A Multicast Scheduling Algorithm for Wideband Multimedia Communication Network

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Abstract: Scheduling plays an important role in providing quality of service (QoS) support to wideband multimedia communication network, especially in multicast communication. Thus, it is essential to propose efficient and high-speed multicast scheduling policies for the multimedia network, which could perform well in the inherent performance properties such as latency and throughput. However, most researches only addressed one aspect of the QoS support, such as latency, throughput and priority, rarely concentrated on various properties. This paper proposes a new multicast scheduling algorithm, called PWBA, which balances the trade-off between throughput and latency and takes the priority into consideration, for the purpose of providing better QoS support to the multimedia network. Its performance is evaluated via simulations.

Keywords: wideband multimedia; multicast; scheduling

1 Introduction

Due to the development of communication, recent years have witnessed an increasing interest in the high-speed, wideband communication. As a result, the wideband multimedia network is becoming more and more important in the field of communication, and the scheduling will become an essential issue as well.

A scheduling algorithm is the method by which different data flows are queued, scheduled and served. At the mean time, it can realize the function of flow control, and bandwidth allocation and management [1]. A proper scheduling algorithm used in multimedia network, which should be able to provide low end-to-end latency, and work as an effective solution of routing congestion in the process of data transmission, provides high-quality and reliable service to users.

However, in the past many researches were mainly based on unicast scheduling, rarely based on multicast scheduling [2-5]. With the increasing proportion of multicast traffic in wideband multimedia network, how to carry out high-speed and efficient multicast scheduling has gradually become one of the most important issues in the field of communication.

WBA [6] (the weight-based algorithm) and PGMF [7] (packet greedy match fairness algorithm) are two typical multicast scheduling algorithms, both of which dispatch the multicast cells queued in the inputs based on the weight.

Specially, at each cell time, as for WBA, each output chooses the inputs with the heaviest weight, independently of other outputs, ensuring more new cells to be served. Hence, WBA owns higher throughput performance, in comparison with PGMF. However, PGMF performs better in latency, as it takes the length of the input queues into consideration.

Based on the two typical scheduling policies mentioned above, this paper presents a novel multicast scheduling algorithm, which performs well in throughput and latency simultaneously. Besides, it takes the priority into account, which fits well for the wideband multimedia communication network.

2 Multicast Scheduling Model

The fan-out splitting multicast scheduling for input-queued switches, in which each input maintains a single queue for arriving multicast cells and only the cell at the head of line (HOL) can be observed and scheduled at a time, has been extensively studied [8, 9] in recent years.

The input-queued means that, when a cell arrives at the switch, while a match cannot be found in an appropriate cache table at the mean time, the cell will be stored in the queue of the incoming interface waiting to be processed. It is assumed that an input cell must wait in line until all of

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the cells ahead of it have been dispatched. Numerous papers [6, 10] have indicated that by using appropriate scheduling algorithm, the cells at the input queues can quickly be departed to the destination through the switch network, without congestion, and it is possible to achieve high throughput. Therefore, the research and development communities are finding a growing interest in the study of input-queued switches.

The service discipline of fan-out splitting means that, the input cells may be delivered to output ports over any number of cell times. Only the cells that are unsuccessful in one cell time continue to contend for output ports in the next cell time. On the contrary, the no fan-out splitting means that, all of the copies of a cell must be sent within the same cell time. Numerous studies [11, 12] show that, the fan-out splitting enables a higher switch throughput with little increase in implementation complexity.

Considering the conclusions above, the algorithms that the paper introduces are all based on the fan-out splitting and input-queued theory. The scheduling model used in this paper is shown in Figure 1, while Figure 2 represents any of the input queues of the model. The queue is filled with several multicast cells, each of which contains a vector indicating where the cell is to be sent.

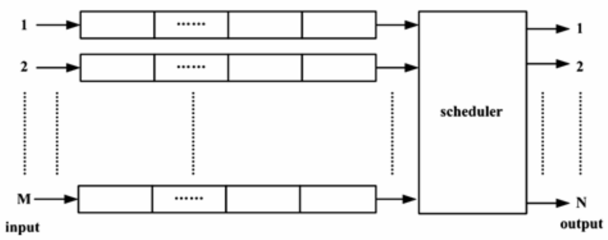

Figure 1 The multicast scheduling model based on input-queued switch

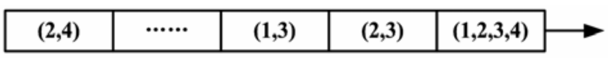

Figure 2 One input queue of the scheduling model shown in Fig. 1

Some definition of terms that will be used later are made precise in this section: (1) Residue: The residue is the set of all output cells that lose contention for output ports and remain at the HOL (head of line) of the input queues at the end of each cell time. (2) Fan-out: The fan-out refers to the constitution and the cardinality of the input vector. Take the HOL cell in Figure 2 for example, it is said to have a fan-out of four.

3 PWBA: A Novel Multicast Scheduling Algorithms

Via analyzing the WBA and PGMF policies, conclusions can be drawn as follows:

(1) At each cell time, as for WBA, each output chooses the inputs, independently of other outputs, ensuring more new cells or residues to be served. Therefore, comparing with PGMF, WBA performs better in throughput.

(2) The PGMF algorithm takes the length of the queue into account, which indicates that it gives priority to the long queues; as time passes, the weight of the short queues is increasing, ensuring no input cell may be held at HOL for more than a fixed number of cell times. In a word, the PGMF meets the fairness constraint, and possesses better average latency performance than WBA.

(3) The above two algorithms are both weight-based algorithms, but neither of them takes the priority into consideration. Since the wideband multimedia communication network supports the ATM traffic with four priorities, it is essential to consider the priority when carrying out scheduling policies.

Therefore, in view of the above three conclusions, this paper puts forward an improved multicast scheduling algorithm, called PWBA (Priority WBA).

Similar with the policy of WBA, the PWBA is a weight-based algorithm as well. The differentiation between the two is that, unlike WBA, the PWBA takes the priority and the length of queue into consideration. The specific scheduling rules are shown as follows:

- Request

At each cell time, the weight of the HOL cells are calculated by the corresponding input plots. The value of the weight W is given as follows:

$$W=C_a\times age-C_f\times fanout+C_L\times length+C_p\times priority \quad (1)$$

in which *age* denotes the time cost for the HOL cell waiting to be departed. And *fanout* here is exactly the same with the definition of fan-out mentioned above; *length* and *P* mean the length of the input queue and the priority of the corresponding HOL cell, respectively. In addition, C_a , C_f , C_L and C_p, which are all positive real numbers, indicates the proportion of *age*, *fanout*, *length* and *priority* in the value of *W*, respectively.

After the calculation, each input submits the weight to all of the outputs that the HOL cell wishes to access.

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- Grant

Each output chooses the input with the heaviest weight from among those subscribing to it, allowing it to be dispatched.

- Dispatch

The chosen inputs dispatch their HOL cells to the destination.

In order to describe the PWBA scheduling algorithm more clearly, the whole scheduling process is shown in Figure 3. For simplicity, the scheduling model is supposed to have two inputs and four outputs. Since the primary concern of the scheduling process is how the cells/residues in the input queues are scheduled, there is no need to draw the output ports. Therefore, Fig.3 only shows the changes of the multicast cells in the input queues.

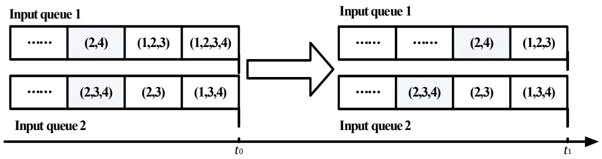

Figure 3 The process of scheduling in PWBA

Suppose at time t_0, the priority of queue 1 is four, and the length of it is ten; while the priority of queue 2 is one, and the length is 11. At each cell time, two inputs, respectively, calculate the weight based on the equation (1). For the sake of convenience, let $C_a=C_f=C_L=C_p=1$, therefore $W_1=10$ and $W_2=9$. Then each input submits the weight to all of the outputs that the HOL cell wishes to access.

Secondly, each output chooses the input with the heaviest weight from among those subscribing to it, independent of others, allowing it to be dispatched. As is shown in Fig.3, the output ports of 1, 3 and 4 all receive the request from the input ports of 1 and 2. Since $W_1 > W_2$, the three inputs will all choose the input port 1. As for the output 2, as it only receives the request from input port 1, it will select the input port 1 as well.

Finally, each input sends its HOL cell to all the outputs that allow it to be dispatched. Therefore, the HOL cell of queue 1 will be copied for four times, and be sent to the output ports of 1, 2, 3 and 4, respectively. As the weight of HOL cell in queue 2 is lower, it could not be dispatched but becomes a residue, waiting to be sent in the next cell time, and the age is increased at the mean time.

At the timeslot t_1, the cells in the input queues are changed, as shown in Figure 3. And the new cells/residues at the HOL will continue to be scheduled following the above steps. Obviously, as a result of considering the priority, this multicast scheduling algorithm which enables the queues with higher priority to be served quickly, can meet the requirements of scheduling flows with diverse priorities in multimedia communication network.

4 Modeling And Simulation

The main objective of this section is to present a comparative analysis of the performances of PWBA, WBA and PGMF algorithms using the OPNET Modeler. This simulation tool enables us to compare the performances of the algorithms by examining average latency and throughput. The network configuration and the OPNET simulation models used in the study will be described in this section.

- Node Model

A simulation node model is set up in this section, which is shown in Fig.4.

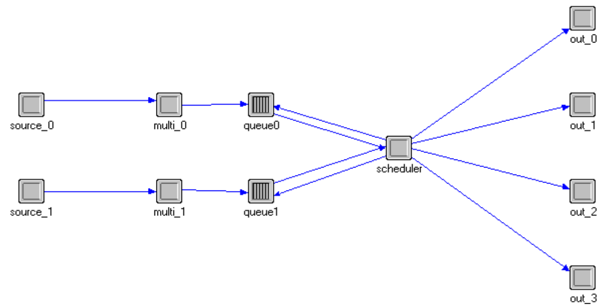

Figure 4 Scheduling Node Model

Suppose the model only has two inputs and four outputs, for simplicity. The source models, marked as source_0 and source_1, represent two sources with different priorities. They generate packets and specify the creation rate of generated packets in the terms of packets/second. This rate is specified by certain distribution of packet inter-arrival time.

The process models marked multi_i, queue i (i=0, 1) and scheduler will be introduced later.

- Packet Format

Fig. 5 shows the ATM cells that the sources generate and send, the first two bytes of which are filled with the information of destinations, while the following bytes represent the age, priority and other information, respectively.

Dest0 (4bits)	Dest1 (4bits)	Dest2 (4bits)	Dest3 (4bits)	age (8bits)	priority (4bits)	others (12bits)
Pay_load (384bits)						

Figure 5 The format of ATM cells

- Process models

The multi_0 and multi_1 are multicast generators, whose process models are shown in Fig.6, are in charge of giving the destination information to the ATM cells mentioned above. While the process models of input queues marked quene0 and queue1, which are extensions of the acb-fifo queue model, are shown in Fig.7.

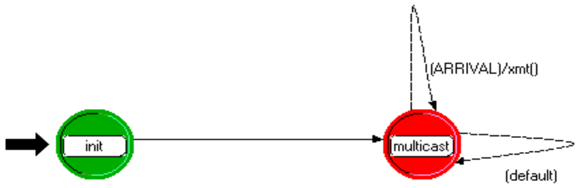

Figure 6 The Process Model of Multicast Generator

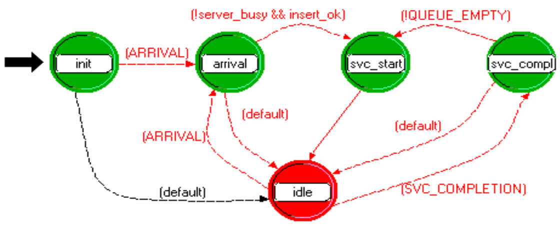

Figure 7 The Process Model of Input Queue

Fig.8 represents the process model of the scheduler, which is the kernel of the simulation. It consists of five main states: init, idle, queue0, queue1 and schedule.

The init state is used to initialize the parameters for simulation.

When either of the two queues are empty at a certain timeslot, the scheduler will only dispatch the HOL cell of the queues are not empty, and the process will transit into the corresponding queue0 or queue1 state.

The multicast scheduling algorithms, PWBA, WBA and PGMF, will be implemented in the schedule state, only when the two queues are both filled with cells.

A process transits into the idle state automatically when no processing is carried out.

5 Performance Analysis

In this section, the latency and throughput performances of the three multicast scheduling algorithms, PWBA, WBA and PGMF, are presented here for comparison.

The simulation process is composed of two parts. Firstly, set the inter-arrival time of generated packets to be a certain distribution, and analyze the performances of the three algorithms. Suppose that, source_0 shown in Fig.4 is a high priority cells generator, while source_1 is low. In addition, source_0 sends packets at a constant rate, while the packets inter-arrival time of source_1 is set to be exponentially distributed.

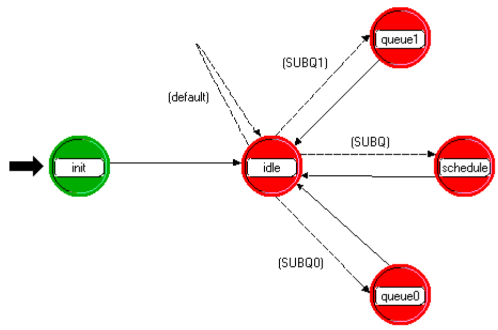

Figure 8 The Process Model of Scheduler

Since the ATM flows have four different priorities, this paper assumes that source_0 generates packets with the priority of 4, and source_1 with the priority of 1, for the purpose of checking whether the latency of the low priority queue will be too high. The simulation time is 3600s, and the results are shown in Figure 9(a) to 9(c).

Secondly, change the distribution of packet inter-arrival time for several times, and observe the latency performance with the increase of throughput. The result is shown in Figure 10.

It can be observed from Fig. 9(a) to (c) that, WBA performs better in throughput, but worse in latency; on the contrary, PGMF is better in latency, but does not perform as well as PGMF in throughput. PWBA, which possesses high throughput performance as WBA, balances the trade-off between throughput and latency. In addition, for the high priority queue (queue 0), the latency of PWBA is lower than WBA and PGMF; while for the low priority queue (queue 1), the latency of PWBA is lower than WBA as well, but a little higher than PGMF. The reason is shown as follows: since PWBA takes priority in to consideration, the queue with high priority possesses heavy weight, and the HOL cells of it can be dispatched with low latency. On the contrary, the weight of the low priority queue is light comparing with the other two algorithms, WBA and PGMF, thus the latency property is not the best. In one word, PWBA inclines to dispatch the HOL cells of the high priority queues.

As is shown Figure 10, comparing with the other two scheduling policies, the PWBA performs better in both latency and throughput with the increase of the throughput.

As a result of comprehensive consideration of the queue length and priority, PWBA possesses low latency performance even with heavy payload. With the latency reduced, more cells could be served at the same timeslot, thus the throughput can be increased, in comparison with the other two algorithms.

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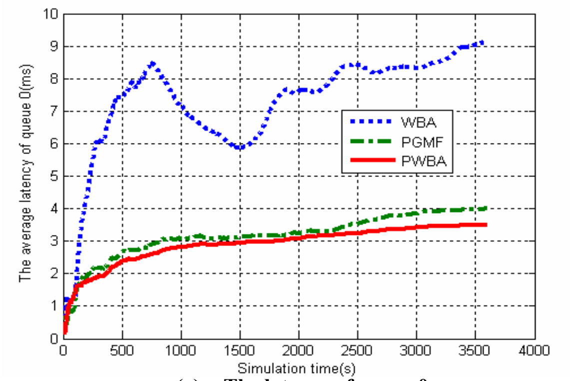
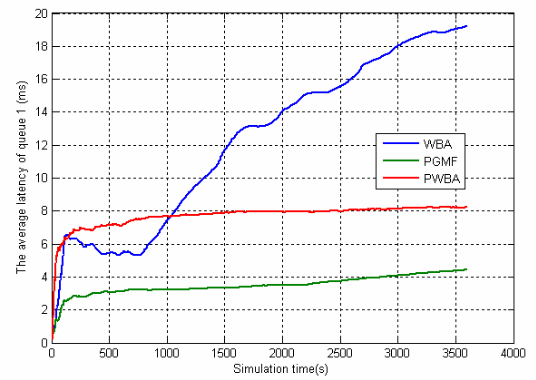
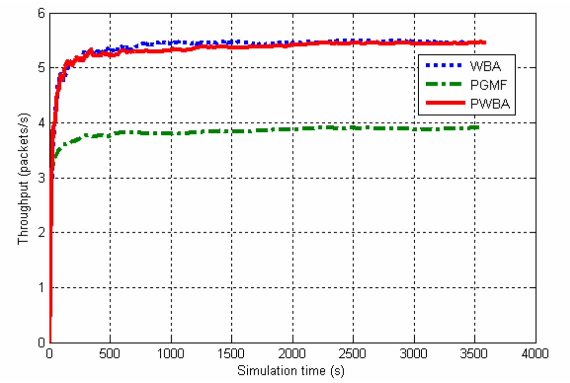


(a) The latency of queue 0



(b) The latency of queue 1



(c) The throughput of the three algorithms

Figure 9 The first part of the simulation results

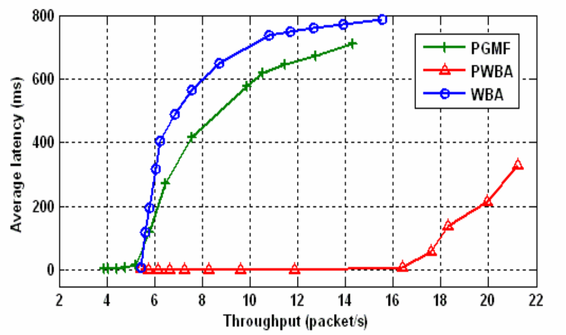


Figure 10 Graph of average cell latency as a function of throughput

6 Conclusion

The multicast scheduling algorithms used in the wideband multimedia communication network should possess the features of high throughput and low latency, in order to meet the needs of QoS. Based on two typical policies, this paper presents a novel multicast scheduling algorithm, which performs well in both throughput and latency. Moreover, it takes priority into account, which is much more suitable to be used in the background. The algorithm that the paper presented, may point out some possible directions of the further research in the wideband multimedia network.

The scope of the research in this article can be broadened, and the scheduling algorithms can be improved to be used in much more complex networks. These issues are being investigated recently and will be presented in the future.

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