Access Delay Performance of Resilient Packet Ring under Bursty Periodic Class B Traffic Load

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Abstract – The IEEE P802.17 workgroup is currently standardizing a ring network architecture and associated protocol called Resilient Packet Ring (RPR). In addition to high-priority guaranteed class A traffic and best-effort class C traffic, RPR supports low-jitter, delay bounded, medium priority class B traffic. This class can, for example, be allocated for VBR streaming video or interactive on-line games. These traffic types are notorious for their bursty periodic profiles. This paper reports on simulation results of several scenarios using the conservative fairness algorithm under varying bursty periodic class B traffic loads competing with background class C traffic. For both one- and two-transit buffer stations, we found that in order to minimize the access and end-to-end delay of class B traffic, the shaperB committed access rate parameter should be configured as the sum of the class BCIR and BEIR provisioned bandwidth instead of BCIR only. Our simulations show that as the periodic bursts magnitude increases, the class B access delay increases in function of fairness round-trip time, rate thresholds and number of stations adding class B traffic.

I. INTRODUCTION

The IEEE P802.17 workgroup is currently standardizing a ring network architecture and associated protocol called Resilient Packet Ring (RPR) [1]. RPR interconnects stations (or nodes) in a point-to-point bidirectional ring topology. RPR implements spatial reuse on the ring by removing packets at their destination. Client packets are first stored in transmit buffers in the MAC Client. The MAC layer scheduler then determines when a client’s packets can be transmitted as RPR frames. Added frames then travel downstream from station to station until the destination is reached. If a downstream station is locally sourcing traffic when transiting frames are received from the ring, the station will temporarily store the frames in a transit buffer. Two configurations are possible: a station with (1) only one small transit buffer (1TB) or (2) one small high-priority transit buffer and a second larger low-priority transit buffer (2TB). The RPR scheduler prevents losing frames by insuring that no transit buffers can overflow.

RPR supports three classes of service: high-priority guaranteed class A; medium priority, low-jitter, bounded delay class B; and best-effort class C. Class A bandwidth is reserved around the ring by appropriate provisioning. Class B is allocated around the ring, however the bandwidth can be reclaimed by class C traffic if not used. Finally, class C bandwidth is opportunistic, reclaiming unused class B traffic and by spatially reusing bandwidth around the ring. In the case of 2TB stations, a special class of traffic, A1, can be reclaimed by class C.

To share fairly class C opportunistic bandwidth around the ring, RPR implements a distributed fairness control algorithm which calculates fair rates and advertises them to upstream stations. These stations then decrease their locally added class C traffic according to the received fair rates. The calculation of the fair rates can be done either by a conservative algorithm or an aggressive algorithm. In this paper we use the conservative algorithm. This pro-active algorithm overdamps the control loop response (advertised fair rates) and tries to maintain the output data rate of the congested link between two rate thresholds (low and high thresholds). Parameters can be chosen to tradeoff between response time and link utilization.

Previous papers presented results on access delays of class C traffic and the oscillatory behavior of the fairness algorithms [2], [3]. In this paper, we study the interaction between class C background traffic and bursty periodic class B traffic added by several stations. While class B traffic has higher priority than class C, if not enough bandwidth is available on a link to carry the newly added class B traffic, it will have to be queued temporarily until the fairness mechanism reduces enough upstream class C traffic, impacting class B traffic access delay.

Section II explains in more detail the configuration of the MAC shaperB and its impact on performance. Section III describes the various scenarios used in the simulations. Section IV analyses the results. Finally, we summarize and conclude our findings.

II. CLASS B SHAPERS CONFIGURATION

Class B bandwidth, for example, can be allocated for VBR streaming video or interactive on-line games. These traffic types are notorious for their bursty periodic profiles [4], [5]. RPR divides Class B in two sub-classes: class BCIR (Committed Information Rate) and class BEIR (Excess Information rate). RPR MAC uses a token bucket (shaperB) to insure no more than the allocated class BCIR bandwidth is added to the ring. If the client sends more than its allocated BCIR bandwidth, credits from the class C shaper are used. If no more shaperC credits are available, class BEIR traffic cannot be added (shaperB CAR=BCIR option).

While this seems reasonable, it could impact negatively on VBR video and on-line gaming traffic which periodically sends bursts of data needed to decode images properly or to quickly update the global game state.

To better cope with this bursty periodic traffic, we propose to configure shaperB CAR (Committed Access Rate) as the
sum of BCIR and BEIR allocated bandwidth. This insures that BEIR traffic is not blocked by lack of shaper C credits, although it can still be temporarily blocked by lack of available bandwidth on a congested output link since class B bandwidth is not reserved.

III. SIMULATION SCENARIOS

We have developed an OPNET simulation model compliant with P802.17 Draft 3.0, with an appropriate MAC Client implementation.

Figure 1 shows the topology of the network simulated. It is composed of six stations linked by a ring with a circumference of approximately 240km. Each hop propagation delay equals 0.2ms. The traffic flows used in all simulations are as follows: stations 1 to 5 send class C traffic to destination station 0 (Poisson traffic with mean rate of 177 Mb/s and mean packet length of 444 bytes, all stations starting at time 0.3s). This amounts to 150% of the link bandwidth from station 1 to station 0. Starting at time 0.4s, class B traffic is added simultaneously by stations 1 to 4, to simulate worst-case scenarios (constant bit rate traffic). An example scenario is shown in Figure 3 and Figure 4.

The conservative fairness algorithm tries to stabilize fairness eligible traffic between two target rates, low and high rate thresholds (see Table I). All the stations weight are equal, thus the fairness algorithm will reduce each station added traffic to approximately 86 Mb/s (see Figure 3, between 0.3s and 0.4s).

When 25 Mb/s of class BCIR is added by stations 1 to 4, the head station fairness algorithm (station 1) reduces the advertised rate to approximately 86 Mb/s to accommodate the newly added traffic. In the example scenario, 75 Mb/s of Class BEIR is then added periodically by stations 1 to 4, for a 30 ms duration.

<table>
<thead>
<tr>
<th>TABLE I. SIMULATION PARAMETERS USED</th>
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<tbody>
<tr>
<td>Parameter</td>
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<tr>
<td>Unreserved bandwidth</td>
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<tr>
<td><strong>Target Rates</strong></td>
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<tr>
<td>rateLowThreshold</td>
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<tr>
<td>rateHighThreshold</td>
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<tr>
<td>MAC Access delay thresholds</td>
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<td><strong>Shapers</strong></td>
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<tr>
<td>shaperB CAR</td>
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<tr>
<td>shaperB Max Burst Size</td>
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<tr>
<td><strong>Primary Transit Queue (PTQ)</strong></td>
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<tr>
<td><strong>Secondary Transit Queue (STQ)</strong></td>
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<tr>
<td>PTQ Size</td>
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<tr>
<td>stqLowThreshold</td>
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<tr>
<td>stqMedThreshold</td>
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<tr>
<td>stqHighThreshold</td>
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<tr>
<td><strong>Varia</strong></td>
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<tr>
<td>rampCoef</td>
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<tr>
<td>rampCoef per decay interval</td>
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<tr>
<td>lpCoef (Conservative Mode)</td>
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</table>

Note: Parameters not shown use P802.17 Draft 3.0 default values.

Figure 3 shows that after class BEIR traffic starts, station 1 temporarily stops adding class C traffic until station 1 advertised fair rate decreases enough to allow it to add class C traffic again. The class C average access delay is represented on Figure 6 (b). Furthermore, in this example, we notice that station 1 class BEIR traffic is not added to the full 75 Mb/s rate immediately, since the required bandwidth is not totally available. As upstream class C traffic decreases, station 1 class BEIR traffic increases. The MAC Client temporarily buffers some class B packets, which causes the spike in class B traffic being added before settling to 100 Mb/s (25+75). In this example, the class BEIR spike is due to shaperB using temporarily shaper C credits.

The buffering of class B packets creates some queuing delay in the MAC Client. The average delay value, equal to 3ms, is shown on graph Station 1 (1TB) of Figure 4 (b).

Finally, enough replications were made to get small 95% confidence intervals for the access delay average values in Figure 4 to Figure 6.

IV. RESULTS ANALYSIS

A. Simulation parameters

A total of 16 scenarios were simulated. Three parameters were modified:

1) Class BEIR (50, 75, 100 and 125 Mb/s).

As class BEIR requirements increase, the average maximum access delay also increases since the fairness algorithm needs to further decrease upstream class C traffic. The approximate decrease in the advertised rate is given by this relationship:

\[ \Delta f = f_1 - f_2 \]

where \( f_1 \) is the advertised fair rate before class B EIR is added and \( f_2 \) is the advertised fair rate after class B EIR is added and transmitted on the congested link. These are given by:

\[ f_0 = \frac{U_R}{N_C} \]

where \( U_R \) is the unreservedRate (%), \( T_A \) is the average target rate (%), \( N_C \) the number of stations adding Class C traffic and \( L \) is the link rate.

\[ F_1 = \frac{F_0 - N_B R_{BCIR}[Mb/s]}{N_C} \]

where \( R_{BCIR} \) is the class BCIR rate and \( N_B \) is the number of stations adding class B traffic. The fairness algorithm uses an exponential decay to calculate the next advertised rate. The number of advertisements needed to reduce the advertised rate from \( f_1 \) to \( f_2 \) is thus given by:

\[ \Delta A = -\ln\left(\frac{f_2}{f_1}\right)\text{rampCoef} \]
Fairness advertisements are sent according to the fairness domain round-trip time (FRTT). In our scenarios, this domain is constant since stations 1 to 5 always send class C traffic. This FRTT is then equal to $8 \times 0.2 \text{ms} = 1.6 \text{ms}$. The access delay incurred by the head station is thus given by:

$$\Delta T_0 = 1.6 \text{ ms} \Delta A$$

$$\Delta T = \min(\Delta T_0, \text{BEIR burst length})$$

2) **One transit buffer (1TB) and two transit buffers (2TB) configurations.**

With the 1TB configuration, the main factor in the access delay of the the classB packets is the queuing in the MAC Client. When transmitted on the ring, they only incur propagation delay and small delays in the primary transit buffers. In the 2TB configuration, classB packets are usually sent immediately on the ring since transiting class C and B frames are queued in the secondary transit buffer (proviso the STQ is not full). Thus, the average maximum access delay is smaller for class B frames, but the average maximum transit delay (not including client queuing) is larger than the 1TB configuration.

3) **shaperB (CAR=BCIR, CAR=classBCIR + classBEIR).**

(1) When shaperB CAR=BCIR, the class B bursts can only use shaperC credits to be added to the ring. The packets which cannot be added immediately are queued in the MAC Client transmit buffer. The buffer will empty at the rate BCIR plus the current shaperC leak rate. If the received fair rates are small, then clearing the buffer will take a longer time. (2) If instead shaperB CAR is set to BEIR+BCIR, the MAC will have more shaperB credits available to add the bursts into the ring. The rate at which the buffer can be cleared is higher than option (1) and can also use additional shaperC credits if available.

**B. Class B queuing delay**

Figure 4 (a) and (b) show the class B average maximum queuing delay in the MAC Client transmit buffer for stations 1 to 4, for both 1TB and 2TB configurations. For class BEIR burst size equal to 50 Mb/s, which gives a total class B traffic of 75 Mb/s and a peak-to-mean ratio of about 3, the queuing delay incurred by the stations is small. As the burst size increases, the queuing delay increases. As discussed above, this delay is somewhat lower for 2TB configurations because transit frames are queued in the head station STQ. However, the end-to-end delays are similar for both configurations (see next section).

As the bursts magnitude increases, the option of setting shaperB CAR=BCIR+BEIR gives smaller access delays for most stations. Only head stations access delay increases as they need to wait for their advertised fair rate to decrease sufficiently.

**C. Class B end-to-end delay**

Figure 5 (a) and (b) show the class B maximum average end-to-end delay, including the queuing delay, the propagation delay and the transiting delay. These graphs show the impact of queuing the transit frames in the secondary buffer of station 1. For example, stations 2 to 4 (2TB) in Figure 5 (a) and (b) have a larger end-to-end delay than station 2 to 4 (1TB).

If we compare (a) and (b) graphs from both Figure 4 and Figure 5, we note that overall, setting the shaper B CAR to the sum of BCIR+BEIR yields lower delays, except for the head stations. For 1TB configuration, the differences in delay are quite significant, but less so for the 2TB configuration.

**D. Class C access delay**

Finally, Figure 6 (a) and (b) present the class C average maximum access delay incurred by stations 1 to 4. When using relatively small class BEIR burst size, setting shaperB CAR=BCIR produces smaller head station access delay.

On the other hand, for larger bursts, setting shaperB CAR=BCIR+BEIR gives a much smaller class C access delay for both configurations. This comes from the fact that class B packets are not using as much shaper C credits as the previous option, so class C traffic can be added.

Finally, we notice that 2TB configuration has a somewhat smaller access average delay. This is mainly due to the fact that 2TB configuration usually has a link utilization a few percent higher than the 1TB configuration, which creates more available bandwidth to absorb the bursts.

**V. CONCLUSION**

Our simulations showed that for an adequately provisioned hub-topology network, RPR used with an appropriate MAC Client implementation can support bursty periodic class B traffic with background class C traffic incurring only small access delays. While the access delays are smaller with two transit buffers when the secondary buffer is large enough, both one transit buffer and two transit buffers configurations give similar end-to-end delays. We have found that setting shaperB CAR to the sum of BCIR and BEIR allocated bandwidth, instead of BCIR only, gives lower access and end-to-end delays, particularly when the peak-to-mean burst ratio is large. The provisioning of the network should take into account that the access delay of the head station increases.

Although this study used worst-case scenarios where all stations transmit at the same time, it is necessary to study RPR in more detail, in order to get a more realistic understanding of its dynamic behavior. More simulations will be done to optimize the parameters, vary randomly the bursts length and magnitude, number of stations and propagation delays.

**REFERENCES**


Stations 1 to 4:
Class B CIR = 25 Mb/s
Class B EIR = 50 to 125 Mb/s

Stations 1 to 5:
Class C = 177 Mb/s

Figure 1. Network topology and traffic flows.

Figure 2. Example scenario. Class C traffic added by stations 1 to 5.

Figure 3. Example scenario. Class B CIR and EIR added by stations 1 to 4. BCIR=25 Mb/s, BEIR=75 Mb/s, shaperB CAR=BCIR+BEIR.
shaperB CAR = BCIR

shaperB CAR = BCIR+BEIR

Figure 4 (a) (b). Class B packets queuing delay in the MAC Client transmit buffer.

Figure 5 (a) (b). Class B packets average maximum end-to-end delay from stations 1 and 2 to destination station 0. Includes transmit buffer queuing delay, ring transmission and transiting delays.

Figure 6 (a) (b). Class C packets average maximum access delay.