Weighted Bandwidth Sharing Scheme to Guarantee the Video Quality in Home Networks

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Abstract— To efficiently provide a video streaming service in home networks, a network node should support QoS (Quality of Service) for the streaming videos. In order to guarantee QoS, it is necessary to allocate the high bandwidth for the video stream flow when multiple flows compete for the scarce bandwidth resource. In this paper, we propose a novel bandwidth sharing scheme, called W-BS (Weighed Bandwidth Sharing), for video streaming service in home networks. To provide network stability in a congested network, the W-BS scheme shares the bandwidth according to the target utilization of bottleneck link. It also adaptively applies weighting factor to service traffics. Through the simulation results, we prove that the proposed scheme guarantees the quality of the video streaming service in home networks.

Keywords- Bandwidth Sharing; Streaming Service; Quality of Service

I. INTRODUCTION

Due to the explosive growth of multimedia devices such as mobile phone, pad, game console and digital TV, there have been significantly increasing demands for multimedia streaming application in home networks [1]. The multimedia devices need to allocate a sufficient bandwidth because video streaming applications require persistently high bandwidth and timely packet delivery. Additionally, the video streams are sensitive to packet losses which led to a significant degradation in the quality for users. However, it is difficult to provide a high bandwidth and low packet loss ratio in home networks, because multiple flows compete for the scarce bandwidth resource, as shown in Fig. 1. Multiple streams are competing for the bottleneck link existing between the AP (Access Point) and the edge router. In many cases, the required bit-rates for video streaming flows may not be provided. In home networks, therefore, effective bandwidth sharing is essential for the bottleneck link.

The way network bandwidth is shared among contending flows has a significant impact on user-perceived quality. To cope with this phenomenon, TFRC (TCP-friendly Rate Control) is commonly used for guiding the video source rate adaptation of each stream [2]. TFRC adopts end-to-end approach in which the video senders infer network condition from estimated packet loss and delay statistics. TFRC can react only to ongoing network congestion or packet losses. It also suffers from long queuing delays and persistent packet losses even at steady state. Furthermore, it usually cannot respond rapidly to sudden changes in traffic or network conditions, such as appearance of new streams in a fully utilized network.

To solve these problems, we present a W-BS (Weighted Bandwidth Sharing) scheme for video streaming service in home networks. The W-BS scheme is useful for improving network stability in a congested network by sharing the bandwidth according to the target utilization of bottleneck link. It also improves the video quality by allocating the bandwidth with different weighting factor. To achieve this, our scheme provides the traffic classification function. Our simulation results show that the proposed W-BS scheme guarantees a video quality by comparing the throughput, packet loss ratio and PSNR (Peak Signal-to-Noise Ratio). The rest of the paper is organized as follows. In the next section, we review some of the related works and in Section III, we present the weight bandwidth sharing scheme to guarantee the quality of video streams. Simulation results and conclusions are given in Section IV and Section V, respectively.

II. BACKGROUND

In this section, we first describe the bandwidth sharing scheme for bottleneck link. It is followed by a related works about the providing a quality of service for video streaming.

A. Bandwidth sharing in a bottleneck link

We now discuss various schemes for bandwidth allocation [3]. A natural method might be to choose the allocation so as to maximize the global network throughput, that is to say, to maximize the sum of allocations. However, a significant
The drawback with this sharing scheme is that it often leads to allocations where allocation must be zero for some flows. Max-min sharing is the classical sharing principle in the domain of data networks. The scheme stated simply is indeed to maximize the minimum of allocation subject to the capacity constraints. The appropriateness of max-min fairness as a bandwidth-sharing scheme has been questioned by Kelly [4] who has introduced the alternative notion of proportional fairness. This scheme may be interpreted as being to maximize the overall utility of rate allocations assuming each route has a logarithmic utility function. All two criteria admit natural generalizations with weighting factors associated with each route such that an increase in this weight leads to an increase in the received share allocations.

There are two broad classes of adaptive bandwidth sharing algorithms which we refer to as “explicit-rate” and “congestion–indication” algorithms. Practical explicit-rate algorithms are based on the distributed calculation of rate allocations. In view of the complexity of explicit-rate algorithms, most network flow-control protocols are based on simple binary indications of congestion issued independently by the network links. Hence, a bandwidth sharing scheme using congestion-indication based weighting factor is needed for video streaming service in home networks.

B. Quality of service for video streaming

Providing a quality of service for video streaming applications in home networks has been a challenging problem of many research communities. In particular, QoS requirements in terms of rate and delay have been among such research interests. A new architecture for streaming video in the Internet scheme called LIVA (Layered Internet Video Adaptation) is proposed [5]. LIVA allows bottleneck link to be shared in an efficient manner, minimizing total distortion of all competing video streams. Rate allocation adapts to transient events with fast convergence, while avoiding steady-state queuing delays or persistent packet losses. The CM (Congestion Manager) framework seeks to share available bandwidth among a set of flows [6]. However, the CM is designed to run on the sender side. The sending host takes priorities into account to allocate bandwidth among flows that have the same destination. Thus, the allocation of resources is performed between the set of flows accessing the same given server. The utility-proportional bandwidth sharing for multimedia transmission supporting scalable video coding is proposed [7]. This scheme proposes a convex optimization formulation for bandwidth sharing and rate control, which is solved indirectly through its dual using gradient projection method. This allowed us to devise a distributed algorithm that can be used to determine the optimal rate allocation in an iterative manner. However, all of these schemes cause network congestion because these schemes do not provide network stability in bottleneck link. Hence, a bandwidth sharing scheme considering the network stability and guaranteeing the video quality is needed for video streaming service in home networks.

III. W-BS (Weighted Bandwidth Sharing) Scheme

In this paper, a new bandwidth sharing scheme in home networks, called W-BS, is proposed to guarantee the video quality. Fig. 2 shows the structure of W-BS scheme. Our scheme operates on the network node located next to the bottleneck link. The proposed scheme consists of the target utilization module, the traffic classification module, the weight calculator module and the bandwidth allocation module. The target utilization of bottleneck link is chosen for network stability according to the estimated available bandwidth and congestion level. The traffic classification module separates video stream and non-video stream by analyzing the IP header. The weight calculator module computes the weighting factor of each stream before allocating bandwidth.

A. Target utilization of bottleneck link

The W-BS scheme sets up a target utilization of bottleneck resource for network stability. Target utilization, $B_{TU}$, is the amount of target bandwidth. Eq. (1) means $B_{TU}$ cannot exceed a capacity of bottleneck link and has to surpass the bandwidth of the difference between total capacity and estimated available bandwidth.
bandwidth.

\[ C_{BL} - B_{ABW} \leq B_{TU} \leq C_{BL} \]  

\[ (1) \]

\( C_{BL} \) denotes a capacity of the bottleneck link; \( B_{ABW} \) indicates to a available bandwidth in the bottleneck link. \( B_{ABW} \) is estimated by packet probing method which is one of the most well-known approaches for bandwidth estimation. We relate the \( B_{TU} \) and \( B_{ABW} \) as:

\[ B_{TU} = C_{BL} - q \cdot B_{ABW} \quad (0 \leq q < 1) \]  

\[ (2) \]

where parameter \( q \) is a congestion level. \( B_{TU} \) has different value according to \( q \). If \( q \) is 0, the network is congested. In this case, \( B_{TU} \) is set to \( C_{BL} \), because the streams flowing to the bottleneck link need more bandwidth.

### B. Traffic classification

The IP header is important to classify traffic. The most widely used network layer marking techniques are ToS (Type of Service) and DSCP (Differentiated Service Code Point). Routers at the edge of the networks classify packets and mark them with either the IP Precedence or DSCP value. Fig. 3 shows the ToS and DSCP fields in a typical IP header. Although the ToS field has been there for quite some time, it has not been widely used. Its use has been superseded by DSCP today. DSCP has more priority levels than that of ToS because DSCP has more priority bits. DSCP uses the same three most significant link ToS to define priority, but uses the next three bits to further refine them. Table I shows a part of the guidelines for DSCP service classes as defined by RFC 4594 [8].

<table>
<thead>
<tr>
<th>Service Class Name</th>
<th>DSCP Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>000000</td>
</tr>
<tr>
<td>Low-Priority Data</td>
<td>001000</td>
</tr>
<tr>
<td>Low-Latency Data</td>
<td>010010, 010100, 010110</td>
</tr>
<tr>
<td>Multimedia Streaming</td>
<td>100010, 100100, 100110</td>
</tr>
<tr>
<td>Multimedia Conferencing</td>
<td>100010, 100100, 100110</td>
</tr>
</tbody>
</table>

![Fig. 3. Structure of modified IP header](image)

The W-BS uses the DSCP fields of the IP header for the traffic classification. The W-BS distinguishes Standard and Low-Priority Data service class and Low-Latency Data, Multimedia Streaming and Multimedia Conferencing service class. In the traffic classification step of W-BS, network node calculates the total bitrates of video streams \( V \) and that of non-video streams \( S \) as:

\[ V = \sum_{i=1}^{n} R_i \]  

\[ (3) \]

\[ S = \sum_{i=1}^{n} R_i \]  

\[ (4) \]

where \( R_i \) means the bitrates of flow \( i \) in bottleneck link. \( v \) and \( s \) are traffic type indicator representing whether flow \( i \) is a video stream or not.

### C. Weighted bandwidth sharing

The W-BS scheme figures out the weighting factors in the weight calculator module. There are two types of weighting factors in the W-BS: one for video stream flow and another for non-video stream flow. Each weighting factor is calculated by Eq. (5) and Eq. (6) respectively.

\[ \omega_v = \frac{n B_{TU}}{(n-1) V + R_{TI}} \quad (n \geq 1) \]  

\[ (5) \]

\[ \omega_s = \frac{B_{TU}}{(n-1) V + R_{TI}} \quad (n \geq 1) \]  

\[ (6) \]

\( R_{TI} \) comprises rates of all video streams and rates of all non-video streams traversing a bottleneck link, that is, \( R_{TI} = V + S \). \( n \) represents the degree of allocating bandwidth for the video streams. The choice of \( n \) has impact directly on the amount of bandwidth allocated for video stream. If \( n \) is 1, the bandwidth is allocated for video streams proportional to the ratio of \( B_{TU} \) to \( R_{TI} \). If \( n \) is a very large value, the bandwidth is allocated about \( C_{BL} \). Finally, the W-BS allocates the bandwidth for each flow based on Eq. (7).

\[ \omega = \omega_v \cdot R_i \]  

\[ (7) \]

\( AB_i \) is the allocated bandwidth to flow \( i \). \( \omega_v \) denotes the weighting factor of flow \( i \). If flow \( i \) is the video stream flow, \( \omega_v \) is assigned as:

\[ \omega_v = \frac{n B_{TU}}{(n-1) V + R_{TI}} \quad (n \geq 1) \]

\[ \omega_s = \frac{B_{TU}}{(n-1) V + R_{TI}} \quad (n \geq 1) \]

\[ \omega = \omega_v \cdot R_i \]  

\[ (7) \]

The weighted bandwidth sharing is illustrated in Fig. 4.

![Fig. 4. Flowchart of the W-BS Scheme](image)
represents \( \omega_i \). And if flow \( i \) is the non-video stream flow, \( \omega_j \) represents \( \omega_v \).

Fig. 4 shows the flowchart of the W-BS scheme performed by a network node. There are three steps: the target utilization of bottleneck, the traffic classification and the weighted bandwidth sharing. In the target utilization step, network node estimates available bandwidth periodically and setting \( q \) value. When new flows come to the network node, \( B_{i}^{T} \) is computed considering the \( B_{ABW} \) and \( q \). Network node classifies the each flow by interpreting an IP header and calculates the total amount of bitrates based on the traffic classification. \( k \) means the number of total flows in bottleneck link. At last, when the weighting factor is computed for each video flows and non-video flows respectively, appropriate bandwidth is allocated in the weighted bandwidth sharing step.

### IV. SIMULATION AND EVALUATION

This section presents the simulation results for the proposed W-BS scheme. In order to evaluate the performance of the proposed scheme, we performed experiments on the basis of the NS-2 (Network Simulator) of LBNL (Lawrence Berkeley National Laboratory) [9]. The simulation topology is shown in Fig. 5. In this simulation, the streaming server transmits video streams via router. There are two competing traffic flows in the simulation. One is video traffic transmitted by using TFRC. Another is CBR traffic transmitted by using TCP packets. Transmission rate for the video traffic is 1.5Mbps; burst and idle time are both set to 0.5ms. The link between the R1 and R2 is 5Mbps. The link between the streaming server and R1 is set at 1Mbps. For the experiments, we used “SOCCER” video clip which is encoded using the reference software JSVM (Joint Scalable Video Model). The “SOCCER” format is CIF and the video frame rate is 30 frames per second.

There are four scenarios in simulation as shown in Table II. In this simulation, the constant value of \( n \) is set to 2 and \( q \) is set to 0.8. The W-BS scheme operates on the R1 router in that the link between R1 and R2 is the bottleneck link. The proposed scheme compare in terms of throughput, packet loss ratio and PSNR.

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>The number of Video Streams</th>
<th>The number of Non-video streams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

![Fig. 5. Network configuration to evaluate the performance](image)

![Fig. 6. Comparison of the average throughput: (a) 2 Video Streams and 3 Non-video Streams, (b) 2 Video Streams and 5 Non-video Streams, (c) 3 Video Streams and 3 Non-video Streams, (d) 3 Video Streams and 5 Non-video Streams](image)
Fig. 6 shows the comparison of the average throughput between the original TFRC and the TFRC with W-BS. The average throughput of the TFRC with W-BS scheme is higher than original TFRC by 20%, because the W-BS shares the bandwidth according to the traffic classification and gives more weighting factor to video stream flow. When there are large numbers of the video stream flows, the W-BS scheme works well. Comparing Fig. 6(a) and Fig. 6(c), the flow 1 improves the throughput by 20% in scenario 3 and improves the throughput by 17% in scenario 1. As naturally competing traffic increases, the throughput decreases.

Fig. 7 shows the comparison of the packet loss ratio between original TFRC and TFRC with W-BS under four scenarios. The proposed scheme reduces the packet loss ratio in every scenario, because the proposed scheme uses the target utilization scheme. It is based on the estimated available network bandwidth and congestion level. Fig. 8 shows the comparisons of the PSNR between original TFRC and TFRC with W-BS. The PSNR of the proposed W-BS scheme is higher than that of the original TFRC as our scheme shares the bandwidth by weighting factor and target utilization. These results mean that the proposed W-BS scheme shares the bandwidth for network stability and guarantees the quality of video streams by increasing a throughput and reducing a packet loss ratio of video stream.

V. CONCLUSIONS

To guarantee the video quality in home networks, we propose the W-BS scheme. The W-BS scheme consists of the target utilization of the bottleneck link, traffic classification and weighted bandwidth allocation according to the weighting factor. The target utilization of bottleneck link can be computed using available bandwidth and congestion level. In the traffic classification step, video stream is distinguished from non-video stream by DSCP field in an IP header. After that, weighting factor is calculated according to the classified traffic, target utilization and total rate of all streams traversing the link in the weight calculator module. The calculated weighting factor is used for bandwidth allocation. Our simulation results reveal that the proposed scheme can provide a high quality video streaming in the home networks.

REFERENCES