Improving QoS – Weighted throughput of multimedia packets through optimal fragmentation using different optimization techniques

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Abstract: The global reach and ubiquity of the Internet has flooded Internet with traditional and multimedia applications with different Quality of Service (QoS) requirements. Multimedia applications such as digital video and audio often have stringent time delay requirements i.e they have to reach the destination in time. The aim of the proposed system is to improve the Quality of Service of multimedia applications by improving the throughput of multimedia packets that reaches the destination before their associated deadlines by (1) Service differentiation by packet size. Multimedia packet are fragmented into optimal packet sizes using optimization techniques. (2) Packets are dropped in case of congestion using modified RED algorithm. The experimental results show an improvement in throughput of high priority fragments and quality of the received video.
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1. Introduction

Multimedia applications such as video streaming, which are delay sensitive and bandwidth sensitive are growing rapidly over Internet. Video packets can tolerate some packet loss. Lost video packets induce different levels of quality degradation. Fragmentation of packet calls a trade off between reducing the number of overhead bits per packet by using large fragment size and reducing transmission error rate by using small packets [1]. Hence optimal packet size should be calculated to balance the above mentioned factors. The packets are fragmented at the Network layer for transmission in the underlying networks. Optimization techniques like Modified Particle Swarm Optimization(Modified PSO), Genetic Algorithm and Artificial Bee Colony(ABC) Optimization are used to derive the optimal fragment size bounded by Maximum Transmission Unit (MTU) of Real Time Protocol (RTP) that maximizes the weighted throughput.

Packet discard is done during deadline violations. In case of congestion modified RED algorithm is used which differentiates the packets based on size where multimedia packets experience less dropping probability than other traditional data packets.

Adapting optimal packet size, scheduling of packets and discard policy based on priority improve the weighted throughput of the packets without affecting the fairness of other data. The Related work is given in section 2.

2. Related Work

Yao-Nan and Yung-Chuan Wun[2] have proposed a Timeliness and QoS aware packet scheduling policy for the environments where each packet has a predefined hop by hop traveling schedule. The proposed approach forwards the packets based on the profit function assigned to the packets based on the timeliness and QoS class. The scheduling policy is based on prioritized packet scheduling like Weighted Round Robin and Weighted Fair Queuing [3-6] and Budget Based Queue (BBQ) Management [7] approach which controls the quality of each network component based on a calculated budget plan.

Styllianos Dimitriou, Ageliki Tsioliaridou and Vassilis Tsaoussidis [8] 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. Hence multimedia packets experience less dropping probability than other packets. The algorithm is derived from service differentiation scheme based on size [9] 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[10].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[11] proposes a packet scheduling scheme "Static Priority with Deadline consideration (SPD)" which integrates a QoS parameter (delay) into classical static priority packet scheduling. The packet drop occurs during buffer overflows and deadline violations. The packets have priorities based on QoS level of the data they have[12-14] and deadlines. The proposed system is discussed in section 3.

3. The Proposed System

The proposed system is an end to end network with hop by hop traveling schedule. The system uses H.264/AVC encoded video. Optimal packet size for different encoding rates are calculated using optimization techniques like Genetic algorithm, Modified PSO and Artificial Bee colony optimization. Modified RED is used to decide the dropping policy of packets with remaining deadlines.

3.1 Algorithm

1. Calculate the optimal packet size(p) for different encoding rates for given bandwidth using Optimization algorithm (Genetic algorithm, Modified PSO and Artificial Bee colony optimization)
2. Determine the remaining_deadline of the packets
3. In each node

```
for each packet arrival
if remaining_deadline < travel_time then
    drop the packet
  else
    if pkt_size > p
     drop_prob = red_drop
else
     drop_prob = Modified RED drop_prob
    end if
 end if
 end for
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3.2 Estimation of optimal packet size

The proposed system aims to maximize the number of multimedia packets that reach the destination on time(throughput) in the presence of other data by assigning optimal size to the multimedia fragments.

$$Th = \frac{\left(\left(ch\_rate - other\_data\right)/_{p-h}\right)(p) + other\_data}{N} \quad (1)$$

Th - Throughput
p - Optimal fragment size in bytes
h - Header size of a packet in bytes
enc_rate - Encoding rate in kbps
ch_rate - Channel rate in kbps
other_data - Traditional data rate in kbps
N - enc_rate + other_data(Total data)

In Equation (1) channel rate available after occupied by other data is divided into equal size fragments of multimedia data. It is added with other data. Throughput is calculated as the ratio of total data sent at the source side to total data received at the destination side.

Number of fragments that will be discarded can be estimated initially as follows (i.e) the multimedia packets that can be accommodated in the available channel rate will be discarded.

$$\text{Fragments discard} = \frac{enc\_rate - (ch\_rate - other\_data)}{p} \quad (2)$$

The distribution of other data with multimedia data is assumed to follows truncated normal distribution. The encoding rate of video data is f and the expected other data is f1/2(other data is half the video data).

$p(f_1)$ probability of other priority data is calculated as

$$p(enc\_rate = f) = \frac{1}{\sqrt{2\Pi}} e^{-\left(f - f/_2\right)^2/_2}$$

$$p(enc\_rate = f) = \frac{1}{\sqrt{2\Pi}} e^{-\left(f/_2\right)^2/_2} \quad (3)$$

f – Different encoding rates.

The value of p(optimal fragment size) is to be calculated which maximizes the weighted throughput.

$$\max_p wTh = \max_p \sum_f p(f)(w * Th) \quad (4)$$

The objective is to maximize G for optimal p value

$$\frac{1}{\sqrt{2\Pi}} e^{-\left(f1/_2\right)^2/_2} \frac{\left(\left(ch\_rate - other\_data\right)/_{p-h}\right)(p) + other\_data}{N} \quad (5)$$

Equation(1) is derived from the formula [1]

$$G = \frac{F_{TX}(1-p_b)^y (y-h)}{R} \quad (6)$$

$$\text{Where } F_{TX} = \begin{cases} \frac{N}{n}; & \frac{N}{n} \leq \frac{R_{CH}}{y} \\ \frac{R_{CH}}{y}; & \frac{N}{n} > \frac{R_{CH}}{y} \end{cases} \quad (7)$$

G - Goodput
F_{TX} - Number of transmitted packets
P_b - Channel error
y - packet size
h - header size

N - R/x where R is the encoding rate and x is the slice size.
n - number of slices per packet
R_{CH} - Channel rate

3.2.1 Genetic Algorithm [15]

1. Choose initial population of packet sizes "p_i" with finite length binary string using coin tosses
2. Evaluate the fitness fit(p_i) using equation(5)
3. Mating : Select best-ranking individuals to reproduce mate pairs at random. Best ranking individuals are chosen by coin toss.
4. Crossover : The chosen strings to mate are crossed over at randomly selected position.
5. Mutation : Select random members of p_i and invert randomly selected bits.
6. Evaluate individual fitness and average fitness.
7. Continue from step 3 till maximum "f" value is achieved.

Table 1: Estimation of time to calculate optimal packet size for different encoding rates using GA

S. No	Frames/ Second	Encoding rate (in kbps)	Optimal Packet Size (in bytes)	Time (in ms)
1	3	384	670	33
2	4	512	587	67
3	5	640	480	30
4	6	768	480	32
5	7	896	397	9
6	8	1024	350	53
7	9	1152	317	33
8	10	1330	317	33
9	11	1408	220	141
10	12	1536	153	56
11	13	1664	111	121

3.2.2 Artificial Bee Colony(ABC) algorithm [16]

The colony of artificial bees contain 3 groups of bees Employed bees, onlookers and scouts.
Onlooker – A bee waiting to make a decision on choosing a food source
Employed bee – Bee going to the food source visited by itself previously
Scout – A bee carrying out random search
The main steps of the algorithm are
a. Initialize
b. Repeat
b.1 Place the employed bees on the food sources in the memory.
b.2 Place the onlooker bees on the food sources in the memory
b.3 Send the scouts to the search area for discovering new food sources
until(requirements are met)

Pseudo code

Control parameters
Colony Size CS
Limit for scout, L = (CS*D)/N
Where D – Dimension
N – Number of variables.
1. Initialize the population of solutions p_i where i = 1..n (n Random packet sizes ranging from 50 to 1500)
2. Calculate f(p_i)(Using Equation 5)
3. Calculate the fitness vector fit(f_i)

$$fit(f_i) = \begin{cases} \frac{1}{1+fi} & \text{if } f_i \geq 0 \\ 1+abs(f_i) & \text{if } f_i<0 \end{cases} \quad (8)$$

4. Produce new solutions (food source positions) υ_i in the neighbourhood of p_i for the employed bees using the formula $\upsilon_i = p_i + \Phi i(p_i - p_k)$ (k is a solution in the neighbourhood of i, Φ is a random number in the range [-1,1]) and evaluate them.
5. Apply the greedy selection process between x_i and υ^i
6. Calculate the probability values $Prob_i$ for the solutions p_i by means of their fitness values using the following equation

$$\frac{fit_i}{\sum_{i=1}^{SN} fit_i} \quad f: \quad (9)$$

Normalize $Prob_i$ values into [0,1]
7. Produce the new solutions (new positions) υ_i for the onlookers from the solutions p_i, selected depending on $Prob_i$, and evaluate them
8. Apply the greedy selection process for the onlookers between x_i and υ_i
9. Determine the abandoned solution (source), if exists, and replace it with a new randomly produced solution p_i for the scout using the following equation

$$p_i=min_j+rand(0,1)*(max_j-min_j) \quad (10)$$

10. Memorize the best food source position (solution) achieved so far
Repeat from step 2 until maximum throughput is achieved.

3.2.3 Modified PSO algorithm [17]

Variables

S - number of particles in the swarm.
p_i ε best known position of particle *i*
pBest - best known position of the entire swarm.
Vmax - parameter that limits the velocity value (1.5 for modified PSO).

Table 2: Estimation of time to calculate optimal packet size for different encoding rates using ABC

S.No	Frames / Second	Encoding rate (in kbps)	\Optimal Packet Size (in bytes)	Time (in ms)
1	3	384	689	9
2	4	512	587	12
3	5	640	481	12
4	6	768	483	19
5	7	896	400	10
6	8	1024	381	14
7	9	1152	332	10
8	10	1330	328	17
9	11	1408	230	10
10	12	1536	156	24
11	13	1664	136	16

Initialization

S ← Number of particles

for each S

Initialize the particle's position p_i with a uniformly distributed random vector x_i ε search space

(Here search space is the permitted fragment size that ranges from 100 to 1500)

Initialize the particle's best known position to its initial position: $p_i \leftarrow x_i$

Initialize the particle's velocity: $v_i \sim U(-|b_{up}-b_{lo}|, |b_{up}-b_{lo}|)$ where b_{lo} and b_{up} are the lower and upper boundaries of the search-space b_{lo} = 100 and b_{up} = 1500.

Step 1

Repeat until the fitness function retains a maximum value

for i ranging from 1 to S

Calculate the fitness function by applying p_i for each value for each S in equation (5).

Pick random numbers: $r_p, r_g \sim U(0,1)$, parameters ω, φ_p, and φ_g as random numbers and Update the particle's velocity:

$$v_i \leftarrow \omega\, v_i + \varphi_p\, r_p\, (p_i - x_i) + \varphi_g\, r_g\, (pBest - x_i) \qquad (9)$$

$v_i = (1-(t/T)^h)Vmax$, if $v_i > (1-(t/T)^h)Vmax$

$v_i = -(1-(t/T)^h)Vmax$, if $v_i < (1-(t/T)^h)Vmax$

T - the given maximum number of generations

t - the number of current generation

h - positive constant

Update the particle's position: $x_i \leftarrow x_i + v_i$

if ($f(x_i) < f(p_i)$) do:

Update the particle's best known position: $p_i \leftarrow x_i$

end if

if ($f(p_i) > f(pBest)$)

Update the swarm's best known position: $pBest \leftarrow p_i$

end if

end for

Step 2

Now pBest holds the best found solution

3.3 Setting deadline for the packets

The multimedia data are fragmented into the calculated p.

if(data_size % p) = 0

travel_time=(data_size/bandwidth)*(n-1)+delay (10)

(n- number of nodes)

else

$$travel\_time = \frac{data\_size + p - (data\_size \% p)}{Bandwidth} + delay \qquad (11)$$

deadline of the first packet = travel_time.

deadline of remaining packets = travel_time of the packet + travel time of preceding packets.

For each hop of a packet

remaining deadline=remaining deadline–time for one hop.

Table 3: Estimation of time to calculate optimal packet size for different encoding rates using Modified PSO

S.No	Frames / Second	Encoding rate (in kbps)	Optimal Packet Size (in bytes)	Time (in ms)
1	3	384	685	22
2	4	512	584	20
3	5	640	486	7
4	6	768	486	2
5	7	896	408	22
6	8	1024	359	31
7	9	1152	332	27
8	10	1330	322	20
9	11	1408	211	55
10	12	1536	153	2
11	13	1664	111	63

3.4 Dropping the packets using Modified RED

avg= 0

count = -1

For each packet arrival

calculate the average queue size-avg

if $min_{th} \leq avg < max_{th}$

$$mRED\_p_b = \frac{avg - min_{th}}{max_{th} - min_{th}} * max_p * (p / pkt\_size) \qquad (12)$$

Increment count

with probability p_b :

mark the arriving packet

count = 0

end if

end for

Drop function of Modified RED

$$mRED\_d(avg) = \begin{cases} \dfrac{avg - \min_{th}}{\max_{th} - \min_{th}} \max_p * (p/pkt\_size) \\ \quad \text{if } \min_{th} < avg < \max_{th} \\ 0 \quad \text{if } avg < \min_{th} \\ 1 \quad \text{if } avg > \max_{th} \end{cases} \tag{13}$$

Saved Variables:

Avg : average queue size
Count : packets since last marked packet
P : Calculated optimal packet size for multimedia data.

pkt_size : Size of the arriving packet.

Fixed Parameters:

min_{th} : minimum threshold for queue
max_{th} : maximum threshold for queue
max_p : maximum value for pb

Other:

p_a : current packet-marking probability
p_b : Dropping probability of RED
$mRED\_p_b$: Modified RED dropping probability

4. Experimental Results & Discussion

The optimal packet size calculated using different optimization techniques is given in the following tables.

Table 4: Optimal packet size and comparison of time taken for computing optimal packet size using different optimization techniques

No	Frames per Second	Encoding rate (in kbps)	Opt Packet Size (in bytes)	Time (in ms)		
				GA	ABC	Modified PSO
1	3	384	689	33	9	22
2	4	512	587	67	12	20
3	5	640	481	30	12	7
4	6	768	483	32	19	2
5	7	896	400	9	10	22
6	8	1024	381	53	14	31
7	9	1152	332	33	10	27
8	10	1330	328	33	17	20
9	11	1408	230	141	10	55
10	12	1536	156	56	24	2
11	13	1664	136	121	16	63

The simulation result for throughput of different packet sizes for different encoding rates is given as graph in Fig. 1. Channel rate is assumed to be 2 Mbps for different encoding rates. Fig 2. compares the throughput of SDP and modified RED for some encoding rates.

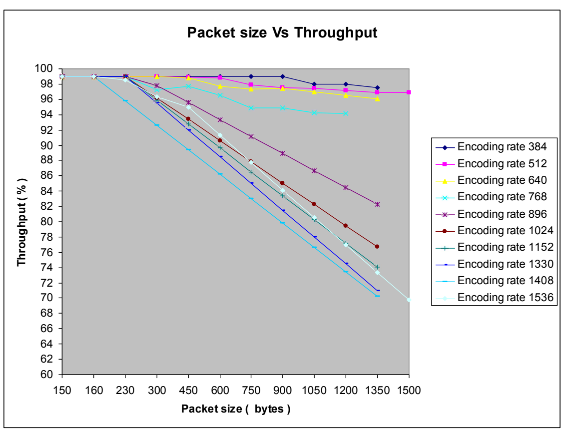


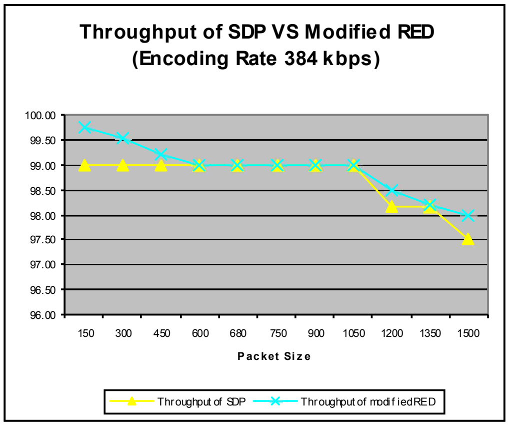
Fig 1: Packet size vs throughput for different encoding rates

Observation 1:

Average time taken to determine the optimal packet size on a Core 2 Duo 2.6 GHz Intel processor with 4 GB RAM is given below. The optimal packet size is approximately the same for different optimization techniques. Hence the average packet size is considered as optimal packet size in Table 4.

Table 5: Comparison of time taken for computing optimal packet size using different optimization techniques

S.No	Optimization algorithm	Time taken (in ms)
1	Artificial Bee colony Optimization	13.90
2	Modified PSO	24.90
3	Genetic Algorithm	55.27



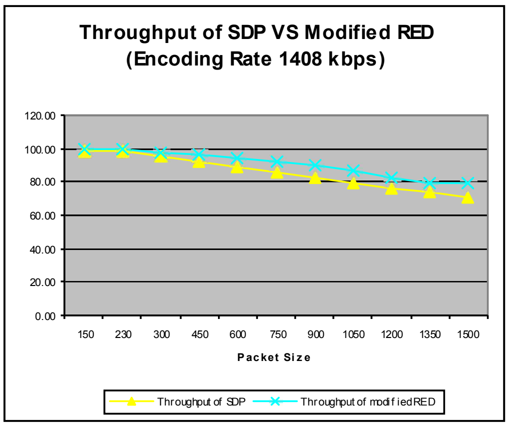


Fig 2. Comparison of throughput of SDP and modified RED

Observation 2

It is observed experimentally (Figure 1) that maximum throughput is gained with optimal fragment size for each encoding rate. But the maximum fragment size is used to avoid overhead. But for higher encoding rates the throughput is observed to be low because the data rate exceeds the channel rate leading to more fragment drops. When fragment size becomes high the throughput decreases proportionally because of the excess padding of data in each fragment. Throughput drops based on the ratio of other data.

Observation 3

Packet drop is simulated using two methods

i. Size oriented dropping policy – Packets are dropped only based on size.(Multimedia packets are smaller than other traditional packets)

ii. Modified RED - Packets are dropped using RED which includes the constraints size, deadline.

The throughput of the above two methods are compared. From Figure 2 & 3. It is observed that the packet loss percentage is reduced i.e throughput is increased with Modified RED when compared with Size Oriented Dropping policy.

5. Conclusion

An efficient packet fragmentation is proposed to improve the quality of pre-encoded H.264 bitstreams transmitted over packet switched networks. The optimal fragment sizes for different encoding rates are determined using Artificial Bee colony Optimization, Modified PSO algorithm and Genetic algorithm and the time taken to find optimal packet size is compared. It is observed that ABC algorithm performs better than other algorithms. Simulation results show that optimal packet sizes for different encoding rates produces maximum throughput of 98% thereby improving the quality of the received video if the encoding rate does not exceed the available bandwidth. The packets are dropped using RED with additional constraints of remaining deadline of the packet and packet size. The experimental evaluation shows

i. Efficient link utilization
ii. Increase in the arrival of useful packets to the destination thereby increasing the perceived quality of multimedia data.
iii. Other packets (non multimedia) are not disturbed.

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