loss along with increasing average waiting time of packets in particular. The BLUE method depends on several parameters in computing packet DP; these parameters include threshold, amount of decreasing DP (P_{de}), and amount of increasing DP (P_{in}). The router buffer decides whether to drop arriving packets according to the DP value. These parameters should be set to specific values to provide a satisfactory performance (Ahmed & Banu, 2010; Da-gang, 2010; Al-Diabat et al., 2012). No specific equation is used for these parameters (Abdeljaber et al.(a), 2007; Al-Diabat et al., 2012), and the dependence of the BLUE method on its parameters (Ahmed & Banu, 2010; Da-gang, 2010; Al-Diabat et al., 2012) generates the problem called BLUE parameterization. Chen and Yang (2009) stated, "BLUE's parameter setting remains a critical unsolved problem". In particular, the settings of the P_{de} , P_{in} , and threshold parameters contribute to performance evaluation. For example, P_{de} in BLUE should be set to a value that is less than that of P_{in} to avoid under-utilization (Feng et al., 2002).

However, the P_{de} and P_{in} parameters cannot be set to any value; instead, they must be set to specific values to obtain a satisfactory performance. Meanwhile, the threshold parameter must be tuned to a specific position on the router buffer to avoid heavy congestion that causes the dropping of many arriving packets and to stabilize the queue length (ql) of BLUE (Feng et al., 2002). When congestion increases, the ql of the BLUE method also increases. This condition may lead to an unmaintained ql around the threshold position, and the ql value can exceed the threshold, thereby leading to the dropping of several packets. However, only a limited number of studies have explored the BLUE method (Abdeljaber et al. (a), 2007; Da-gang, 2010;

Ahmed & Banu, 2010; Al-Diabat et al., 2012). Therefore, we aimed to propose an AQM method as congestion control mechanism based on the BLUE method.

Another problematic situation is the evaluation of existing AQM methods, with evaluation methods that depends on linear the nature of network traffic, which is not sufficient to simulate real Internet traffic (Lim et al., 2009; Lim et al., 2010). However, Internet traffic in which routers are functioning is aggregated by nature (Lim et al., 2009; Lim et al., 2010); aggregated traffic, such as multimedia traffic, is bursty and correlated. Modeling traffic is an essential part of evaluating queue management methods (Karagiannis et al., 2004).

1.3 Research Questions

This research will answer the following questions:

- a) How can the BLUE method be made capable of stabilizing the number of packets in the router buffer at a specific value around the optimal position by considering the nature of traffic (which suddenly changes) to avoid congestion?
- b) How should the performance of the proposed method be evaluated using a traffic model that considers the bursty and correlated nature of Internet traffic?
- c) How should the proposed method be validated?
- d) How should the dependency of the proposed method on its parameter settings be reduced using fuzzy logic (FL)?

1.4 Research Objective

The main aim of this thesis is to propose AQM methods that control congestion at an early stage before buffer overflow by considering the nature of Internet traffic.

The objectives of this thesis are formulated as follows:

- To propose an AQM method based on the BLUE method that dynamically adjust the dropping probability, avoid congestion and enhance the performance of the network. This resulted in having the following sub- objectives:
 - To evaluate the proposed method using Markov Modulate Bernoulli process under bursty and correlated properties of Internet traffic.
 - To validate the proposed method based on statistical analysis and discrete-time analytical model.
- To propose a method using Fuzzy logic based on the method that is developed in the first objective in order to reduce dependency on its parameter settings. As a result, the following sub-objectives have to be accomplished:
 - To evaluate the proposed method compared to some of the recent and well-known methods.
 - To validate the proposed method based on statistical analysis.

1.5 Research Contributions

This study proposes two methods to overcome the problem of network performance degradation when congestion occurs. These two methods are inherited from existing AQM methods. The contributions of this research are stated as follows:

- a. A new AQM method based on a dynamically adaptable dropping mechanism to control the queue in congestion and non-congestion states namely, Gentle BLUE (GB).
- b. Evaluation of the proposed and existing AQM methods using two different packet arrival models, namely, the Bernoulli process (BP) and the Markova Modulated Bernoulli process (MMBP).
- c. Validation of the proposed method based on a discrete-time analytical model.
- d. A new AQM method based on Fuzzy Logic (FL) to control queue and reduce the parameterization problem.

1.6 Organization of the Thesis

This thesis is organized into six chapters. This chapter (Chapter One) introduces the principles behind network congestion control along with the research problem, questions, objectives, and contributions.

Chapter Two presents the literature review, background, and the fundamental concepts related to the congestion problem and congestion control techniques. The gaps in the literature, the motivation behind the proposed and designed methods for congestion control are discussed.

Chapter Three covers the methodology phases in detail and the procedure used to analyze the correctness and efficiency of proposed methods. In addition, discrete-time performance analyses approach for GB method under bursty and correlated traffic that uses MMBP-2. Moreover, explains the performance measures used to evaluate the proposed methods.

Chapter Four covers the implementation of the proposed methods (GB, GB-MMBP-2 and GBFL), Simulation environment, parameters setting of the proposed methods. Furthermore, explanation of simulation cycle, performance measures and validation model calculations.

Chapter five comprises the analysis and discussion of the performance of each proposed method in the experiments. In addition, a discrete-time analytical model for the proposed GB method is established and the analytical model is provided along with the results.

Chapter six provides the conclusions and recommendations for further research.

