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FAIR BANDWIDTH DISTRIBUTION MARKING AND SCHEDULING ALGORITHM IN NETWORK TRAFFIC CLASSIFICATION

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By

AMEEN MOHAMMED ABDULKAREM AL-KHARASANI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

January 2019

DEDICATIONS

I would like to dedicate this thesis
To my late mother who taught me to use what I have learned to help people.
To my late father who taught me that a wish with hard work would come true.
They taught me to be brave and patient.
To my brothers, my sisters, my wife, and my wonderful kids.
To my supervisor and entire committee.
"YEMEN ".

&

To all whom I love.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman: Mohamed Othman, PhD
Faculty: Computer Science and Information Technology

The traffic classification has the ability to solve and manage many network difficulties and problems for network management and service providers. Despite these efforts, various challenging tasks still remain unsolved in DiffServ. The concept DiffServ network defines two main routers. First, an edge router that is involved in marking, shaping or issuing the policy for flows based on their SLAs. Second, core routers which offer the schedule of different traffic using the marks they carry from the edge router. However, DiffServ fails to provide individual flow guarantees, but it provides statistical guarantees of service classes.

This thesis focuses on the fair share of excess bandwidth distribution among aggregates flow; First, analyse the effect of aggregate based marking schemes on the fair sharing of excess bandwidth among aggregates. Second, propose an Optimized Time Sliding Window based Three Colour Marker. Finally, propose a new method of obtaining optimal parameters dropping functions for Random Early Detection (RED) algorithm.

The analytical model was improved, computing the marking probability can be used in the planning of a network architecture. They can be useful for taking a decision on choosing concrete values of traffic classification environments element parameters in a real network. Appropriate selection of configuration parameters of network elements is crucial for providing a certain level of QoS for customers as well as for fulfilling the SLA. Careful scrutiny of markers and droppers characteristics, as well as characteristics of a compound network architecture, supports such a decision.

Therefore, in order to improve bandwidth fairness along with efficient optimization to alleviate this problem, we propose two marker algorithms; a Double Modified Double Improved time sliding window Three Colour Marker (M^2I^2TSWTCM) algorithm, which makes a new value of γ that depends on the logarithm peak information rate (PIR) and which is added to the adaptive factor that exists in the previous algorithm. Second, an Optimized time sliding window packet marker (OTSWTCM) algorithm. This algorithm depends on the adaptability of the γ concept in the ITSWTCM, I^2TSWTCM and M^2I^2TSWTCM algorithms for affecting the fairness and multiple protocols. This is achieved by using a new design algorithm by separating marker TCP and UDP protocols and extended the marking probability for injecting more green and yellow traffic into the network. In addition, the marking probability mechanism was studied to check how the parameters in the traffic rate affect fairness.

Additionally, the traffic are relying on the markers and scheduling algorithms to the service classes at the routers. The higher level priority agreements give a higher or equal probability than the lower level, this technique is perfect at a core router by scheduling algorithm. Thus, proposing the method of reestimating the dropping functions in the RED algorithm. This method manages resources at the core routers to guarantee the QoS. The main goal in this part is not only to improve bandwidth fairness, but also to improve average throughput and reduce the average delay and packet loss. More importantly, integrating the marker with scheduler algorithms in order to reduce the traffic loss and improve bandwidth fairness.

Several simulation experiments and analytical models have been presented with respect to traffic classification environments and scenarios. This enables evaluating the performance of the proposed mechanisms compared with the existing various approaches. The simulation results show that the proposed mechanisms significantly improve edge and core routers' performance at traffic classification network. The improvement goal is not only to fairly share excess bandwidth distribution among aggregates, but also to reduce the average delay and packet loss. Moreover, it satisfies the stringent requirements for supporting real-time services in terms of traffic loss, end-to-end delay as well as fairness.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGAGIHAN JALUR LEBAR SAKSAMA PENANDAAN DAN ALGORITMA PENJADUALAN DI RANGKAIAN KLASIFIKASI LALU LINTAS

Oleh

AMEEN MOHAMMED ABDULKAREM ALKHARASANI

Januari 2019

Pengerusi: Mohamed Othman, PhD
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Klasifikasi lalu lintas mempunyai keupayaan untuk menyelesaikan dan mengurus banyak kesukaran dan masalah untuk pengurusan rangkaian dan penyedia perkhidmatan. Dengan usaha ini, pelbagai tugas mencabar masih tidak dapat diselesaikan di DiffServ. Konsep rangkaian DiffServ mentakrifkan dua penghala utama. Pertama, penghala tepi yang terlibat dalam menandakan, membentuk atau mengeluarkan dasar untuk aliran berdasarkan SLA mereka. Kedua, penghala teras yang menawarkan jadual lalu lintas yang berbeza menggunakan penandaan yang mereka bawa dari penghala tepi. Walau bagaimanapun, DiffServ gagal memberikan jaminan aliran individu, tetapi ia memberikan jaminan statistik kelas perkhidmatan.

Tesis ini memberi tumpuan kepada bahagian saksama pengagihan jalur lebar yang berlebihan di antara aliran agregat; Pertama, analisa kesan skema penandaan berdasarkan agregat pada perkongsian adil lebihan jalur lebar di kalangan agregat. Kedua, mencadangkan Tetingkap Gelongsor Masa Dioptimumkan berdasarkan Penanda Tiga Warna. Akhir sekali, cadangan kaedah baru untuk mendapatkan parameter optimum yang menjatuhkan fungsi untuk algoritma Pengesanan Awal Rawak (RED).

Model analisis telah diperbaiki, bagi mengira kebarangkalian penandaan boleh digunakan dalam perancangan seni bina rangkaian. Ia boleh menjadi kepentingan untuk pembuatan keputusan mengenai pemilihan nilai-nilai konkrit parameter dalam klasifikasi persekitaran lalu lintas rangkaian sebenar. Pemilihan parameter konfigurasi yang sesuai bagi elemen rangkaian adalah

penting untuk menyediakan tahap QoS tertentu untuk pelanggan serta untuk memenuhi keperluan SLA. Pengawasan berhati-hati terhadap ciri-ciri penanda kejatuhan, serta ciri-ciri seni bina rangkaian kompaun, menyokong keputusan sedemikian.

Oleh itu, untuk meningkatkan kesaksamaan jalur lebar dengan mempunyai pengoptimuman yang cekap untuk mengurangkan masalah ini, kami mencadangkan dua algoritma penanda; Tetingkap Gelangsar Masa Penanda Tiga Warna Pengubahsuaian Berkembar Peningkatan Berkembar (M^2I^2TSWTCM), yang memberikan nilai baru γ yang bergantung pada kadar maklumat puncak logaritma (PIR) dan yang ditambah kepada faktor penyesuaian yang wujud dalam algoritma sebelumnya. Kedua, algoritma Tetingkap Gelangsar Masa Penanda Paket Optimum (OTSWTCM). Algoritma ini bergantung kepada kesesuaian konsep dalam algoritma ITSWTCM, I^2TSWTCM dan M^2I^2TSWTCM untuk mempengaruhi kesaksamaan dalam pelbagai protokol. Ini dapat dicapai dengan menggunakan algoritma reka bentuk baru dengan memisahkan penanda protokol TCP dan UDP dan memperluaskan kebarangkalian penandaan dengan menyuntik lebih banyak lalu lintas hijau dan kuning ke dalam rangkaian. Di samping itu, mekanisme kebarangkalian penandaan telah dikaji untuk melihat bagaimana parameter mempengaruhi kesaksamaan dalam kadar trafik.

Di samping itu, lalu lintas bergantung kepada penanda dan penjadualan algoritma kepada kelas perkhidmatan di penghala. Perjanjian keutamaan tahap yang lebih tinggi memberikan kebarangkalian yang lebih tinggi atau sama rata dari tahap yang lebih rendah, teknik ini bersesuain digunakan di penghala teras dengan algoritma penjadualan. Oleh itu, kaedah untuk menggerakkan fungsi penjatuhan dicadangkan dalam algoritma RED. Kaedah ini menguruskan sumber pada penghala teras untuk menjamin QoS. Matlamat utama di bahagian ini bukan sahaja untuk meningkatkan kesaksamaan jalur lebar, tetapi juga untuk meningkatkan keupayaan purata dan mengurangkan kelewatan purata dan kehilangan paket. Lebih penting lagi, adalah untuk mengintegrasikan penanda dengan algoritma penjadualan untuk mengurangkan kehilangan trafik dan meningkatkan kesaksamaan jalur lebar.

Beberapa eksperimen simulasi dan model analisis telah dibentangkan berkenaan dengan persekitaran dan senario pengelasan lalu lintas. Ini membolehkan penilaian terhadap prestasi mekanisme yang dicadangkan berbanding dengan pelbagai pendekatan yang sedia ada. Hasil penyelidikan menunjukkan bahawa mekanisme yang dicadangkan dengan ketara meningkatkan kelebihan prestasi penghala teras pada rangkaian klasifikasi lalu lintas. Matlamat penambahbaikan bukan sahaja untuk berkongsi pembahagian jalur lebar yang agak banyak di kalangan agregat, tetapi juga untuk mengurangkan kelewatan purata dan kehilangan paket. Selain itu, ia memenuhi keperluan yang ketat untuk menyokong perkhidmatan masa nyata dari segi kehilangan trafik, keterlambatan hujung ke hujung serta kesaksamaan.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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This is to confirm that:
- the research conducted and the writing of this thesis was under our supervision
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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LIST OF ABBREVIATIONS

AF	Assured Forwarding
AQM	Active Queue Management
AQMRD	Adaptive Queue Management with Random Dropping
ARED	Adaptive Random Early Detection
AS	Assured Service
ATM	Asynchronous Transfer Mode
AWK	Alfred Aho, Peter Weinberger and Brian Kernighan
BA	Behavior Aggregates
BE	Best Effort
CBR	Constant Bit Rate
CIR	Committed Information Rate
CoS	Class of Service
CR	Core Router
DiffServ	Differentiated Services
DSCP	Differentiated Services Code Point
ECN	Explicit Congestion Notification
EF	Expedited Forwarding
ER	Edge Router
FARED	Fast Adapting Random Early Detection
FIFO	First-In-First-Out
FIO	First Input and Output
FRED	Flow Random Early Drop
FTP	File Transfer Protocol
FWMRED	Fair Weighted Multi-level Random Early Detection
GRED	Gentle Random Early Detection
H(x)	Heaviside step function
HTTP	Hypertext Transfer Protocol
I^2TSWTCM	Double Improved Time Sliding Window Three Colour Marker
IETF	Internet Engineering Task Force
IntServ	Integrated Services
IoT	Internet of Things
IP	Internet Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
ITSWTCM	Improved Time Sliding Window Three Colour Marker
LAN	Local Area Network
LTE	Long-Term Evolution
M^2I^2TSWTCM	Double Modified Double Improved Time Sliding Window Three Colour Marker
MI^2TSWTCM	Modified Double Improved Time Sliding Window Three Colour Marker
MMPP	Markov Modulated Poisson Process
MPLS	Multi Protocol Label Switching

MRED	Random Early Discard or Random Early Drop
MSS	Maximum Segment Size
NS-2	Network simulator version 2
OTSWTCM	Optimized Time Sliding Window Three Colour Marker
PaITSWTCM	Provision aware Improved Time Sliding Window Three Color Marker
PAPTCM	Provision Aware Proportional fair sharing Three Color Marker
PDF	Probability Density Function
PHB	Per-Hop Behaviour
PIR	Peak Information Rate
QoS	Quality of Service
RBN	Reverse Beacon Networks
Re-ARED	Refined Adaptive Random Early Detection
RED	Random Early Detection
REM	Random Exponential Marking
RIO	RED Input and Output
RR	Round Robin
RSVP	ReSerVation Protocol
RTT	Round Trip Time
SDN	Software-defined networking
SLA	Service Level Agreement
SrTCM	Single Rate Three Color Marker
TCP	Transmission Control Protocol
TOS	Type of Service
TRED	Three-section Random Early Detection
TrTCM	Two Rate Three Color Marker
TSW	Time Sliding Window
TSWTCM	Time Sliding Window Three Colour Marker
UDP	User Datagram Protocol
UPN	Under Provisioned Network
V2R	Vehicle-to-Roadside
V2V	Vehicle-to-Vehicle
VoIP	Voice over IP
VoLTE	Voice over Long-Term Evolution
WAN	Wireless Area Network
WFQ	Weighted Fair Queuing
WRED	Weighted Random Early Detection
WRR	Weighted Round Robin

CHAPTER 1

INTRODUCTION

This chapter provides a background and an overview of traffic classification network, identifies the research problems and motivation. It also presents the research objectives, describes the scope of this research. Furthermore, this chapter highlights the research significance, justifies the benefits, and clarifies the implications of this research. Finally, this chapter summarizes with the organization of the thesis.

1.1 Background

Guaranteeing high-quality performance or critical applications, the Quality of Service (QoS) is the set of standards used for such tasks in communication networks. Often understood as a network capability to improve the services in selected network traffic over various technologies [5].

Traditionally in real-time communication, the QoS depends on the time at which messages are successfully delivered to the recipients. QoS requirements is typically having the three general categories of performance metrics, such as a proliferation of fixed bandwidth, delay sensitive real-time applications that deploy aggressive transport layer protocols and packet drop. Without implementing any requirements, the internet best effort service is offered for every user. The rapid growth of the internet and its irreplaceability made it important to efficiently handle service delivery for applications such as Voice over IP (VoIP), Video on Demand (VoD) and Internet Protocol Television (IPTV); the efficiently manage bandwidth becomes a challenging. Thus, the internet has to develop an algorithms at routers to provide some degree of QoS.

In general, dropping a packet, giving queuing preference, policing, shaping or fragmenting are most common problems in traffic classification. The marker in traffic classification gives a large role to solve these problems.

Marking in traffic classification will change specific bits in the packet header. The QoS tools of traffic classification will check the marked bits to classify the traffic. Most QoS tools classify the traffic in which allows each class or type of traffic to receive a various level of process priority from other traffic classes [6].

The Integrated Services (IntServ) [7] and Differentiated Services (DiffServ) [1, 8] networks uses data network for applications communication which were defined by Internet Engineering Task Force (IETF) to meet QoS requirements as two approached for network architecture. While both guarantee QoS, DiffServ approach guarantees at an individual router level, however, Intserv approach at individual connection level [9, 10]. Optimizing QoS service classes in DiffServ through Per-Hop Behaviour (PHB) mechanism was then provided by IETF [2, 11]. The delay and sensitivity of the traffic flows are maintained by the queues of Expedited Forwarding (EF) which is the first class of QoS. The scale of reliable traffic flows is then provided by Assured Forwarding (AF) which is the second class [12, 13, 14]. To ensure that applications gets its deserved QoS, many technologies were developed by the IETF which require resources such as bandwidth and buffers to be explicitly reserved for a given data flow. Hence, multi traffic flows with problem buffers congestion is also a challenge. The DiffServ networks is not designed to provide individual flow guarantees, but it provides statistical guarantees of service classes.

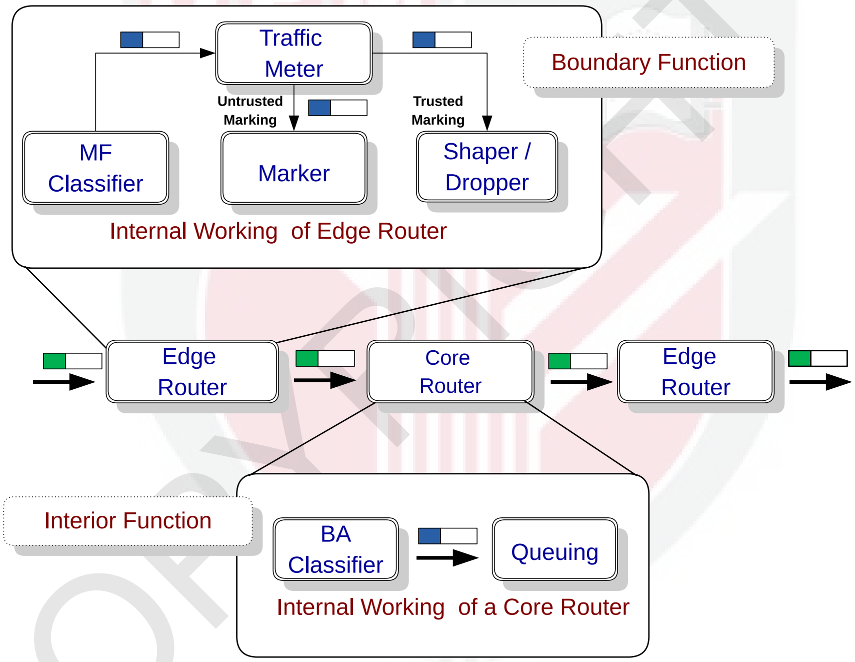

Figure 1.1: DiffServ Management Domain Approaches [3].

Core routers and edge routers are the two main router of DiffServ architecture. Figure 1.1 shows managed flows in the edge router which is classified as meter or marked traffic and are placed into various levels of priority, as well as traffic shaping and dropping in the forwarding classes. Depending on queue algorithm and marker, core router process traffic on the basis of their service classes [15, 16]. Red, yellow and green are the three color or different level of agreements in traffic are marked with depending on the priority level where higher level have higher or equal probability than the lower level [2, 11, 15], such that of Time Sliding Window Three Colour Marker (TSWTCM). Queueing algorithms such as Weighted Round Robin (WRR), Weighted Fair Queuing (WFQ), Weighted Random Early Detection (WRED) and Random Early Detection (RED) with an RED Input and Output (RIO) are the mean in which this mechanism is performed [15, 16]. Guaranteeing QoS in the DiffServ network is hindered by several caused some of which are unfairness problem of sharing bandwidth among flow aggregates [17, 18, 19]. Thus, to improve and find the optimal solution for the fair sharing of the Transmission Control Protocol (TCP) flow aggregates, many algorithms were designed.

1.1.1 Traffic Classification

Traffic classification identifies an income stream of traffic that may require service differentiation and separate it into N logical separate traffic streams based on specified rules (also referred to as packet filtering). There are two types of classifiers have been defined [20]: the Behaviour Aggregate classifier and the multi-field classifier. The behaviour aggregate classifier is classifying the network traffic based on the DiffServ code point only, while the multi-field classify by selecting the network traffic based on the combination value of one or more header fields. The objective is to guarantee QoS Scalability in DiffServ, thus, the DiffServ is include three targets, which depending on the traffic classification to provide differentiated service levels basis, the targets of the DiffServ as follows:

- Specify and classify traffic into category.
- Mark traffic on trust limit.
- Build the policies to lead the PHB for the classified traffic.

The criteria of the classified traffic are as:

- Incoming interface (Policies).
- Application type.
- Internet Protocol (IP) address for Source or destination.
- Class of Service (CoS) value in an Ethernet header.
- Type of Service (TOS) (IP Precedence or Differentiated Services Code Point (DSCP)).
- Multi Protocol Label Switching (MPLS) experimental bits value in a MPLS header.

In a typical Wireless Area Network (WAN) and Local Area Network (LAN), different types of network applications have special requirements with respect to the network performance such as bandwidth, jitter and delay. These unique heterogeneous applications are transfer the traffic through the flows in the network. However, to meet these requirements, the usability, and quality of these applications have to severe compromise and challenges, thus, to properly prioritize different applications across the limited WAN bandwidth, traffic management must exist to ensure that these requirements are met. Furthermore, network manager needs to implement appropriate security policies in which a proper understanding of the applications and protocols in the network traffic is essential.

In fact, the DiffServ should be marked as traffic and added to the required level of QoS service at the Layer-2 header or the Layer-3 header. These marks will help the router to determine the appropriate service policies to be applied for those flows.

1.1.2 Traffic Marker

The traffic classification is a mechanism that distinguishes the applications or protocols, while the marking is the method that colours the traffic based on specific classification policies, which used at the edge routers to provide suitable treatment for those traffics. There are several traffic flows can be defined as standard marks, which used at network layer (layer 3) and at data link layer (layer 2) [1, 2, 21].

• **Data Link Layer (Layer 2)** is the IEEE 802.1 Q/p standard wherein 3-bits of an additional 16-bits inserted into the header of the Ethernet frame, where it can be used to designate the priority of the frame. The CoS in network interface must be present and enabled to process 802.1 Q/p tags. Traffic with 802.1 Q/p tags will then be generated by the enabled network interface, as governed by QoS capable applications. Inserted tags are not available with the general network communication by default [22, 23, 21].

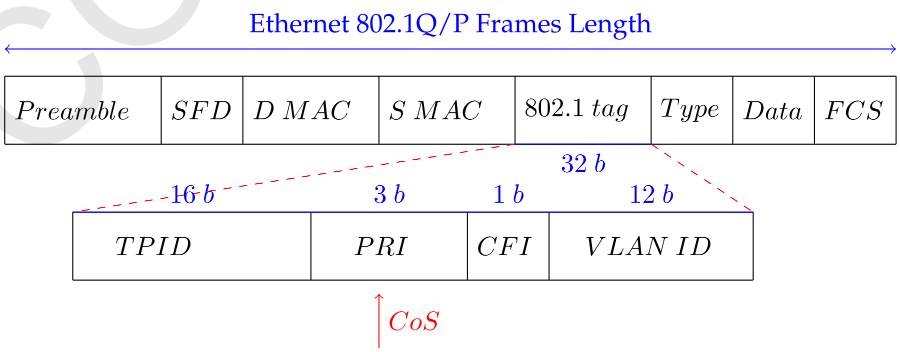

Figure 1.2: Ethernet Header [4].

Class of Service (CoS) is a mechanism to manage various traffic profiles in the network by giving confirmed types of traffic priority over each others. CoS does not offer guarantees with bandwidth or delivery time like QoS because it is based on the best effort. It only operates on one type value can be used to classify traffic based on Table 1.1 to meet requirements in Ethernet network 802.1 Q/P frame file at Figure 1.2 [23, 21].

Table 1.1: CoS and Definitions [1].

CoS (bits)	Type	Application
000	Routine	Best-Effort
001	Priority	Medium Priority
010	Immediate	High Priority
011	Flash	Call Signaling
100	Flash-Override	Video Conferencing
101	Critical	Voice Bearer
110	Internet	inter-network control
111	Network	Network Control

• **Network Layer (Layer 3)** uses the 8-bit in the design IP header traffic to achieved marking, it is called TOS field. The TOS use two marking methods, IP Precedence and DSCP; which divided to the first 3-bits and the first 6-bits respectively. Figure 1.3 describe that [1, 22, 23].

IP Precedence: Each IP traffic stander includes a TOS byte in both Internet Protocol version 4 (IPv4) and Internet Protocol version 6 (IPv6). This field use to reinforcement the appropriate QoS commitments. The IP's traffic precedence value define the operation type, the router will drop the traffic with the low priority when the case of congestion. Table 1.2 and Figure 1.3 describe the IP precedence value with the operation type and its application serves [2, 22, 23].

Table 1.2: Size and Shape Distribution for a Sampled Rock Riprap [1].

IP Precedence (bits)	Type	Application
000	Routine	Best-Effort
001	Priority	Medium Priority
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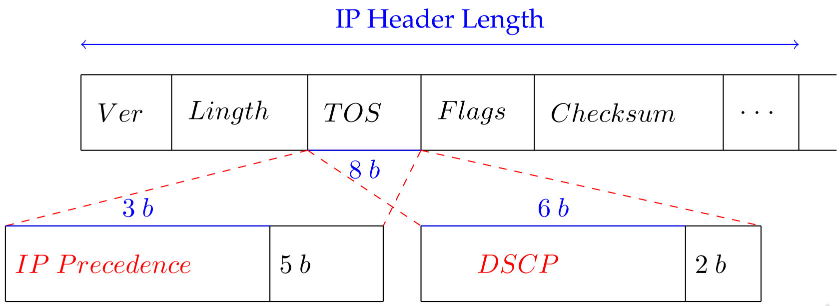

Figure 1.3: IP Header ToS Byte [1].

Differentiated Services Code Point (DSCP): The concept of DiffServ was proposed to move traffic to edge network to mark them then to core network to regulate them by dropping according to the color marked. However, lower flexibility and fair share among aggregate is encountered from the QoS provided by DiffServ when supporting the network. Using scheduling and queuing algorithms, PHBs implemented in DiffServ network nodes process using markers and shapers as its effective elements causing the problem of unfairness in the DiffServ. [1] defined the use of DSCP bits and various QoS mechanism to provide different QoS levels in network. Traffic conditioning and PHB are the two main components of DiffServ. The first happen in the edge router where traffic are marked, shaped, coloured and policed while the second consists of essentially scheduling, dropping and queuing mechanisms [1, 2, 22, 23, 21].

PHB mechanisms are divided into three classes by DiffServ [2, 24, 25, 26]; the first class, Classic Best Effort (BE), guarantees QoS level. The second class, EF, maintains short delay for the traffic flows. Finally, AF class which has four subclasses with three dropping level each to ensure minimum throughput level. The colors in which mark packets are green, yellow, and red. Green packets have higher receiving priority followed by yellow packets, while red packets have the lowest priority and the higher dropping probability [2, 15, 25]. Additionally, DiffServ is made of two main routers; edge router which classify traffic and apply traffic conditioning from various sources then inject the treated packets into the core router where the forwarding mechanism is done implementing an active queue management algorithm such as RED based on In/Out RIO or First In/Out First Input and Output (FIO) [15, 27].

The implementation of PHBs depends on the scheduling and queuing algorithm used in switches or routers, and the excess core bandwidth in a DiffServ network is shared among flows instead of aggregates in the existing TSWTCM. A small service subscriber will inject more yellow traffic than a large service subscriber leading to unfairness. The main cause of this unfairness problem is by marking the yellow and red traffic without taking the service profile of the aggregate. The probability of marking yellow traffic is proportional to their service profile, which achieve a proportional fair share of excess bandwidth [26, 28, 29, 30, 31, 32].

1.1.3 Queuing Management

The traffic has been a selected to marked and policed, this traffic must be processed differently in some behaviour buffer. Because the buffer is effected by putting in queue different classes of traffic into different edge router. Then the buffer is out of queue onto the link in deference to their priority, so high priority queues will be served more than low priority ones.

Several scheduling algorithms are applied to classify the traffic networks and determine a solution for managing resources data processing at the routers as well as to support QoS. Using other suitable algorithms can significantly change the characteristics of the simulation results with many performance metrics. In particular, the traditional mechanisms for bandwidth management depend on the weighted concept mechanisms to determine the traffic service order. [2, 33]. The MRED scheduling algorithm does not depend highly on the dynamic queue parameters such as weight (Wq), maximum drop probability (Maxp), or management drop traffic to evaluate the traffic of queues in the service classes of the MRED algorithm. These details do not guarantee that the traffic within the set algorithms can be delivered.

1.2 Motivation

The cost of communication services, controlling available bandwidth inability, and maximum utilization of the network's capacity have all increased corresponding to the rapid growth in communication systems. Thus, to provide higher QoS solutions supporting the wired and wireless networks, application services have been proposed. DiffServ support End-to-End QoS through efficient management of corporate network resources which ultimately optimizes available bandwidth making it the most vital feature. For instance, using Reverse Beacon Networks (RBN) [34, 35, 36, 37] could provide convertible wired roadside network solutions for Vehicle-to-Vehicle (V2V) or Vehicle-to-Roadside (V2R). The existing wired infrastructure could facilitate accidents and street congestion avoidance by displaying safety messages. Furthermore, traffic classification technique is an appropriate issues to achieving QoS performance in several platforms with different kind of networks such as Security policies and cloud computing services [38, 39, 40, 41, 42, 43].

The QoS and DiffServ provide better control of network traffic. They limit the use of network resources as per business needs for the different applications. Traffic management decision for network engineers is one of the outcomes this thesis sought to help with. The interaction of how DiffServ, QoS and MPLS

V2Vs work together will be better understood and how useful its applications are such as enterprise network that run different data traffic over the same network infrastructure.

Additional, the emergence of cloud technology, Internet of Things (IoT) and Software-defined networking (SDN) have come to be thanks to its advantages such as the indispensable use in hardware sharing as well as infrastructure services which proved that data sharing is not the end goal behind its existence. The remote access to real time services shed lights on the increased resources demand which, if exists, should bring forth more efficient infrastructure services. Thus, the drive to obtain a better resource utilization have increased which facilitated the use of QoS mechanisms to overcome the challenge. Achieving such feat require a thorough analyses on the performance metrics of QoS such as end-to-end delay, delay variation, throughput, packet loss, injection and queuing delay for real-time applications. Considering the direction of the field, DiffServ and IntServ may combine to meet the requirements and demand of the real-time applications as well as multicast services [44, 45, 46, 47, 48].

1.3 Problem Statement

The packets in traffic classification will not receive the same process priority, the common unfairness problem can be alleviated by mapping them to different drop precedences by using separate buffer, or by using per-flow marking schemes.

Furthermore, the effect of flow distribution between TCP, and TCP with User Datagram Protocol (UDP) traffic, and traffic size on edge router or marker algorithm will increase the drop traffic probability while calculating the percentage of probability traffic distribution. Thus, an increased need to develop a mathematical model that can find marker characteristic when parameters of marker algorithms and traffic rate change.

Additionally, the reduction of the throughput will be raised when the buffer head approach to be full, thus the throughput worsens with different traffic application protocol TCP and UDP. The Random Early Discard or Random Early Drop (MRED) in the Active Queue Management (AQM) technique, that is responsible for dropping traffic through the random early drop technique, depends on queue size which executes various RED policies and measures the drop probability of the traffic. This problem is an outcome of a poor buffer management.

This research will solve unfairness issues and manage the buffer MRED resources in traffic classification network, which are closely related to each other by improving the bandwidth fairness. The proposed markers algorithm Double Modified Double Improved Time Sliding Window Three Colour Marker (M^2I^2TSWTCM) and Optimized Time Sliding Window Three Colour Marker (OTSWTCM) will improve and enhance the bandwidth fairness by providing a proportional fair share of the excess network bandwidth among different aggregates, it will also solve the different traffic protocol type issues, while The scheduler algorithm Fair Weighted Multi-level Random Early Detection (FWMRED) can balance End-to-End QoS. The proposed analytical model will help find better marker algorithm characteristics and check the parameters value that affect the characteristics of the whole network.

1.4 Research Objectives

The research objectives of the thesis include defining the architecture components for the traffic classification and developing a routing strategy aimed at making the best use of network resources. Furthermore, the research is necessary to carry out a study of marker and scheduler techniques with guarantee of QoS. The detailed objectives of this research are as follows:

- To propose the efficient and optimized marker algorithms using adoptive parameters to find the optimal solution for the unfairness of sharing bandwidth among aggregates in DiffServ.
- To propose an optimised MRED algorithm by redefining mathematical equations to improve average throughput, and reduce average delay and packet drop. Accordingly, queue space is made available to the new arriving packets.
- To propose an analytical model for the probability of traffic markers used in calculating the percentage of classified traffic within the TSWTCM algorithms in DiffServ supporting AF PHB. The analytical model show marker characteristic when parameters of marker algorithms and traffic rate change. The model can compare several existing markers algorithm based on various TCP, TCP with UDP, and traffic size.

1.5 Research Scope

In the DiffServ of traffic classification area, this research focuses on finding optimal efficient solution of unfairness problem. In specific, the sharing of bandwidth among aggregates flows with different traffic standard TCP and UDP is by marking and scheduling algorithms. Additionally, it focus on the area of QoS, congestion control, buffer managements and resource utilization. The TSWTCM simulation uses only File Transfer Protocol (FTP)/TCP and Constant Bit Rate (CBR)/UDP traffic applications of IPv4 protocol, the evaluation is carried out using simulation and analytical approaches. The performance metrics used for the evaluation are fairness, bandwidth throughput, average queue size, delay and packet loss. Unless explicitly otherwise stated, it will be mentioned throughout this work.

1.6 Research Significance

Understanding behaviour of traffic is important to design a strong method for the classification and management. There are some research on classification of traffic which provided different methods to identify types of traffic information. Fairness pocket loss and bandwidth are the core metrics when categorizing performance to meet QoS requirements, AF is used to aggregate PHBs traffic at varying levels of service provided by DiffServ routers yet the problem of unfairness still surface. Nonetheless, achieving full accuracy is almost impossible for the rapid changing nature of internet traffic, thus, the accuracy of classification is rather questionable due to the lack of ground truth dataset availability. This made research varies in methods when approaching the different levels of classification; some of the classification goals aims at classifying the protocol of traffic or applications type while others underwent a thorough classification goal such as identifying the exact application name. Hence, the comparability of classification methods in term of accuracy achieved is often inappropriate.

Hypothetically, the dilemma can be overcome if more meaningful information are obtained within the limitation faced when classifying traffic rather than classification accuracy improvement, most internet application use transport layer protocol ports to ease the identification. However, recently there is a noticeable increase in applications that use none standard or random ports. Network application are usually configured to standardized protocol ports assigned to other applications disguising their presence such as TCP port 80 originally reserved for web traffic. All that made it a standard practice to investigate the classification of traffic flow correctly, traffic inspection and its novel approaches, statistical and machine learning techniques, as well as behavioural methods.

This thesis addresses the most frequent trend in classifying traffic field and provide proposals from other researchers to improve the bandwidth fairness of QoS performance significantly for the DiffServ network by; resolves the simultaneous unfairness issue, support successive fast routing, increase the bandwidth, reduce packet loss rate and ensure high guarantee for real-time traffics.

1.7 Thesis Organization

A brief background and motivation of the research are presented in this chapter, as well as the research problem, significance, objectives, and research scope.

Furthermore, the rest of this thesis is organized as follows.

In chapter 2 we introduce classification of traffic overview. In addition, it shows several related research studies that address different marker and scheduler Algorithms. Finally, various classification of traffic issues and challenges are also presented.

We will present the performance analysis strategies, research framework, and the proposed discrete event simulator used in this research and explores the stages in detail in chapter 3. The experimental setup and topologies as well as the performance metrics and validation of the model have been presented in this chapter.

In Chapter 4 we describe and explain in detail the basis of most famous markers used in this research, and describes the specification and implementation strategies used to propose M^2I^2TSWTCM and OTSWTCM.

Chapter 5 describes the modification on MRED scheduling algorithm, called the FWMRED. The FWMRED provides a new definition of weight in terms of priority of service classes as AF, EF and Default PHB, which will be computed by bandwidth requirements and delay. In addition, the FWMRED also design to recalculate the drop probability to reduce delays accordingly.

Providing an analytical model for improving the efficient optimization performance of TSWTCM probability flows is introduced in Chapter 6. The model is integrated with two specific models to evaluate the network performance and the probability measurement of traffic type performance.

Finally, a conclusion of the whole thesis, limitations and potential future work are given in chapter 7.

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LIST OF PUBLICATIONS/PATENTS

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Ameen M. Alkharasani, Mohamed Othman (2012). M2I2tswTCM: A New Efficient Optimization Marker Algorithm to Improve Fairness Bandwidth in DiffServ Networks. *Journal of Network and Computer Applications*, Volume 35, Issue 4, 2012, Pages 1361-1366, ISSN 1084-8045. **(2012, IF = 1.467, Q1)**

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