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Priority Queuing Technique Promoting Deadline Sensitive Data Transfers in Router based Heterogeneous Networks

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Abstract

A heterogeneous network connects various operating systems and different protocols. Due to the versatile technology and enormously large number of nodes, the data traffic in internet is unpredictable and keeps increasing monotonously. This leads to congestion which mainly overburdens the routers since the router is responsible for directing the traffic in the required network direction. Real-time data transfers which have deadlines on various Quality of Service (QOS) parameters may suffer from severe problems of throughput and delay while getting transferred through internet. This can be overcome either by a scheduling mechanism or by a dropping policy which help the real-time data transfers achieve their QOS requirements without keeping a bias against non-real-time data flows. In this work, we propose a congestion avoidance technique which works on the basis of priority queuing. When congestion is sensed, the deadline sensitive data is serviced before the lower priority data. Thus, the network can be maintained stable without collapse and data transmission can also be achieved to a satisfactory level.

Keywords: AAQM, Quality of Service, real-time data transfers, NCQ, utilization factor

INTRODUCTION

During data transmission, congestion occurs when the incoming packets rates are very high when compared to the shared resources like queue buffer within the router and outgoing bandwidth. When congestion is experienced in the network, delay is experienced by numerous data packets and several packets get dropped as the queue starts overflowing. Excessive congestion in the network leads to throughput degradation and increased rate of packet loss. Network efficiency and reliability also reduces due to congestion. Sometimes, due to excessive congestion, the overall performance of the network fails and there will be no data delivery [1]. The general router policies designed for fair bandwidth sharing in internet majorly concentrates in restricting the non-responsive category. Non-responsive traffic flows are those which do not reduce the transmission rates even when a congestion notification is received. But this will become a severe blow for the real-time data transfers which contribute only small rates. There should be a policy by which the scheduling or dropping module should identify real-time flows from all other traffic and promote them. The extent of favour may be proportional to the data rate they contribute to the internet. Those flows contributing less data rates should be able to achieve their QOS deadlines. The Active queue management schemes (AQM) like RED and its variants helps to check and react to the congestion prone situation but they lack service differentiation capability to infer whether the traffic is deadline sensitive or not. Therefore a queuing policy implementing easy service differentiation and accurate prioritization help to build a stable transmission rate even at the time of congestion.

RELATED WORK

Integrated service [2] & differentiated service [3] are application level architectures for ensuring QOS for any type of traffic. The disadvantages of QOS architectures are additional protocol overhead, poor scalability and high infrastructural needs.

Random early detection gateway for congestion avoidance [4] was proposed in 1993 by Floyd and Jacobson and is now recommended for deployment in the Internet. RED allows a router to drop packets before its queue becomes saturated. Therefore congestion responsive flows will back-off early resulting in shorter average queue lengths which is good for interactive applications. Another advantage is packet drops will not occur in bursts. RED achieves this by dropping packets with a certain probability depending on the average queue length. RED does not categorize the flows into real-time and non-real- time, so RED policy does not explicitly promote real-time data transfers. The variants of RED, RIO (RED IN/OUT) [5] & Weighted RED (WRED) [6] are other examples of active queue management schemes. The dropping policy is based on priority levels which are indicated within packets and in a congested scenario, lower priority packets are dropped .RIO and WRED need packets to be marked with priority levels.

D.Lin and R. Morris [7] proposes a separate queue management scheme called FRED (Flow Random early Detection, modified version of RED) suitable for fragile and adaptive flows. FRED maintains better fairness by admitting the equal share of flows. Hence it controls misbehaving flows from consuming more bandwidth. But the policy is also not focussed towards promoting real-time data transfers. Floyd and K. Fall [8] propose a router policy to restrict the unresponsive flows that does not reduce the sending rate even when packets are dropped. Such flows are termed as non-TCP friendly flows and such flows are identified from the drop history of RED. R. Mahajan and S. Floyd [9] propose a mechanism to control the dropping of responsive flows. The technique have two parts 1) Identifying the responsive flows 2) Mechanism to prevent the dropping for responsive flows. Identifying the flows is performed by random sampling from the RED drop history. W. Feng and et al. [10] proposes another Active Queue Management Algorithm, BLUE. A problem with queue management (like RED) algorithms is highlighted in the paper as they use queue lengths as the indicator of the severity of congestion. Instead BLUE uses packet loss and link idle events to identify congestion.

R. Pan, B. Prabhakar, and K. Psounis [11] propose a stateless active queue management scheme-CHOKe which deals with an alternate queue management scheme inspired from RED. The queue for incoming packet is FIFO which is having a RED like minimum and maximum thresholds. But RED tries to maintain fairness only after the queue length become greater than minimum threshold and by this time misbehaving flows may have occupied the queue. Therefore fairness in RED is only granted after queue length is greater than minimum threshold. CHOKe scheme only differs in policy between minimum threshold and maximum threshold when compared to RED. CHOKe algorithm try to bring better fairness. It assumes that the statistics of misbehaving flows are present in the occupancy before attaining minimum threshold.

L. Mamatas and V. Tsaoussidis [12] propose a new service differentiation policy for real-time traffic. They suggest a new scheduling policy for non-congestive packets. Non-congestive packets are packets that do not cause congestion in network (real-time packets).They are analysed by their small packet sizes. The router captures the size of the packet and learns whether it is real time traffic, if so it is serviced faster. The limit of favour is controlled by a configurable threshold. They experiments the impact of non-congestive queuing, NCQ [14] for sensor traffic. The authors propose LIBS [13] (Less Impact Better Service) philosophy. The packets can be classified into congestive and non-congestive based on packet sizes. Packet sizes serves as an easier identification for real-time data transfers in internet.

Rahim Rahmani et al [15] have proposed an Adaptive AQM (AAQM) scheme. A specific method has been proposed based on the Markov Modulated Poisson Process (MPP) to confine the burstiness of the traffic and also the buffer occupancy. This scheme manages to keep the packet arrival rate and the packet departure rate very close.

Kang Min Lee et al [16] have presented the LQ-Servo controller for AQM (Active Queue Management) routers. The controller in this proposed work is developed by using the conventional servo technique which works on the basis of the Linear Quadratic Approach and then adding a state variable into the feed forward loop. The controller structure includes a standard optimal feedback regulator and also a feed forward controller. This is capable of improving the resource utilization and then minimizing the needless reservation of the router memory like RAM (Random Access Memory) or SMA (Shared Memory Area).

Tushar Raheja et al [17] have presented an uninterrupted single-lane traffic based on the queuing analysis. The Jackson Queuing network analysis is utilized to attain the traffic flow density diagram. To determine the result of the non homogenous traffic, the simpler analytical models are utilized.

The paper, Survey on Router Policies Providing Fairness and Service Differentiation Favoring Real-Time Data Transfers in Internet [18] provides a detailed study and comparison of all the major router policies and service differentiation architectures.

PROPOSED PRIORITY QUEUING TECHNIQUE FOR CONGESTION AVOIDANCE

Overview

In this work, we propose to design a deadline based priority queuing technique for congestion avoidance in router based heterogeneous networks. During packet arrival, the packet size is checked. Then the utilization factor (U) which is the ratio of number of packet arrivals per departures is calculated [15]. The queue is divided into two sub-queues: high priority and low priority. If there is congestion, the packet dropping probability is increased for lower priority queues and decreased for high priority queues. By this way both congestive and non congestive packets are served without affecting the quality of service and deadline constraints.

Packet Arrival Event

Adaptive AQM (AAQM) utilizes the packet arrival event when a packet arriving at one of access router incoming interfaces is supposed to be transmitted to the outgoing interface. The packet arrival event is described in the algorithm given bellow

n Data Packet

Q current queue length

Q_{max} maximum queue length

P packet marking probability

R_{num} random number

$C_{arrival}$ counter counting the number of packets arrived at the queue

1. When n arrives at a queue, its Q value is compared with Q_{max}.
2. If Q > Q_{max}, then the packet is dropped.
3. If Q < Q_{max}, then the packet is enqueued and a R_{num} is generated using a random number generator.
4. If $R_{num} < P$, then the packet is marked.
5. If $R_{num} > P$, then the packet is discarded.
6. Then $C_{arrival}$ is incremented by one.

Packet Departure Event

When a packet which was enqueued at the router is transmitted over the outgoing link, then this process is called as the packet departure event. The packet departure event is described in algorithm bellow

n Data Packet

$C_{departure}$ counter counting the number of packets departed from the queue

1. During the packet departure event, n is initially dequeued from the queue at the router.
2. Then the $C_{departure}$ value during the last pre defined time interval is incremented by one.

Utilization Factor

The utilization factor (U) is the ratio of the number of packet arrived per departure.

$$U = \frac{C_{arrival}\ value}{C_{departure}\ value}$$

Congestion Control based on Packet Priority

Non Congestive Queuing (NCQ)[12] is incorporated into routers to differentiate services according the impact of each traffic class on delay. When there is a class with smaller packets and sending rate receives better service than one with large packets or high sending rate. To avoid reaching a state where the transmission of the small packets creates a delay in the transmission of the long packets, a threshold level is defined in this technique. The favoured non-congestive traffic cannot exceed a predetermined threshold, which represents the upper limit of permitted prioritized service. The threshold typically reflects a service percentage for prioritization. However, this percentage corresponds to the number of packets; not the occupied buffer space.

After the determination of the utilization factor in the network, the congestion can be handled by dividing the data packets into high priority data and lower priority data. Therefore during congestion, the higher priority data will be transmitted first and then the lower priority data is considered for transmission. This mechanism is described in algorithm bellow.

$Thresh_{size}$ Threshold value for the size of the data packet

U Utilization Factor

n incoming data packet

$packet_{size}$ size of the incoming data packet

P Packet Dropping Probability

1. Initially a $Thresh_{size}$ value is defined.
2. During congestion, the size of n is determined.
3. Then the $packet_{size}$ is compared with the predefined $Thresh_{size}$.
4. If $packet_{size} < Thresh_{size}$ and $U \leq 1$, then the data packet is moved into the high priority sub queue.
5. If $packet_{size} > Thresh_{size}$ and U<=1, then the data packet is moved into the high priority sub queue.
6. If $packet_{size} > Thresh_{size}$ and U > 1, then the data packet is moved into the lower priority sub queue.
7. If $packet_{size} < Thresh_{size}$ and U > 1, then the data packet is moved into the higher priority sub queue.
8. After the data packet categorization, the data packet in the higher priority queue is transmitted and the lower priority queue is enqueued.
9. When there is a need to drop packet in order to stabilize the network from overburdening, the packets in the lower priority queue are dropped.
10. The P for every packet in the queue is determined according to the following equation:

    For packets in high priority queue: P = P – P1

    For packets in low priority queue: P = P + P2

    Where P1 and P2 are the pre defined values.

By this way both congestive and non congestive packets are served without affecting the quality of service and deadline constraints.

The overall Priority Queuing Technique

The overall algorithm of proposed for priority queueing for deadline sensitive data transfers:

1. In the heterogeneous network, the number of packets

arriving at the router is initially calculated by considering the queue length as the deciding factor for letting in the packet or dropping the packet.

2. Then the number of packets departing is determined.
3. Next, the U is calculated.
4. Based on the NCQ technique, the packet queue is divided into high priority queue and low priority queue.
5. Based on the packet size and utilization factor criteria, the packets are transmitted into the high priority queue and low priority queue accordingly.
6. The packets in the high priority queue are transmitted first and the packets in the low priority queue are enqueued.
7. During congestion, the packets in the low priority queue are dropped with higher probability and the packets in the high priority queue are dropped with lower probability.
8. Thus, the packet transmission is performed very efficiently even during congestion.

CONCLUSION

In this work, a priority queue technique has been proposed for the routers to avoid congestion in the heterogeneous network. Initially the utilization factor is determined based on the packet incoming rate and the packet outgoing rate. Next, the packet size is determined and is compared with the predefined threshold size. Based on the utilization factor value and the packet size, the data packet is moved into either the high priority queue or the low priority queue. Then the data in the high priority queue is transmitted first and the data in the lower priority queue is enqueued. During excessive traffic, the lower priority packets are dropped with higher probability and higher priority data is dropped with very low priority. Thus, the network maintains the high priority data and transmits it as quickly as possible. So, this proposed technique is efficient in congestion handling in the heterogeneous network. The future work involves the simulation of environment where the real-time data transfers and bulk transfers co-exist and the QoS parameters like through put, delay and packet delivery ratio has to be analysed.

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