AN IMPROVED LOW LATENCY DYNAMIC SCHEDULING QUEUING ALGORITHM FOR REAL TIME APPLICATIONS

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DECLARATION

I Kato Charles do hereby declare that this Project Proposal is original and has not been published and/or submitted for any other degree award to any other University before.

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1 INTRODUCTION

This study examines how to increase the Quality of Service for the real time applications during traffic congestion. Quality of Service (QoS) [11] is the performance level of a service offered by the network to the user. The level of the service is based on some parameters or constraints such as available bandwidth, end-to-end delay, delay variations or jitter, probability of packet loss etc. Voice and video traffic are very sensitive to delayed packets, lost packets, and variable delay (jitter). The effects of these problems manifest as missing sounds, echo, or unacceptably long pauses in the conversation that cause overlap. QoS configurations provide bandwidth guarantees while minimizing delay and jitter for priority traffic like VoIP through traffic handling mechanisms. The main mechanisms here are classification, channel access, queuing mechanism, and traffic policing.

Queuing mechanisms are used primarily to manage the allocations of bandwidth among various flows. The five major router-based queuing mechanisms include Priority Queuing (PQ), Custom Queuing (CQ), Weighted Fair Queuing (WFQ), Class-Based Weighted Fair Queuing (CBWFQ) and Low-Latency Queuing (LLQ) according to [19]. Although these mechanisms attempt to prioritize and distribute bandwidth to individual data flows there is no unique queuing mechanism to handle most applications requirements. Different queuing mechanisms have different advantages. Thus, combining different queuing mechanisms into a new hybrid queuing mechanism with the most possible positive properties of an individual mechanism can improve time sensitive application requirements. Time-sensitive application traffic must travel undisturbed through the network. For time-sensitive application traffic, a combination of PQ and CBWFQ mechanisms (PQ-CBWFQ) or LLQ are especially appropriate according to [2].

1.1 BACKGROUND

LLQ is a simple option of CBWFQ applied to one or more classes, which treats these classes as strict-priority queues. PQ-CBWFQ mechanism permit delay sensitive voice and video traffic to be scheduled first before the packets in the other queues. To enqueue the real-time packets to a strict-priority queue (SPQ), the priority command for the given class must be configured. Within a policy map, you can give the priority status to one or more traffic classes. When multiple classes within a single policy map are configured as priority classes, all traffic from these classes is enqueued to the same, single, strict priority queue according to [8]. A PQ-CBWFQ's priority queue drains all frames queued in the highest-priority queue before continuing on to service lower-priority traffic classes. It assumes that the different types of traffic can be differentiated and treated preferentially. Separate FIFO queues are created for each defined priority level and the arriving traffic is sorted into its proper queue as it arrives. Typically between two and five levels of priority are defined (e.g high, medium, normal and low), although there is no theoretical limit to how many levels can be defined. More queues, however, means more complexity in running the algorithm.

At the service side of the queue, the processing rule is simple: higher priority FIFO queues are always processed to completion before lower priority queues are processed. Traffic randomly enters a router and leaves the router according to its sorted priority. As shown in the figure below.

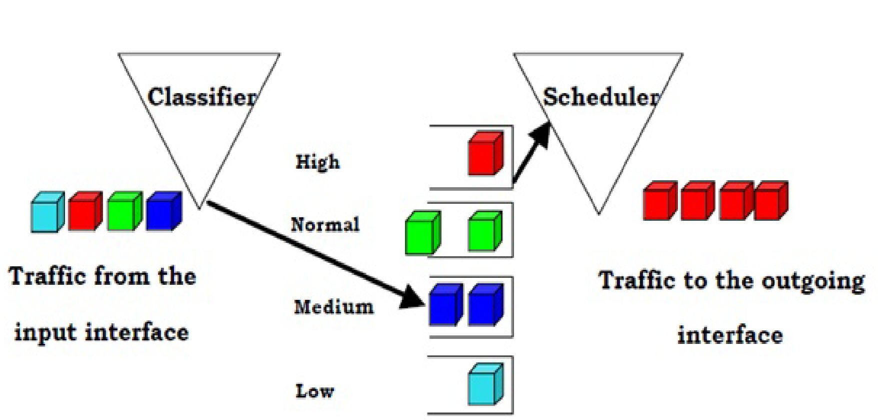

Figure 1: Priority Queuing (PQ)

The moment a higher priority packet arrives in its FIFO queue, servicing of the lower priority packets would be interrupted in favor of the higher priority queue. Although putting voice and interactive video into the LLQ may be good for queuing, discarding packets that exceed the configured rate for the queue would be harmful to those types of traffic. Unfortunately the increase in demand for higher quality video services due to applications such as video conferencing, interactive video applications, which deliver both video and voice and E-Learning applications has reduced the expected QoS levels which cannot be guaranteed especially if sensitive audio and video packets are processed in the single priority queue due to resource sharing between many applications. There is no distinctive consideration for video applications, which also require more throughputs and less delay.

1.2 STATEMENT OF THE PROBLEM

In addition to the voice traffic, strict priority status can be given to the video traffic to satisfy the QoS requirements in interactive video applications and to provide the service guarantee in streaming video applications. In the existing LLQ algorithm, sensitive audio and video packets are processed by first come first served basis in a single SPQ. Unfortunately, the expected QoS level cannot be guaranteed. When a bursty video packet comes with sensitive voice traffic, packets that exceed the configured rate for the queue would be discarded. Thus the voice traffic may not be delivered successfully as stated by Dekeris [5]. Video traffic could also introduce a variation in the delay, thereby spoiling the steadiness of the delay required for successful voice traffic transmission in interactive video applications. SPQ allows delay-sensitive data such as voice packets to be removed from the queue and sent first before video traffic. In simulations performed in [18] it is observed that their is a slight variation in the end-to-end delay compared to other algorithms because the video packets in the secondary SPQ are scheduled after scheduling the voice packets in the primary SPQ. Applications such as remote surgery has necessitated the need to prioritize and implement any kind of its five traffic levels besides voice and video depending on the needs of the robot as stated by Diaz in [6].

In order to overcome these problems a dynamic sheduling algorithm is proposed in which an additional strict PQ is introduced along with the existing one. The existing SPQ which is primarily dedicated for delay sensitive voice traffic in the existing algorithm will coexist with a new queue that will be exclusively used for video traffic along with the policer. All other classes of traffic will be processed using class based weighted fair queuing algorithm. The new algorithm will dynamically decide the selection of the strict PQ for scheduling the packets by considering the nature of the application which will prevent voice traffic from always being sheduled first. The queue sizes and threshold values could be fixed based on the application requirements.

1.3 GENERAL OBJECTIVE

The main objective of the study is to improve traffic schedulling of time sensitive applications by designing a algorithm that will dynamically determining the allocation and division of bandwidth for voice and video traffic when using the PQ-CBWFQ queuing discipline.

1.3.1 SPECIFIC OBJECTIVES

The study will be guided by the following objectives:-

1. To study the issues related to PQ-CBWFQ queuing discipline in relation to network performance.
2. To develop an algorithm for a dynamic PQ-CBWFQ queuing discipline that meets the requirements of handling multiple time sensitive applications.
3. To validate the designed algorithm.

1.4 SIGNIFICANCE OF THE STUDY

Research solutions proposed and validated in this research will make the following contributions:

1. They will improve the QoS due to reduced resource sharing between many applications withing one strict queue.
2. They will provide assurance of Video conference services with specified QoS requirements (delay and loss).
3. The network will be more manageable and the traffic condition will be much better and thus enhance the network capability.

1.5 SCOPE

The study is aimed at designing an algorithm for dynamically determine the allocation and division of bandwidth in the Priority Queue when using the PQ-CBWFQ queuing. It is limited to the PQ-CBWFQ hybrid queuing mechanism due to limitations of time, cost and complexity.

2 REVIEW OF THE RELATED LITERATURE

This chapter provides a brief review of the extensive literature that exists in the area of improving the quality of Service for the real time applications, as relevant to our study. In addition to the introduction, this chapter will also deal with thematic review, the empirical studies and synthesis of the literature review.

2.1 Introduction

Avoiding and managing network congestion and shaping network traffic are managed by using different queuing disciplines that form the basic part of QoS assurance. Switch and router queues are susceptible to congestion. Congestion occurs when the rate of ingress traffic is greater than the successfully processed traffic serialized on an egress interface. By default, if an interfaces queue buffer fills to capacity, new packets will be dropped. During periods of congestion, QoS provides switches and routers with mechanisms to queue and service higher priority traffic before lower priority traffic and also to drop lower priority traffic before higher priority traffic. In order to provide a preferred level of service for high-priority traffic, some form of software queuing must be used. Velmurugan in [23] discussed that various queuing disciplines can be used to control which packets get transmitted (bandwidth allocation) and which packets get dropped (buffer space). The queuing discipline affects the latency experienced by a packet, by determining how much time a packet waits to be transmitted.

2.2 Thematic Review

Queues are managed in a way to ensure each queue gets the level of services required for its class. Software queuing techniques include First-In First-Out (FIFO) (default), Priority Queuing (PQ), Custom Queuing (CQ) , Weighted Fair Queuing (WFQ), Class-Based Weighted Fair Queuing (CBWFQ) and Low-Latency Queuing (LLQ). Each queuing mechanism has their own feature and different queuing mechanisms have different advantages. Combining different queuing mechanisms into new hybrid queuing methods will reduce the end-to-end delay, Ethernet delay, and jitter as stated in [10] Many different hybrid queuing methods are possible but LLQ which is the combination of PQ and CBWFQ is a queuing scheme that adds strict priority queuing to CBWFQ.

2.2.1 Issues related to PQ-CBWFQ queuing discipline

In LLQ, time sensitive traffic is queued to the priority queue and all other traffic is allocated to the CBWFQ queues. The priority queue is serviced before any of the weighted fair queues, thus allowing important real-time traffic to be processed as fast as the network elements can according to [12]. Voice packets that enter the LLQ system are stored in the priority queue of the LLQ system, where they have a fixed bandwidth allocation and where they are served first. To enqueue the real-time packets to a strict-priority queue, the priority command for the given class must be configured. Within a policy map, the priority status can be given to one or more traffic classes. When multiple classes within a single policy map are configured as priority classes, all traffic from these classes is enqueued to the same, single, strict priority queue [8].

Bursty traffic is related to relatively high bandwidth traffic at inconsistent levels. If video conference and voice traffic are merged together into one class, the bursty, large-packet of video stream would severely punish the small-packet of voice traffic as stated in [16] causing delays in real time sensitive traffic. Again, the expected QoS level cannot be guaranteed, if sensitive audio and video packets are processed in the single priority queue due to resource sharing between many applications. To avoid jitter, voice traffic requires a non variable delay which is the most important for voice applications. But the video traffic could introduce variation in delay, thereby spoiling the steadiness of the delay required for successful voice traffic transmission as stated by Brunonas Dekeris et al in [3].

2.3 Empirical Studies

Time-sensitive applications require different Quality of Service (QoS) in terms of delay and throughput in a resource constrained network. PQ-CBWFQ places delay sensitive applications such as voice and video in the high priority queues and treats them preferentially over other traffic by allowing the applications to be processed and sent first from these queues. LLQ related simulations have been done using OPNET Modeler. It is an extensive and powerful simulation software tool with wide variety of capabilities. It enables the possibility to model a network structure with various protocols. The main goal in these simulations is oriented towards improving the network performances with regard to the VoIP end-to-end delay, Ethernet delay, and jitter. Web and FTP applications are applied only for creating low-priority traffic flows.

2.3.1 Comparison of Existing Algorithms Implementing LLQ Mechanism

A model has been developed to give a higher priority to voice and video traffic which is the most sensitive traffic as stated in [9]. The model monitors all incoming traffic and categorizes it based on the level of their sensitivity. Then, it assigns the highest priority to voice and video traffic and a lower priority to other traffic which are delay tolerant. This sequence occurs so that high priority traffic can be delivered to the destination directly without considering a congestion avoidance technique. While the remaining traffics follows and share the bandwidth according to some specific set of policies. However, this model cannot control traffic generated by an unknown user.

Sotirios et al [21] proposed Queue management architecture for delay tolerant networks. The scheduling algorithm assigns priority for the packets based on application requirements, data requirements and time to live which reduces waiting time and increases application satisfaction.

Another novel Low Latency and Efficient Packet Scheduling (LLEPS) algorithm is developed to ensure low latency for real time audio and video streaming applications in [7]. The behavior of queues and their traffic is monitored to address the buffer under-run problem.

Roja Kiran Basukala et al in [17] assured QoS for multimedia traffic using Custom Queuing (CQ) and Low Latency queuing (LLQ) algorithm in residential network with Hybrid Coordination Function (HCF). They show that CQ with HCF performs better than LLQ in terms of delay and jitter.

QoS is improved in the performance of multimedia applications by adapting QoS in the multi-media application based on Class Based Weighted Fair Queue - Low Latency Queue (CBWFQ-LLQ) which classifies and prioritizes the multi-media traffic. In this simulation it shows that the applications of CBWFQ-LLQ for video traffic gives better performance to video traffics only, while the applications of CBWFQ-LLQ for voice traffic gives better performance to all types of traffic according to Badr and Darwesh in [1]. However, this work prioritizes voice and video traffics individually, there is need to test this model on other traffics required in collaborative systems such as e-learning system.

Brunonas Dekeris et al in [3] combined Weighted Fair Queuing (WFQ) algorithm with

Low Latency Queuing (LLQ) algorithm for ensuring Quality of Service for real time applications. Unfortunately in this simulation when the network load is high, the WFQ algorithm cannot achieve expected QoS for real time applications.

Shaimaa and others in [20] have also demonstrated that the combination of Class-Based Weighted Fair Queuing and Low Latency Queuing (CBWFQ-LLQ) improved the performance of multimedia applications. They proposed a model to support real time service in e-learning system and developed a QoS model in multi tiered real time systems. They evaluated the performance voice and video traffic in the e-learning system and showed that the combined algorithms gave better performance for voice and video traffic. However, the low latency in CBWFQ-LLQ is provided in a single priority queue the voice traffic may not be delivered successfully.

2.3.2 Synthesis of the literature review

The increased use of technologies has increased the demand for the real time audio and video applications. In a resource constrained networks these applications require different Quality of Service (QoS) in terms of delay and throughput and thus packet scheduling algorithms such as PQ-CBWFQ have been developed. PQ-CBWFQ places delay sensitive applications such as voice and video in the PQ and treats them preferentially over other traffic by allowing the application to be processed and sent first from the PQ. Although it is possible to enqueue various types of real-time traffic in PQ-CBWFQ, its been noted that having multiple real time applications such as video and voice could introduce variation in delay, thereby thwarting the steadiness of delay required for successful voice traffic transmission in the priority queue. In this research we propose an algorithm that will make use of two separate dedicated priority queues. One for scheduling the video applications and another for the voice applications. This algorithm will be able to decide the selection of the strict priority queues for scheduling the packets dynamically.

2.4 Conclusion

In Section 2.1 of this Chapter we discussed the increase in video streaming services and real-time applications such as Web Server, VoIP, E-mail, FTP and Voice Server which has resulted into network congestion. Avoiding and managing network congestion and shaping network traffic are provided by using different queuing disciplines, which are a basic part of QoS assurance.

In order to provide a preferred level of service for high-priority traffic, some form of software queuing must be used as discussed in Section 2.2 of this Chapter. Many different hybrid queuing methods are possible but LLQ which is the combination of PQ and CBWFQ is a queuing scheme that adds strict priority queuing to CBWFQ. Strict-priority queuing allows for delay-sensitive data, such as voice, to be sent first, before packets in other queues are de-queued. In Section 2.2.1 of this Chapter we discuss the issues related to PQ-CBWFQ that have resulted into reduced QoS levels in real time applications.

In section 2.3 of this Chapter we discussed the different existing models such as the one in [9]. This model monitors all incoming traffic and categorizes it based on the level of their sensitivity. However, this model cannot control traffic from outside sources. According to the Badr and Darwesh simulation in [1] it shows that the applications of CBWFQ-LLQ for video traffic gives better performance to video traffics only, while the applications of CBWFQ-LLQ for voice traffic gives better performance to all types of traffic. However, this work prioritizes voice and video traffics individually, there is need to test this model on other traffics required in collaborative systems such as e-learning system. Sotirios et al [21] proposed Queue management architecture for delay tolerant networks. The scheduling algorithm assigns priority for the packets based on application requirements, data requirements and time to live which reduces waiting time and increases application satisfaction which will be useful in our solution. Therefore based on these researches we propose an improved LLQ algorithm that will dynamically make use of two separate dedicated priority queues. One for scheduling the video applications and another for the voice applications.

3 METHODOLOGY

This chapter presents the methodology of the study. It deals with many different methods that will be used in carrying out the the specific objectives of the study in general terms. This chapter discuses the main methodological aspects that includes data collection methods, data interpretation and analysis, algorithm design and evaluation.

3.1 Literature Survey

In this study various documented information and other case studies in the current or in the developing areas of queueing mechanisms will be sourced from scientific journals, research published papers, textbooks, thesis/dissertations, papers on international proceedings, and the Internet in order to identify different types of time sensitive applications and how they are considered to be critical to the network performance. Analysis of the existing simulations will be done using existing simulation results.

3.2 Algorithm Design

A new algorithm to address the problems resulting from the allocation and division of bandwidth to a single Priority Queue when using the PQ-CBWFQ queuing discipline on multiple time sensitive applications is designed using flow charts.

3.3 Simulation of the proposed algorithm

Simulation is a valuable tool to verify and evaluate the performance of networks. The most commonly used tools include OPNET [14], NS-2, NS-3 [13], OMNeT++ [15] and QualNet [22]. Currently, QualNet mainly for wireless networks and OPNET Modeler are known as a commercial simulation but in this research we will use the OPNET modeler 14.0 educational version which includes nodes and link models for simulating the an end to end network. The main difference with other simulators lies in its power and versatility. It is very useful when working with complex networks with a big number of devices and traffic flows, or in networks where a little change could be critical. Before implementing any change, it is possible to predict the behavior and to verify the configurations of the devices. OPNET has different tools that allow administrators to analyze their networks and the future implementations they want to do.

3.3.1 Implementation and OPNET modifications

There are three basic phases of the five phases of the OPNET design cycle shown below. First, build models by choosing and configuring node models to use in simulations. Second, execute the simulations by organizing the network and setting up connections for different entities. Third, analyze the results by selecting the desired statistics (local or global) to collect during the simulation.

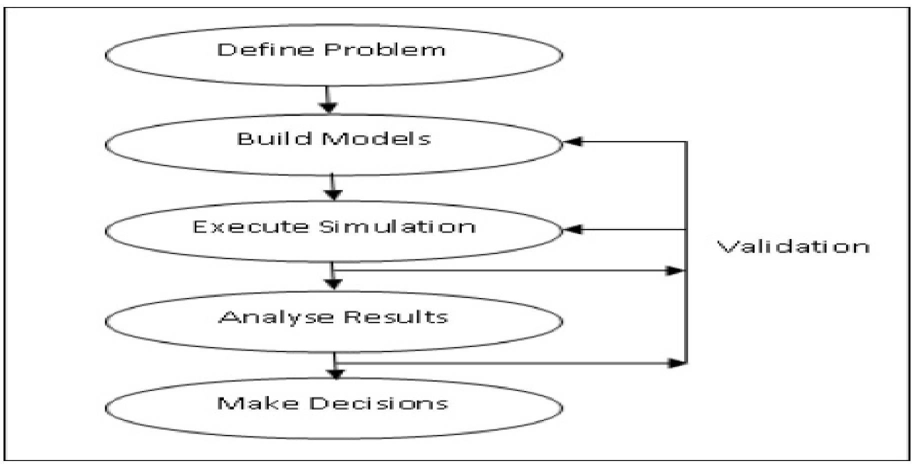

Figure 2: Modelling and simulation cycle in OPNET, adapted from [4]

3.3.2 Simulation Objects and Configurations in the proposed solution

In OPNET, an application definition specifies an application with parameters and may have tasks that may have multiple phases. A phase can have many requests and responses. Several example application configurations are available under "Default" setting. In the proposed network, there will be three applications such as voice, video conferencing and file transfer (FTP) originating from home/office location. Video and FTP applications use servers for traffic flow namely video and FTP servers whereas voice traffic flows between voice user. All three applications will be defined and configured on the application definition object.

Profile definition object is used to create user profiles. These user profiles can then be specified on different nodes in the network to generate application layer traffic. The applications defined in the Application Config object are used by this object to configure profiles. Configured profiles are then assigned to the workstations to enable them crerate the backround traffic and communicate the servers and other workstations. There will be three profiles in the proposed network such as voice profile, video profile and FTP profile which are matched with the appropriate applications defined in the application definition object such as voice over IP (GSM Quality), video conferencing (heavy) and file transfer (heavy) applications, respectively.

Qos definition object defines attribute configuration details for protocols supported at the IP layer. Queue category attribute determines whether the queue has the Default Queue and/or Low Latency Queue property. Low latency queuing introduces strict priority CBWFQ and enables use of a single, strict priority queue for time-sensitive traffic. The Default queue receives all traffic that does not match the clasisification criteria of any of the existing queues. In our proposed solution, we shall introduce an additional strict priority queue that is dedicated for video applications.

3.4 Illustration for proposed solution

When the TX Ring (Hardware Queue) has free space, voice and video packets will be dynamically scheduled as shown in the diagram below.

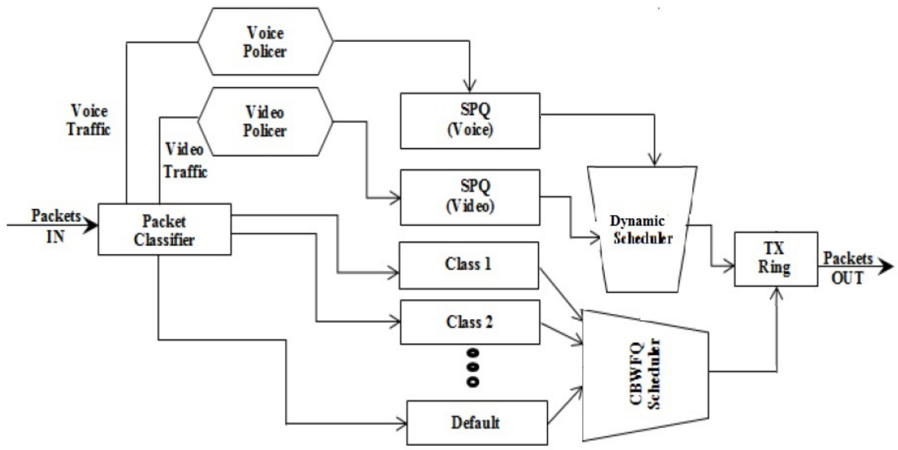

Figure 3: Proposed System

3.5 Evaluation Of Algorithm

We will evaluate the performance of the proposed solution by comparing with the performance of an existing solution. We choose to compare our results with that of Enhanced Low Latency Queuing solution [18].

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4 APPENDICES

4.1 Appendix 1: Work plan and Timeframe

This is the schedule or timetable of activities and the period in which the research is to be conducted with due regard to budgetary limitation.

Activity	Duration	Dates
Submission & approval of the proposal	5 – 10 days	January
Design of a research plan	5 – 10 days	January
Literature review	10 days	January
Algorithm design & implementation	10 – 15 days	February
Analysis of quanitative data	10 days	February
Report up of findings	5 – 10 days	February
Presentation of final research product(s)	5 – 10 days	February

Table 1: Work plan and Timeframe