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Congestion Control Mechanisms for Optical Burst Switched Networks

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IN

TELECOMMUNICATIONS

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Declaration

I hereby declare that, except where otherwise indicated, this document is entirely my own work and has not been submitted in whole or in part to any other university.

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Abstract

In this studies, I review burst congestion control problems in optical burst switching networks from the viewpoint of network throughput maximizaation and to reduce additional signal requirement while minimizing burst loss. Burst collision occurs when two or more bursts access the same wavelength at the same time, and the occurrence becomes more frequent with the offered load increases. Burst must be dropped since OBS don't provide buffer on intermediate core router. That is said contention is inherent to the OBS network. There are a lot of predecessors have done a lot of research on this topic. General speaking, it has two jointly operating mechanisms, namely a burst congestion detection and a burst control algorithm. In this work, I want to overcome the shortcoming of previous research and develop a new mechanism to enhace OBS network stability and make congestion controllable.

Keyword: Optical Switching Networks, Congestion Control

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Chapter 1

Introduction

1.1 About optical burst network

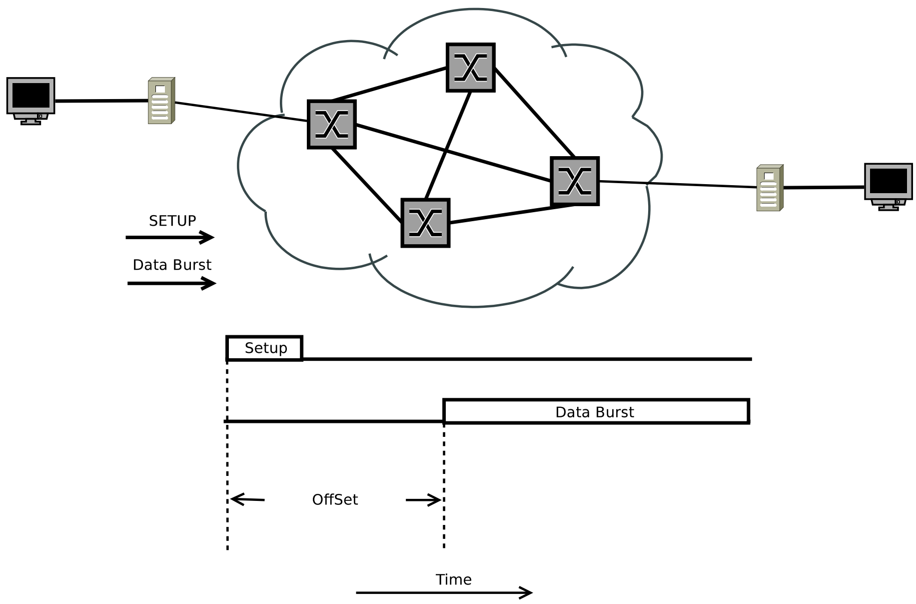

Figure A-1.1: Burst assembly,Burst reservation

Among all optical switching technology, OBS seek to enhance the statistical multiplexing. It has proposed as a new paradigm switching technology for next generation Internet backbone network. Before we get closed to it. We need to get some foundational knowledge, such as what are the big characteristics of this form of exchange of technology. What is the biggest difference compare with traditional switching technology? Does it have born deficiency?

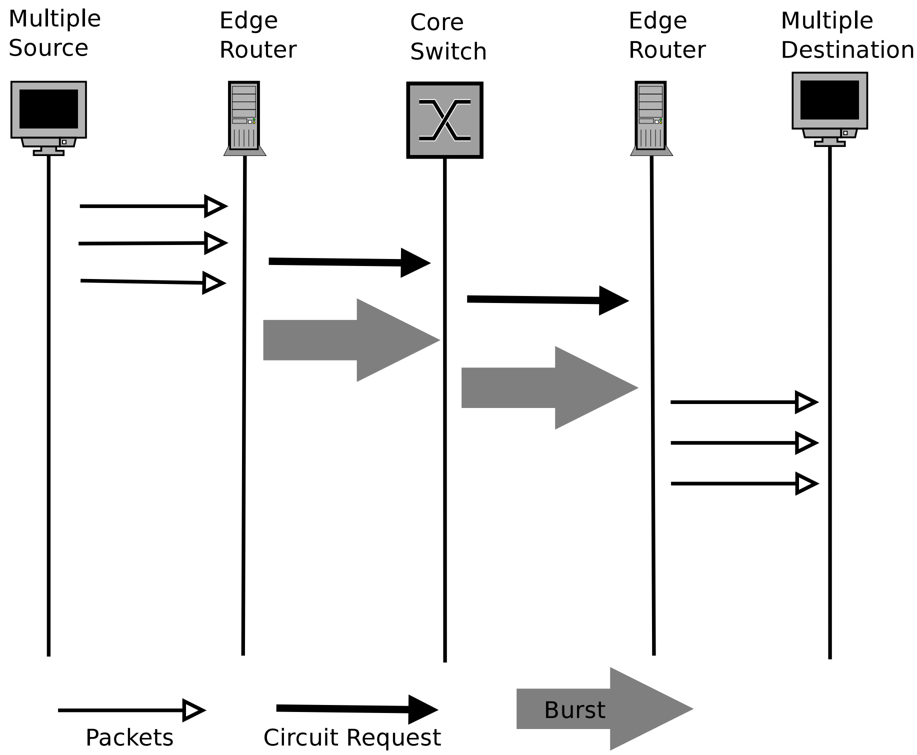

Figure A-1.2: Sample time diagram of a network using OBS

src_node_id
dest_node_id
burst_duration
burst_offset_time

Figure A-1.3: OBS burst format sample

The main different compare to conventional packet switching is bufferless on core node. OBS put all intelligent such as buffer, electronic processor, to edge side. As figure A-1.1 show. All input data bursts are collected into bursts. There may be a classifier to classify packet to different burst according to their destination and

Qos requirement or something else. After complete burst assemble and before the burst transmission begins, a Burst Header Cell (BHC) is sent on the control channel that is separate from data burst channel, carry information about the destination of the burst, duration of the burst, the number of hops it pass through. A sample burst format is shown in figure A-1.3

A burst switcher, once receiving the BHC, schedule and determine an outgoing link for leading toward the desired destination with an idle channel available, and then establishes a connection between the channel specified in BHC and the channel through schedule algorithm by core switcher to transmit the burst. It also pass the BHC to next hops on the control channel of the selected link. After the core router prepare for arriving burst, the burst go through core router without additional operation. It also refer as one-way reservation. The burst just wait a certain offset time and don't need to check the ACK from reservation process. Once burst arrive to core router, It can be transmit in whole optical domain. That is the reason why OBS better than others mechanism. The mechanism for resource reservation and release has been study for a long time. In simple term, There are four major combinations as table A-1.1 show.

setup / release	Immediate setup	Delay setup
Immediate release	Immediate setup Immediate release	Delay setup Immediate release
Explicit release	Immediate setup Explicit release	Delay setup Explicit release

Table A-1.1: Classification of reservation/release schemes

There are two main scheduling mechanism, that is so called `LAUC` and `LAUC-VF`, `LAUC` is abbreviation of First-Fit, Horizon, Latest Available Unscheduled Channel. And `LAUC-VF` is abbreviation of `LAUC` with Void Filling. Since `LAUC-VF` is the improvement of `LAUC`, I employ `LAUC-VF` algorithm in simulation.

1.2 About congestion control

To understand what is congestion control. The first question what causes congestion must be answer. Fortunately, the answer is simple, congestion occurs when the total traffic load is greater than network bottleneck capacity. Especially, OBS take one-way reservation to avoid the long end-to-end setup times and without buffer on intermediate router. Once contention occurs, some or all of data burst have to be dropped. Hence, contention is inherent to the OBS technique and contention issue could affect tremendously the network performance in terms of burst blocked rate and throughput.

General speaking, the contention problem is due to the lack of communication between the nodes and the absence of global coordination between the edge routers and core routers. Congestion issue will lead to a large waste of resource due to drop of bursts on last one router before destination since fail to compete fail. Even worse, the network is statistical multiplexing, many burst may share a link, that lead to load is not balance over all core routers. Some core router may overload, the others may be idle.

There are two approaches to handle burst contention problem: bursts contention resolution and burst congestion control. The burst contention resolution approaches should have capacity to store burst with fiber delay lines (FDLs) [1], deflection routing [5], and wavelength conversion [3]. These approaches can reduce burst loss rate by absorbing short-term burst congestion. But if the burst congestion lasts long, all of above approaches can't reduce burst loss rate anymore. Even worse, they may introduce longer end-to-end delay and enhance congestion impact.

The burst congestion control mechanism handle the burst congestion by controlling the data burst transmission rate at the optical network edge. There are two paradigm to limit the source flow rate, refer as open-loop and closed-loop congestion control. The main different between these two mechanism is that closed-loop is dynamic adaptive system with feedback message. Open-loop is a per-define system without dynamic adjust stage. There are two jointly operating mechanisms, namely a burst congestion detection and a burst control algorithm in closed-loop network[4]. Thus, in the feedback-based network it is required for the core router to work out 3W1H (what,where,when,how) question. What information should feedback to network edge router? Which router should monitor the network information and report to edge router? When this statistic result can detect the congestion and tell the edge router to reduce transmission rate? On the other side the core router should tell when the edge router increase transmission rate to keep network throughput high? The last question is how to detect and predict the network congestion? How to guarantee fairness and self-organizing?

1.3 Motivation

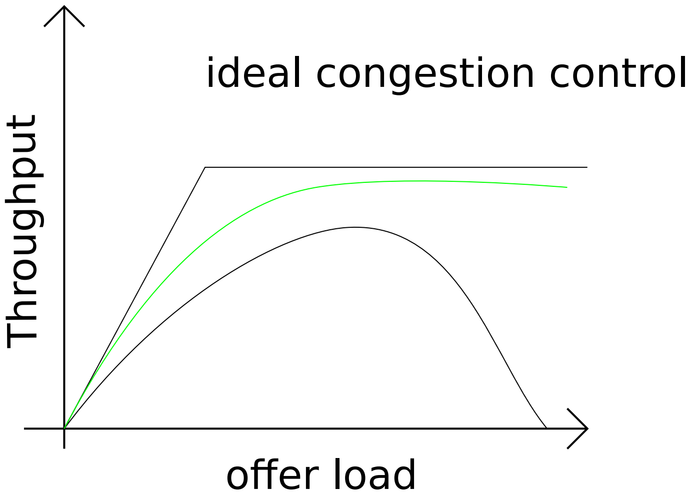

Figure A-1.4: Congestion Control

As figure A-1.4 shows, The performance of network would reduce to zero if without any control. The ideal congestion control will enhance the network stability, and gain the capacity of network. However, in real network, the reaction delay much be token account. It only be closed to the ideal line. The green line show the real world congestion control. It may jitter since control packet loss or expired. In this study, I will develop a congestion control to improve the throughput of network and reduce burst blocked probability.

There are several goals that congestion mechanism should achieve, the cost of implementation and deploy is cheap. That is said minimize additional hardware requirement and limited by router ability. Be fair among to all user.

Congestion control is a comprehensive problem. The effective is very limited by control with any single method. Monitor and rate controller should co-operate to expand the effective. It may work with other mechanism, something like early drop packet, soft contention strategy.

1.4 Summary

Overview the history of the development of OBS technology. The original goal is to compete with ATM network which have great potential in electronic domain. Compared with primitive Burst switching, ATM is more cost effective. But when WDM technology can provide huge bandwidth. It posed a challenge to current switch technology, that is how to use this bandwidth efficiently. The switch technology become the network bottleneck. OBS is a new technology that is currently under study. It has not as yet been commercialized and standardized. But It has great potential to replace current switch technology. It has some advantages:

1. More flexible and efficient compared with wavelength routed network
2. More scalable and cost effective compared with opto-electronic approaches
3. Smaller overhead and more practical compared with OPS

It also have some prominent feature:

1. Separation of transmission and control, Each user transmits data in bursts
2. Basically, assumes the network is bufferless
3. Network nodes(OXC) allocate resources for just this single burst

By contrast, we can find that OBS has a lot of advantages for packet switch. However, unfortunately contention is inherent to the OBS technique. The contention problem is due to the lack of information at the nodes and the absence of global coordination between the edge routers and core routers. In one word, I want to proposed a new scheme to avoid and control congestion effectively in this study. And then drive OBS into standardized earlier.

Chapter 2

Literature Review

2.1 Methodology

As mention above, the study intends to develop a new congestion control scheme for OBS. Thus, the following main question arise:

1. How to indicate congestion state
2. Design the feedback message packet
3. How to determine edge router reaction
4. How to measure the result
5. Does it work for any type of network application

Each of the main questions was investigated by considering the following sub question:

No.	Questions
1	How to indicate congestion state
	What information should collect? Where can store this information? How to calculate the congestion threshold? The threshold can adjust dynamic? To finish this job, is it necessary to enhance core node?
2	Design the feedback message packet
	What field contain in the message packet? Is the size of message body minimum? When this congestion control message send to edge router? How often this message send to edge router? Which channel wiil be used to send this message?
3	How to determine edge router reaction
	Reduced delivery rate Select other idle path
4	How to measure result
	Assign various rank for different performance factor Fairness to each factor Is effective when traffic load become higher Fairness to each edge router

Table A-2.1: Questions and Sub-Questions

In this study, `OPNET` and simulation will be utilized. Simulation is a cheap and quick method. It could also suggest analysis method. Nonetheless, it would a little hard to do a quantitative analysis. But it use to make a qualitative analysis to verify the simulation result.

In the stage `Model` and `Implementation`, Use `OPNET` as main tool. Because of `OPNET` have provide a basic platform before progressing to the `OBS` model. `OPNET` simulation model library provide a series of simulation model for customer. On the basis of these simulation model, we can customize our network model and run a simulation. `OPNET` simulation model library separate with the network simulation engine(`OPNET` Modeler,`ITGuru`,Application DecisionGuru). This architecture is very convenient for model change and upgrade. For this study, we can deploy our congestion control algorithm to a `OBS` network which build with `OPNET` easily.

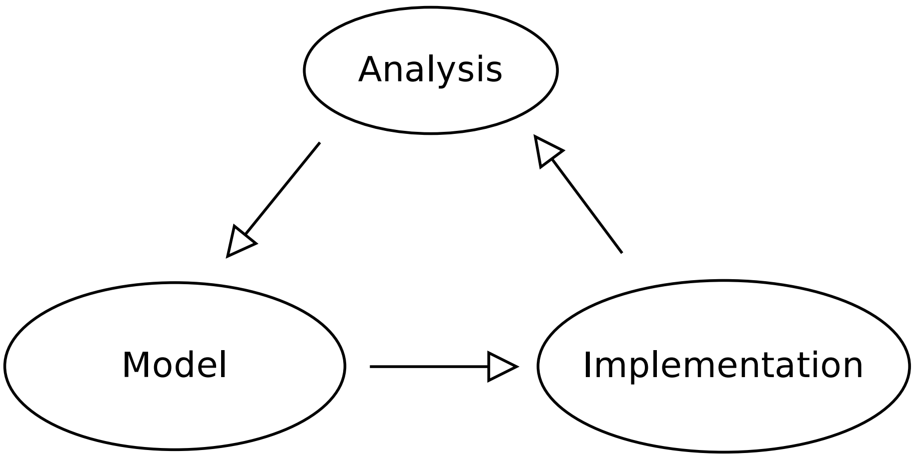

Figure A-2.1: Instructional Simulate model for this study

To generate burst from all ingress node, we need to assume the arrive process follow certain distribution. That may be some common randomness processes. Such as negative exponential distribution, geometric distribution, drop-tail distribution. Thus we need to know how to generate this randomness process meet some distribution requirement.

In order to measure our congestion control mechanism achievements. We need to setup a optimal target. In this study, that is maximum throughput and minimum burst loss and block ratio. It is hard to work out through pure analysis method. So we need to collect data from simulation. We can do some comparative experiments. Such as compare the throughput of two case. One with congestion control, the other without congestion control. Also, use some generally knowledge truth in queuing theory and probability theory to let us get closed optimal target step by step. It is a very good idea to make our data intuitive with data visualization technology.

2.2 Finding & Trends

As we know, in OBS, all intelligence resides in the edge nodes, which are at the same time the buffer and the processor on the network. Simply put, current congestion control scheme are same pattern. They all gathering network state information first. Setup a certain threshold to estimate the congestion state. And then send a customize message to edge router according to the current network state.

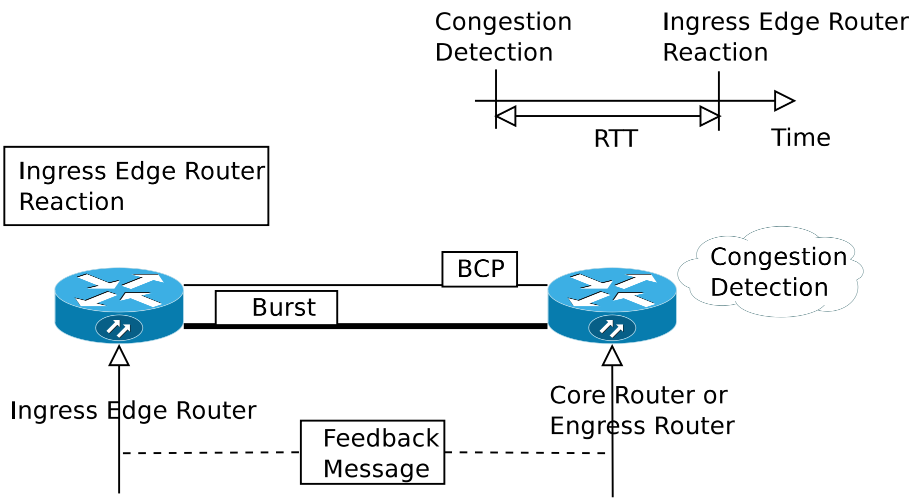

Figure A-2.2: Pattern to control OBS congestion

Figure A-2.2 not only tell us the current popular pattern on research about OBS congestion control. It also tell us the steps to control congestion. This patter is practical and correct. So it will also be used in this study. Although the petter of vary congestion control mechanism are same. But there are a large amount difference among vary scheme in implementation detail. Such as different frequently to send feedback message to edge router, different way to determine the congestion state threshold, different feedback message body. Certainly, they result in different performance.

In their paper, they don't tell how to setup the threshold. They just give a final result. The value maybe have test a lot of times and they think that is proper for their model. It also is a constant value. But I think this value should adjust with the change of network topology. Besides, They don't tell how long is the RTT. The `RTT` can use to measure the speed of ingress react. The `Threshold` is a most important factor to affect the scheme to indicate congestion state or not. But there is not a formula to got these two value through pure analysis. Current scheme just by trial and error to find a proper value for their simulation model.

Moreover, Once their model is determined. All parameter is definite during simulation time. Include the most important `Threshold` value. In my opinion, Congestion control is a dynamic optimization problem. This `Threshold` should self-adjust accordingly. Burak Kantarci and Sema Oktug propose a congestion control scheme base on adaptive threshold [2]. The improvement is also very good.

The previous researcher use throughput and loss ratio to measure their result. The higher throughput and the lower loss ratio. That will be propose as a better congestion control scheme. There also very important factor should be consider to determine whether a new scheme is better. That is whether as effective at high load as at low load. All previous researcher have pay much attention to this point.

Previous mostly assume the burst arrive process follow the Poisson process and their lengths are negative exponentially distributed. But base on the some newest study. It has been shown that whereas flow arrivals are Possion (or close to Possion), flow sizes are not exponential, but rather heavy-tailed, and thus they are closer to a Pareto distribution than an exponential one.

2.3 Issues May Encounter

Note that in OBS networks, intelligent functions such as burst assembly, burst scheduling and generation of control packets are implemented at edge nodes while core nodes perform less complex functions such as processing control packets, resource reservation and switching bursts. However, many existing works have proposed to implementation some simple extra functions at the core node such as load calculation, burst segmentation and priority-based burst dropping for service differentiation. It is hard to predict whether it is necessary to add extra function to core node in this study. If yes, is it complicate so that the core node is reject to add it.

To meet QoS requirement such as bounded delay or guaranteed delivery is part of new scheme objective. But it is incompatible to achieve guaranteed delivery rate and congestion control by reduce transmission rate at the same time. It is clear that even in ideal networks, where the switches use number of buffers and can perform wavelength conversion, congestion collapse still occurs when the load gets higher. On this moment, it seem impossible to resolve this contradiction.

2.4 Related Work

As a new switching technology which has not been standardized yet, OBS faces many problems and challenges. However, there are also many researchers and new achievements. In resolving the issues of contention and the associated loss bursts issue. There are some other related studies.

The most important and related study is contention resolution. As mention above, there are three ways to resolve burst contention. Fiber delay line, wavelength conversion and deflection routing by now. They are for a same goal. When contention occurs, they can buffer it instead of drop it. But these three method are not viable now. They all have their own shortcomings. Optical buffering currently can only be implemented using FDL. But this type of optical buffer is usually small and it does not scale up. The wavelength may have some potential since the number of wavelengths that can be coupled together onto a single fiber continues to increase. In view of deflected routing, the end-to-end delay for an optical burst may be unacceptably high. But fortunately research on these contention resolution are going on. Once the breakthrough of these problems will also provide help for congestion control.

Nowadays, IP packet switching already dominates global communications. But it cannot keep up with the Internet traffic demand. Many researchers are studying a new scheme to replace it. In electronic domain, ATM network has matured and is not far from being feasible. Other researcher have proposed integrate circuit switching in the core and packet switching in the edges as next generation network architecture. All of these efforts are aimed at accommodating for the traffic growth in the Internet. Study on the OBS can draw on their achievements. Also include conventional TCP congestion control.

Chapter 3

Conclusions

Up to now, we have know that DWDM take the bottleneck of networks from bandwidth to switching technology. OBS emerge as this requirement. OBS have many advantage with the advance of DWDM technology. It have great potential to be next generation switching technology in the core network. Since it have some special feature. Such as not require buffer, separation of transmission and control packet.

As mention above chapter, contention is very possible occurs in ideal network without congestion control. OBS have no standardize yet. Many researcher work on this challenging topic. The main research method is simulation. Overview of all previous, they have build a theory framework to solve congestion collapse for OBS. That is three steps: detect, feedback, reaction. They are different in implementation detail. All mechanism are tightly coupled with the burst assembly mechanism at the ingress edge router. This was decided by two reasons. The First is all intelligence resides in the edge router, which are at the same time the buffer and the processor. The second is the hurdle for congestion is lacking of communication between the nodes and the absence of global coordination between the edge routers and core routers. Hence, monitor on corn router and controller on edge router will be focus on the future work.

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