Literature Survey for Improving Quality of Service for Multimedia Applications

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Abstract: The global reach and ubiquity of the Internet has created a large number of applications which leads to an extensive need to support both real time multimedia applications and traditional text based applications. Each application has different Quality of Service (QoS) requirements [1,2]. QoS for multimedia applications could be achieved by: (1) Difference in packets handling based on the content of the packet and its priority(Differentiated Service). (2) Fragmenting the multimedia data into optimal size packets. (3) Maximizing the number of packets that reach the destination before deadline. (4) In case of congestion dropping policy should be such that multimedia data should be dropped with less probability.Some of the fragmentation techniques, scheduling algorithms and packet dropping policies are analyzed in this paper.
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1. Introduction

The recent advancement in communication technologies has led to a variety of multimedia applications including Video on Demand, Voice over IP (VOIP) which are QoS sensitive (i.e.) they cannot tolerate the effect of packet loss, delay and fluctuations in throughput compared to traditional applications [3-5]. Hence QoS sensitive flows should be given more priority in routers by following proper scheduling policy and dropping policy. Differentiated services are used to support IP QoS which classifies individual micro flows i.e differentiates different applications the edge of the network into one of several unique classes and then apply a per-class service in the middle of the network [6-8].

Yao-Nan and Yung-Chuan Wun[9] have proposed a Timeliness and QoS aware packet scheduling policy for the environments where each packet has a predefined hop by hop travelling schedule. The proposed approach maximizes the overall satisfaction factor of traffic formula which comprises of QoS metrics like delay, jitter and packet loss. A flow is free of charge if any quality metric gets below a fixed minimum threshold. The scheduling policy is based on prioritized packet scheduling like Weighted Round Robin and Weighted Fair Queuing [10-14] and Budget Based Queue (BBQ) Management [15] approach which controls the quality of each network component based on a calculated budget plan.

Styllianos Dimitriou, Ageliki Tsioliaridou and Vassilis Tsaoussidis [16] propose a service differentiation scheme namely "Size Oriented Dropping Policy" which uses packet size to categorize time sensitive from delay tolerant flows and prioritize packet dropping probability accordingly. Multimedia applications use smaller packet size than other applications. The algorithm is derived from service differentiation scheme based on size [17] and promotes a class of service as Less Impact Better Service (LIBS) which favors high priority packets and forwards them to the destination immediately upon the arrival. SDP is implemented along with modified RED[18] inherited from Weighted RED[19] and RED preferential dropping[20]. They have proved that in SDP gateways small packets experience less dropping probability than in RED thereby improving the throughput of multimedia applications.

Tamer Dag[21] proposes a packet scheduling scheme "static priority with deadline consideration" which integrates a Qos parameter (delay) into classical static priority packet scheduling[22]. The packet drop occurs during buffer overflows and deadline violations. The packets have priorities based on QoS level of the data they have[23-25] and deadlines. The proposed scheme focuses on reducing delay and improving throughput.

Lonshe Hou, Qiang Fu, Yuanzhi Zou and Wen Gao [26] refine the video data as Group of pictures(GOP)[27], determine the sending window for each GOP and selectively drops the frame with low priority. The system is a simplified version scalable coding[28-30]. They have proved that the proposed system improves the quality of the video received at the receiver side.

Kashyap K.R. Kambhatla,Sunil Kumar, Seethal Paluri and Pamela C.Cosman[31] introduce a cross layer priority aware packet fragmentation scheme at MAC layer to enhance the quality of H.264/AVC. H.264 slices are classified into priorities based on the CMSE (Cumulative Mean Square Error)[32] towards the video quality. Optimal fragment size is derived for each priority class based on CMSE which achieves maximum goodput at different encoding rates, slice sizes and bit error rates. They have proved that proposed method provides considerable Peak Signal to Noise Ratio(PSNR)[33] and Video Quality Metric(VQM)[34] gain of the received video.

Fei Li[35] considers online scheduling of packets with hard deadlines in a finite capacity queue. The objective is to maximize the weighted throughput sent by their deadlines in an online manner. Competitiveness is a metric to measure an online algorithm's worst case performance in theoretical computer science[36,37].

An online algorithm is k-competitive if

Weighted throughput = 1/k*(weighted throughput of an offline algorithm).

Packet's parameters could be updated in an online manner. They have shown that determinized memoryless algorithm is 3 competitive and randomized memoryless algorithm is 2.618 competitive.

Different real time and non real time applications exist in Integrated network. Traditional network communication such as file transfer, email and remote login are examples of non real time applications. Multimedia conferencing, remote medical diagnosis, process monitoring systems, aircraft controller systems and interactive games are examples of real time communication application. The most important characteristic of all real time traffic is that, the value of communication depends on the time of delivery of the message at the recipient. A deadline is associated with each message. A message is of no use if it arrives to the destination after its deadline has passed and messages have to be discarded. A message that arrives earlier may be considered harmful as it requires buffering at the receiver to achieve constant end to end delay. Hence delivery at the recipient as close as possible to the deadline is sufficient and desired. Hence multimedia packets have to be properly fragmented, scheduled and discarded.

Survey of some of the scheduling algorithms, packet discard schemes and packet fragmentation schemes are presented in section 2-8 and the comparison of the same is given in section 9.

2. Timeliness and QoS aware packet scheduling[9]

The authors have proposed a charge based optimization model for packet scheduling aiming to maximize overall QoS satisfaction factor. The router first assigns an appropriate profit function to the packets based on its timeliness as well as the loading status of succeeding router along its travelling path and then inserts the packet into an appropriate position in the output queues.

They have assumed 3 different output queue architectures.

i. **Single preemptive Queue (SPQ):** The newly arrived packet can be inserted into any position in the queue.

ii. **Multiple FIFO Queue (MFQ):** A newly arrived packet will be inserted into tail end of a FIFO queue and the scheduler selects a queue in round robin fashion.

iii. **Priority Multiple Queue (PMQ):** Similar to multiple FIFO queue but with additional priority queue which has highest priority among all FIFO queues.

They propose an optimization model that takes QoS class(conversational, Streaming, non real time) timeliness and quality metrics into account.

$$\sum_{i=1}^{3}\sum_{j=1}^{Ni}(q_{i,j}.C_i\lambda_{i,j}) \qquad (1)$$

N_i – Number of flows in class i.

C_i – Unit price / byte of class i.

$\lambda_{i,j}$ - Number of bytes admitted in the flow j of class i.

Packet scheduling can either be independent or dependent on the loading status of succeeding routers in the travelling path of a packet. The former scheduling method is called Intra Router Scheduling(IRS) and the latter is called Look Ahead Scheduling(LAS). For each incoming packet the scheduling agent assigns a profit function based on transmission latency. The resources are allocated to different classes of data based on the profit function.

2.1 Experimental results

Case i: The three architectures were evaluated with evaluation metrics delay, jitter and loss rate. It was observed that SPQ performed the best.

Case ii: When comparing the performance of LAS and IRS, LAS outperforms IRS

Case iii: 12 Scheduling policies integrated with proposed profit function was compared with Simulated Priority Queue[27]. The profit based approach outperforms Simulated Priority Queue by 34% under heavy load.

3. Size Oriented Dropping Policy (SDP)[16]

The authors propose a novel service differentiation method namely Size Oriented Dropping policy which differentiates real time and non real time flows using packet size. SDP promotes a class of service defined in service differentiation based on size [38] to Less Impact Better Service(LIBS) which imposes that traffic that causes only minor delays should enjoy increased privileges over the rest of traffic. Size Oriented Dropping Policy is based on NCQ[39] and NCQ+[40] which incorporated LIBS distinguish traffic into non congestive(small and tiny packets) and congestive (big packets).

Transmission delay of a packet is proportional to the size. Hence small packets are usually used by applications that require fast delivery times, constant inter arrival times and big packets are preferred for bulk data transfers like FTP or Bit Torrent. The continuous packet loss in real time applications severely degrades the performance and distorts the user perceived quality. Packet dropping is based on modified RED scheme where small packets experience less dropping than in RED thereby increasing the perceived quality of real time applications.

3.1 Algorithm

Let sdp_thresh be moving average of incoming packet.

```
if next arriving packet size > sdp_thresh
        Classify as big packet
        Apply RED algorithm for dropping
else
        classify as small packets
        apply SDP_drop
end if
```

sdp_drop = red_drop*(pkt_size/sdp_thresh) (2)

3.2 Experimental results

1. SDP does not penalize big packets more than RED and decreases the packet loss ratio of small packets by providing them with increased privileges.
2. SDP achieves better service differentiation compared to DropTail[41], RED[42] and NCQ+.
3. SDP increases the perceived quality in real time applications.

4.Static Priority with Deadline Considerations (SPD)[21]

The author proposes a packet scheduling algorithm which integrates QoS parameter, delay into classical static priority algorithm and analyze packet losses by considering buffer overflows and deadline violations. Packets belonging to different flows need to be treated differently based on Qos parameters hence packet scheduling algorithms serve them based on QoS parameters.

In Static Priority (SP) algorithm the packets are given priorities based on the type of data they carry. If network node becomes congested these packets are sorted at the network node's queue according to their priorities with the highest priority queue at the head of the queue. SPD works like SP but instead of complete sorting only k packets in the buffer are sorted.

4.1 SPD Vs. SP

1. SP algorithm creates overhead when full sorting is done, but in SDP only k-sorting is performed where only first k packets are sorted thereby avoiding overhead.
2. In SP the unfairness is caused because every packet arrival makes highest priority packet to move ahead leading to the starvation of low priority packets but in SPD only k-packets are sorted leading to the reduction of fairness.
3. In SP deadline is not considered but in the case if SPD the packets with no remaining deadline is discarded thereby reducing the unnecessary traffic.

4.2 Experiments results

Loss and delay depends on

1. The degree of SPD-k.
2. Buffer size – Packet loss is due to overflows if the buffer size is less and due to deadline violations if the buffer size is more.

5. Network Adapted Selective Frame Dropping Algorithm for Streaming media[26]

Longshe Huo, Qiang Fu, Yuanshi Zou and Wen Gao present a network adapted selective frame dropping algorithm that determines a sending window for each GOP and selectively drops frames with low priority to ensure that important frames within a GOP could reach the destination within deadlines. In video compression standards every GOP starts with I frame followed by a series of P and B frames. B-frame has the lowest priority that can be dropped at any time. When a P-frame is dropped all other P-Frames following this frame should be dropped. When I-Frame is dropped all other P and B frames within the sane GOP should be dropped. The playback time of GOP is called playing window that is determined by the time interval between 2 consecutive I-Frames. If the sender cannot transmit all the frames of GOP during limited time interval due to bandwidth limitation it drops some frames and jumps to the transmission of next GOP.

5.1 Algorithm

1. Compute the playing window of GOP by subtracting the time stamp values of 2 consecutive I-Frames.
2. If current time > starting point of current GOP
   a. if sent frame is I-Frame

. Drop all the IBP frames of the same GOP
else
Drop all B frames and send I and frames.
3. Send RTP packets as per predefined schedule.
4. If current time > endpoint of GOP
Drop all the following unsent P-Frames and B-Frames contained in current GOP and directly
switch to step 2
else
maintain no changes to the predefined frame dropping policy and go to step3
4. Continue from step 1 for all GOPs.

5.2 Experimental Results

Experiments conducted with a test video compressed with AVS video standard and tested for different bandwidth with the proposed selective frame dropping method enabled and disabled. With the proposed algorithm enabled the client could observe pictures with good quality and with the proposed algorithm disabled the client could observe intact or mosaic like pictures.

6. Video Quality Enhancement through optimized packet fragmentation[31]

Kashyap et. Al introduce a cross layer priority aware optimal packet fragmentation scheme to enhance the quality of pre-encoded H.264/AVC compressed bit streams over error prone links in wireless networks. H.264 slices are classified in 4 priorities at the encoder based on CMSE towards the received quality. The slices of a priority class in each frame are aggregated into video packets of corresponding priority. Optimal fragment size for each priority class which achieves maximum goodput is derived. Goodput is a measure of reliable transmission of packets over error prone channels.

6.1 The proposed system

1. The videos are pre-encoded using H.264/AVC into slices and the slices are aggregated into a video packet for transport over IP network appended with RTP/TCP/UDP headers[43]. Optimal packet size is calculated.
2. The slices are prioritized based on their distortion contribution (based on CMSE) to the received video quality.
3. Packet fragmentation could be done in 2 ways.

a. Priority agnostic and priority aware which in turn is classified into slice fragmentation enabled(slices could not be fragmented) and slice fragmentation disabled(slices could be fragmented)

6.1.1 Priority agnostic fragmentation:

They consider all frames in GOP with equal priority.

$$G = \frac{F_{RX}(y-h)}{R} = \frac{F_{TX}(1-P_b)^y(y-h)}{R} \quad (3)$$

where

$$F_{TX} = \begin{cases} N/n \ ; (N/n) \le (R_{CH}/y) \\ R_{CH}/y; (N/n) > (R_{CH}/y) \end{cases} \quad (4)$$

y - nx+h (5)
x - slice size
h - header length
n - number of slices
G - Goodput
F_{TX} - Number of frames transmitted.
F_{RX} - Number of frames successfully received.
y - Fragment size
h - Header length(40 bytes)
R - Encoding rate
R_{CH} - Channel bit rate.
P_b - Channel error rate.

The experimental results show that Goodput depends on error rate and optimal y size.
When R increases to 960 kbps and 1080 kbps the value of G drops to 77% and 69% respectively when $P_b = 5x10^{-5}$.
Discard rate increases as R increases.

6.1.2 Priority aware fragmentation

The video packets are divided into 2 priority classes and the expected goodput is a linear combination of individual goodput.

$$Gw = w_1g_1+w_2g_2. \quad (6)$$

Truncated normal distribution is used to assign probability for arrival of higher priority packets.

$$P(l_1=k) = \frac{K_1 e^{-(k-N/2)^2}/2}{\sqrt{2\Pi}} \text{; for k = 0,1,2,3…N} \quad (7)$$

K_1 – Normalization constant.

$$G_w = \sum_{l_1} p(l_1)(w_1 g_1 + w_2 g_2). \quad (8)$$

$$w_1 = \frac{CMSEofhigherpriorityslices}{CMSEofallslices} \quad (9)$$

N = l_1+l_2 where
N - Total number of fragments slices generated / second.
l_1 - high priority slices
l_2 - low priority slices.

$$\begin{cases} (1-P_b)^y & ; (l_1/n_1) \le (R_{CH}/y1) \\ & \end{cases}$$

$$g1= \frac{R_{CH}(1-P_b)^y(y-h)}{y*R} \quad ; (l_1/n_1) > (R_{CH}/y_1) \tag{10}$$

Low priority goodput g_2 is computed from the bits remaining to be allocated after all high priority fragments have been transmitted during each second.

$$G \begin{cases} (1-P_b)^{y1} & ; (l_1/n_1) \le (R_{CH}/y_1) \\ \dfrac{\left[\dfrac{R_{CH}-(l_1/n_1)y_1}{y_2}\right](y_2-h)(1-P_b)y_2}{R} & ; \text{ if } (l_1/n_1) > \left[\dfrac{R_{CH}-(l_1/n_1)y_1}{y_2}\right] \end{cases} \tag{11}$$

The optimal fragment sizes were estimated using Branch and Bound(BnB)[44] technique and they have proved that BnB technique takes less time compared to exhaustive search.

They have showed that Peak Signal to Noise Ratio(PSNR) and Video Quality Metric(VQM) gain are achieved by priority aware fragmentation over priority agnostic fragmentation without slice fragmentation.

7. Competitive Scheduling of packets with Hard deadlines in a finite capacity queue[35]

The authors propose deterministic memoryless algorithm and randomized memoryless algorithm which aim to maximize the weighted throughput. Weighted throughput is the total value of transmitted packets by their deadlines. Bounded delay model[45] is used for buffering. The time is discrete. Packets arrive over time and they are buffered upon intervals. Arriving packet 'p' has a non negative value 'w_p' and an integer deadline d_p.

The authors contribute:

1. A strictly 3-competitive deterministic memoryless algorithm.
2. A strictly 2.618-competitive randomized memoryless algorithm.
3. A new analysis method based on charging scheme.

7.1 Algorithm:

The authors propose 2 type of memoryless algorithms as follows:

7.1.1 Deterministic memoryless algorithm:

A packet arriving at time r_p has a weight w_p and an integer deadline d_p. Buffer is divided into slots and when packets are placed in the buffer will be assigned a virtual deadline.

1. Sort all the pending packets in decreasing weight order.
2. Initially the virtual deadline of an arriving packet to the buffer from pending packet = real deadline of the packet.
3. Optimal provisional schedule for pending packets is proposed to achieve the maximum weighted throughput of the packets.
4. Update virtual deadline t_j of a packet j ε optimal provisional schedule as t+i, where i is the index of the buffer slot that j is residing in the optimal provisional schedule queue.
5. Send the packet with earliest virtual deadline or maximum value packet based on the ratio of 2 packets.

Let packet with earliest virtual deadline be 'e'. Let the maximum value packet be 'h'.

```
if we ≥wh/α then (α – constant)
   send e
else
   send h
end if
```

Continue from step 1 till there are no packets pending.

7.1.2. Randomized memoryless algorithm

Here a random variable β is used to facilitate scheduling and γ influences competitive ratio.

1. Sort all the pending packets in decreasing weight order.
2. Initially the virtual deadline of an arriving packet to the buffer from pending packet = real deadline of the packet.
3. Optimal provisional schedule for pending packets is proposed to achieve the maximum weighted throughput of the packets.
4. Update virtual deadline t_j of a packet j ε optimal provisional schedule as t+i, where i is the index of the buffer slot that j is residing in the optimal provisional schedule queue.
5. Send the packet with earliest virtual deadline or maximum value packet based on the ratio of 2 packets.

```
if we ≥wh/α then (α – constant)
   send e
else
choose β uniformly in [0,1]
if β ε [0, γ] then
        send e
else
        send h
        end if
        end if
```

Continue from step 1 till there is no packets pending.

7.2 Experimental Results

Experiments show an improvement in the weighted throughput of packets. Deterministic memoryless algorithm is 3-competive and Randomized memoryless algorithm is 2.618 competitive.

The best precision and recall was achieved for the proposed GA-SVM RBF kernel.

8. Comparison Chart

Category	Timeliness and Qos aware packet scheduling[9]	Size Oriented Dropping policy[16]	Static priority with deadline consideration[21]	Network adapted selective frame drop[26]	Wireless H.264-optimal fragmentation[31]	Competitive Scheduling of packets with Hard deadlines in a finite capacity queue[35]
Basic idea	Assigning a profit function based to each packet based on the timeliness and QoS class and forwarding the packets based on the profit function	Categorizes time sensitive and delay tolerant flows based on size of packets and prioritize dropping probability accordingly	The packets are sorted based on the priority and deadline. While a packet is being served if the packet has no remaining deadline the packet is discarded.	Before sending GOP the playing window is predicted based on the results of previous hop and frame dropping is based on the priority of frames	H.264 slices are prioritized based on the CMSE contribution towards video quality. Optimal fragment size is derived for each priority for maximum goodput	Performs online scheduling of packets based on hard deadlines. Packets transmitted by deadlines will add to the weight of the packets. The objective is to maximize the weighted throughput.
QoS parameter	Delay, jitter, loss rate	Delay, Packet loss rate	Delay, packet loss	Packet loss rate	Weighted goodput, frame drop	Weighted throughput
Service Differentiation	Based on QoS class(conversational, Streaming, non real Time)	Based on size of packets. Multimedia data corresponds to small packets.	Based on the type of data that are carrying(i.e) video application has higher priority than an email application	Video traffic is only considered.	The slices in a GOP are differentiated based on the CMSE values.	Based on hard deadlines
Fragmentation	Not considered	Not considered	Not considered	Not considered	Fragmented	Not considered
Packet Dropping	Only in overflow condition	Based on RED. Small packets have less dropping probability.	Based on buffer overflow and deadline violations	If the frames could not be played within playing window the frames starts dropping starting from low priority frames.	Low priority frames will be dropped during overflow or low bandwidth	Based on buffer size and deadline violations
Scheduling	First In First Out(FIFO).	LIBS(Less Impact Better Service) favors high priority packets and forward them to their destination upon their arrival.	Earliest Deadline First Scheduling	First In First Out(FIFO).	First In First Out(FIFO).	Optimal provisional schedule which sorts packets based on deadlines and weights gained.
Deadline	Not considered	Not considered	Deadline is considered	Deadline is considered	Not considered	Deadline is considered
Sorting of packets	Not Sorted	Not Sorted	Sorting is done	Not Sorted	Not Sorted	Sorting is done
Fairness to other data	Fairness of other data are not affected	Better fairness to other data.	Better fairness to other data.	Other data are not considered in this algorithm	Only video data is considered for this algorithm	Fairness of other data are not affected
Experimental results	Profit based approach can outperform Simulated Priority Queue in optimizing QoS parameters	Increase in perceived video quality as a result of less packet loss rate and delay.	Study of packet loss based on buffer size. Small buffer size – dropping based on overflow Large buffer size – dropping based on deadline	Achieves error free and fluent rendering effects in video even in the case of worst network conditions.	Maximized weighted goodput which provides large gains in PSNR and VQM	Improved weighted throughput. Deterministic memoryless algorithm is 3-competive and Randomized memoryless algorithm is 2.618 competitive.
Future work	-	The algorithm can be incorporated with a time scheduling mechanism that allows special priority for selected packets that require less delivery time	Study of impact of jitter	-	-	Shrinking the gap of competitive ratio gap[1.618,2.618]. Application of the algorithm to multibuffer models.

8. Conclusion & Future work:

Yao-Nan and Yung-Chuan Wun[9] presented a new packet scheduling approach that takes into account both the timeliness and QoS class of a packet to insert an outgoing packet into the best queuing positions aiming to optimize the QoS factors. Each packet is assigned with a profit function based on timeliness and Qos factors. They have shown that the presented algorithm outperforms even under heavy load.

Styllianos Dimitriou, Ageliki Tsioliaridou and Vassilis Tsaoussidis[16] proposed a new service differentiation scheme based on packet dropping which classifies packets according to their size. Packet dropping probability depends on the comparative packet sizes in the queue. They have shown an improvement in goodput, link utilization, system fairness, quality of real time applications.

Tamer Dag[21] proposed a packet scheduler based on Static Priority algorithms. Different from classical schedulers the SPD algorithm integrates the delay and loss parameters. SPD also reduces the processing overhead of sorting by introducing order-k sorting. Sorting creates overhead.

Lonshe Hou, Qiang Fu, Yuanzhi Zou and Wen Gao [26] presented a novel selective frame-dropping algorithm adaptive to network bandwidth. Compared with other video adaptation techniques, such as transcoding and scalable coding, the proposed algorithm has lower computational complexity and better real-time performance. It is suitable for almost all of the market-prevailing video compression standards, and is easy to be deployed in large scale media streaming applications, such as P2P based live IPTV broadcasting systems.

Kashyap K.R. Kambhatla, Sunil Kumar, Seethal Paluri and Pamela C.Cosman[31] proposed priority aware fragmentation to improve the quality of pre-encoded H.264 bitsreams transmitted over unreliable error prone links. Optimal packet fragmentation was used to boost PSNR and VQM values. They have shown maximized expected goodput providing large gains in received video quality.

Fei Li[35] presented two online algorithms for scheduling weighted packets with hard deadlines in a finite capacity queue and provided their theoretical competitive analysis. Both algorithms provide worst case guarantees to maximize the weighted throughput without applying any stochastic assumptions over the traffic. Instead of using real deadlines virtual deadlines is used which are updated over time to make the decision on when to send the packets.

Deadline of the multimedia packets are not considered in [9], [16] and [31]. Other data is not considered in [26] and [31]. Optimal fragmentation is not used in [9],[16],[21],[26] and [35]. The proposed system focuses on improving Quality of Service for multimedia applications by maximizing the number of packets that reach the destination before deadline by calculating the optimal packet size using any optimization technique. The system includes other data traveling across the routers.

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