
Predictive DBA

The “Right” Method for Dynamic Bandwidth Allocation in Point-to-Multi-Point FTTH Networks

Overview

A PON network specified by G.983.1 is comprised of an OLT system connected to multiple ONT systems in a point-to-multi-point network. A basic characteristic of a PON network is the sharing of upstream bandwidth between end systems. The OLT is responsible for the allocation of bandwidth to the ONTs in accordance to traffic contracts. In order to use the network resources efficiently, the OLT should devise a method by which bandwidth is allocated dynamically, responding to the dynamic changes in traffic demands of the different ONTs.

The G.983.4 standard defines the mechanism for DBA in PON network. It introduces Traffic Containers (T-CONTs), which are upstream traffic flows within the ONT, to which the OLT grants bandwidth, and the messaging protocol for ONTs to report T-CONT queue status to OLT.

The standard also identifies various methods to implement DBA based on “IDLE-cell monitoring” – i.e. by tracking the ONTs bandwidth usage patterns.

The purpose of this paper is to describe the Predictive DBA method developed by BroadLight, and demonstrate its efficiency. First a short comparison between status-report DBA and Predictive DBA is described, and then a performance comparison between the two methods is shown by traffic simulation tests.

As the results will show, Predictive DBA proves to be highly efficient for FTTH.

In the rest of the document, the term ONT is used interchangeably with T-Container.

DBA performance criteria

The basic criteria for DBA performance is three-fold:

1. Packet delay time – average and maximum, which directly affects queue buffer size
2. Link throughput
3. Fairness between ONTs – i.e. beyond granting each ONT its contracted sustained traffic rate, the excess bandwidth available should be allocated fairly between ONTs with similar traffic contracts and needs

These basic criteria can be further elaborated, to consider packet delay variations, fairness in and between different QoS categories, etc.

G.983.4 mentions additional measurements – waiting time and transition time – however these values do not necessarily reflect the actual performance resulting from the implementation.

In this paper, the key measurement used is of packet delay, since it also reflects the queue buffers in ONTs required in order to avoid packet loss.

The fairness criterion is more subtle, and harder to measure and demonstrated as a cumulative figure. Here also the measurement of the effective traffic rate and packet delay can be used to reflect some level of fairness amongst ONTs.

Status Report DBA (SR-DBA)

SR-DBA method is based on queue-status reports sent by ONTs to OLT periodically, as depicted in Figure 1 below. The grant scheduler at the OLT defines a granting cycle W . On each W period, the OLT solicits the queue-status reports from ONTs, the ONTs respond with queue-status reports, and then the grant scheduler processes these reports and assigns bandwidth for the next W period.

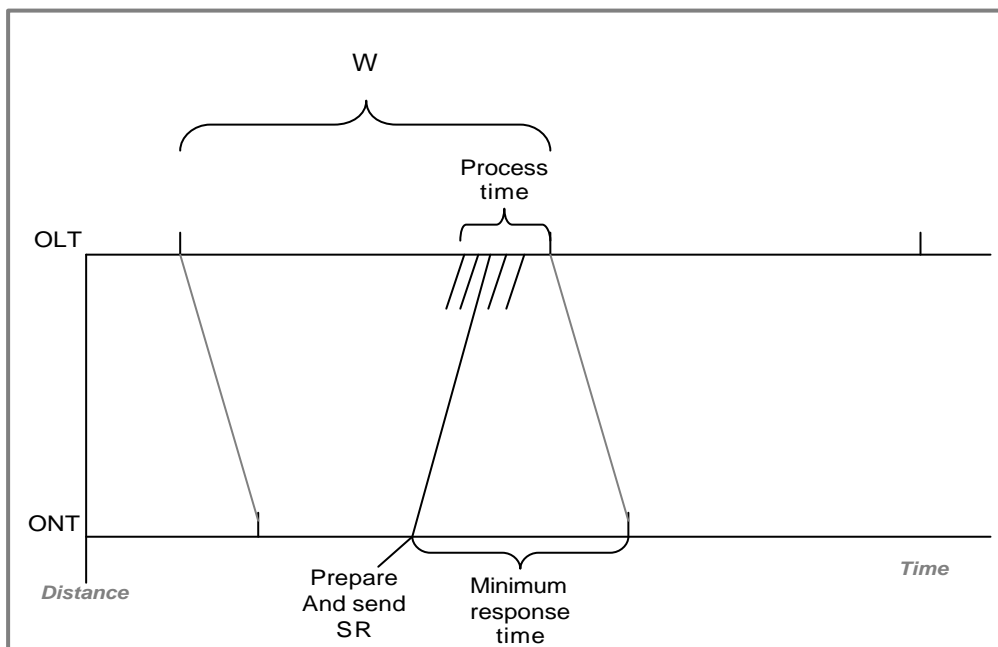


Figure 1: SR-DBA time and distance factors

There are several factors that affect the performance and efficiency of SR-DBA:

- SR delay time: the time from the moment a queue status is prepared for report, till it is actually sent to the OLT.
- PON round-trip time: this is determined by the farthest ONT, and affects the SR delay time and the minimal response time
- The OLT process time: the OLT needs to wait for status reports from all ONTs and process them to create the allocation for the next W period.



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- Status reports bandwidth: there is a fixed amount of bandwidth that is dedicated for status reports. The lower W size, the higher bandwidth required for these reports.
 - W size: although the window size W should ideally be very small, it has to be large enough relative to the round-trip time of the PON, the status-reports bandwidth, and relative to the OLT process time.

As depicted in the figure above, there is a minimal response time which is determined by the SR delay time, the OLT process time, and the PON round-trip time. During this time period, the queue status changes, and therefore SR-DBA typically does not achieve optimal accuracy.

In addition to bandwidth efficiency, SR-DBA deployment depends highly on interoperability between OLT and ONT systems. Specifically, ONTs complexity increases due to the higher real-time constraints and additional circuitry needed to support queue-status reports.

Predictive DBA

Predictive DBA is based on creating 'pseudo' status-reports from ONTs, based on monitoring their bandwidth usage pattern. The mechanism is based on a window time period W , in which the OLT compares between the allocated bandwidth and used bandwidth of each ONT, in order to predict its needs in the next W period. Based on these demand predictions, the OLT builds a bandwidth assignment map for the next W period.

There are some essential principals related to Predictive DBA:

1. Excess bandwidth is almost always fully granted: If ONTs have nothing to send, they send IDLE packets, which is an indication that their queue was emptied. On the other hand, when ONTs are active, this method is very efficient in decreasing packet delay and increasing link throughput, due to the 'down-payment' effect.
2. Each active ONT is granted at least once in a W period, so a minimal information of allocated-vs-used is available to the OLT. If the ONT is inactive for several windows, the sampling rate can be decreased to once every N windows.
3. There is a trade-off between optimizing link throughput and packet delay. The Predictive DBA mechanism is instrumented with several parameters that control this trade-off.

A major advantage of the Predictive DBA approach is by simplifying ONT design, and reducing the risk of having inter-operability problems between OLTs and ONTs from different vendors.

Broadlight has developed a unique Predictive DBA algorithm. The algorithm is instrumented with several parameters that control the trade-off between throughput optimization and packet-delay optimization, and provides the ability to fine-tune the DBA for different scenarios, e.g. FTTH vs FTTC. The mechanism supports 'dynamic' T-CONTs as well as 'static' T-CONTs - i.e. T-CONTs used for fixed-bandwidth traffic such as voice and leased-lines traffic.

In Predictive DBA, each T-CONT is configured with the following parameters:

1. GBW – Guaranteed bandwidth that must be sustained (if demanded)
2. MBW – Maximum bandwidth allocated to the ONT. This value is typically equal to the link rate
3. EBW – Relative portion (weight) of excess bandwidth allocated to the ONT. This parameter determines the level of fairness between ONTs when it comes to allocating excess bandwidth.

Predictive DBA vs SR-DBA in Traffic Simulations

The following sections illustrate the results of traffic simulations comparisons between SR-DBA and Predictive DBA. In actuality many more simulations were done, but since the results were pretty consistent, only a few sample cases are described here.

For the SR-DBA simulations, a simplified model is used: No bandwidth is used for requesting and receiving the status reports, the SR delay time is 0, and OLT process time is 0. Although it is not a realistic model, it serves the purpose of being a good reference. The scheduling algorithm employed for SR-DBA is a conventional weighted max-min fairness.

Conclusions

The main conclusions that can be drawn from the traffic simulations are:

- Predictive DBA is very efficient by all performance criteria, under varying traffic conditions. Packet delay remains low in most cases, under 4 ms. This also implies low buffer requirements, and very low packet loss ratio.
- In most load conditions, Predictive DBA is as good as SR-DBA, and sometimes better, whether all or part of the ONTs are active.
- In case of continuous load of 100% link capacity, Predictive DBA results with average packet-delay higher by 30% - 50%, compared to SR-ONU.
- In case of continuous load of 60% and very bursty traffic, average packet delay is higher than SR-DBA, however it is within the reasonable range of around 4 – 6 ms.

Traffic Model

The traffic model has several elements:

4. The simulated network has a round-trip time of 200us.
5. The link rate tested is 155Mb/s.
6. The packet-size is 56-byte, which is the upstream slot-size in G.983.1.
7. The window time W is 1, 2 and 4 ms. In all of the following samples a 2 ms window size is used.
8. In all the simulations, 32 ONTs were tested. Each ONT is associated with a queue and a traffic generator. This would represent a typical PON FTTH scenario, in which each ONT has one data T-cont. Other T-contents (for voice, OAM, video) would typically be granted a fixed amount of bandwidth, when active, so they wouldn't participate in the DBA play.
9. The queue size was large enough to avoid any packet loss. In this way, an accurate information for packet delay (max and average) and queue occupancy (max and average) could be identified.

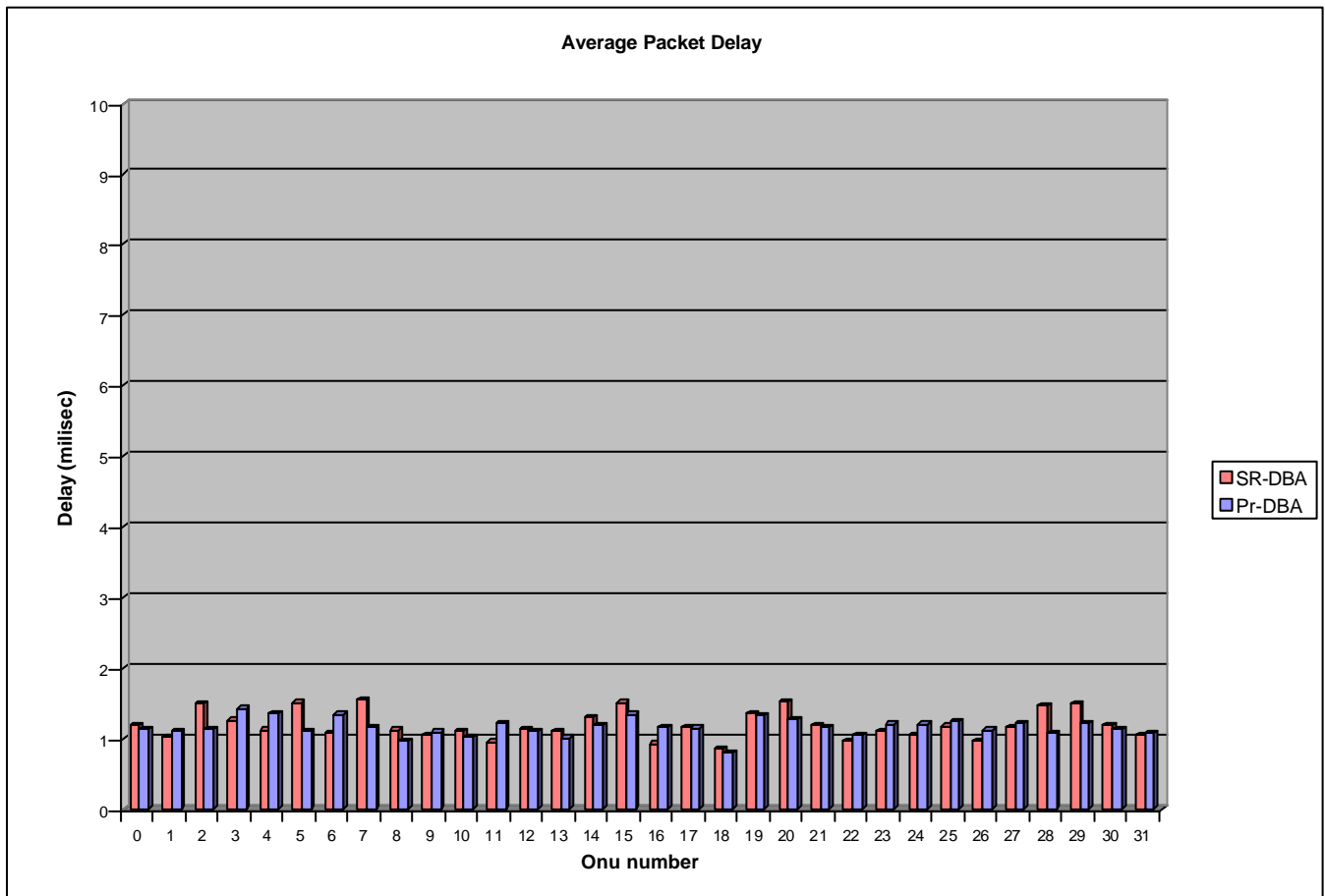


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10. Traffic generators have an exponential distribution behavior, which is an approximation of a Poisson distribution. Each is configured with an average (effective) throughput, and an average busy time and average idle time. The ratio between busy and idle times, together with the sum of these, gives different burstiness factors (between 0.1 to 1.0, for cycles of 10ms – 100ms).
 11. The total sum of traffic generated for all ONTs is from 15% to 100% of the link capacity. In some simulations all of the 32 ONTs are equally active. In other simulations 7 ONTs are much more active than the other 25 ONTs
 12. Each ONT is configured with the following parameters:
 1. Different values tested for GBW – Guaranteed bandwidth that must be sustained. In the following sample cases, the GBW value for all ONTs is fixed on 1.8 Mb/s.
 2. MBW – Maximum bandwidth – is fixed on the link rate.
 3. EBW – Relative portion (weight) of excess bandwidth allocated to the ONT. This value was either the same for all ONTs (about 3%), or randomly un-equal between ONTs (between 1% to 6%).

Traffic simulations

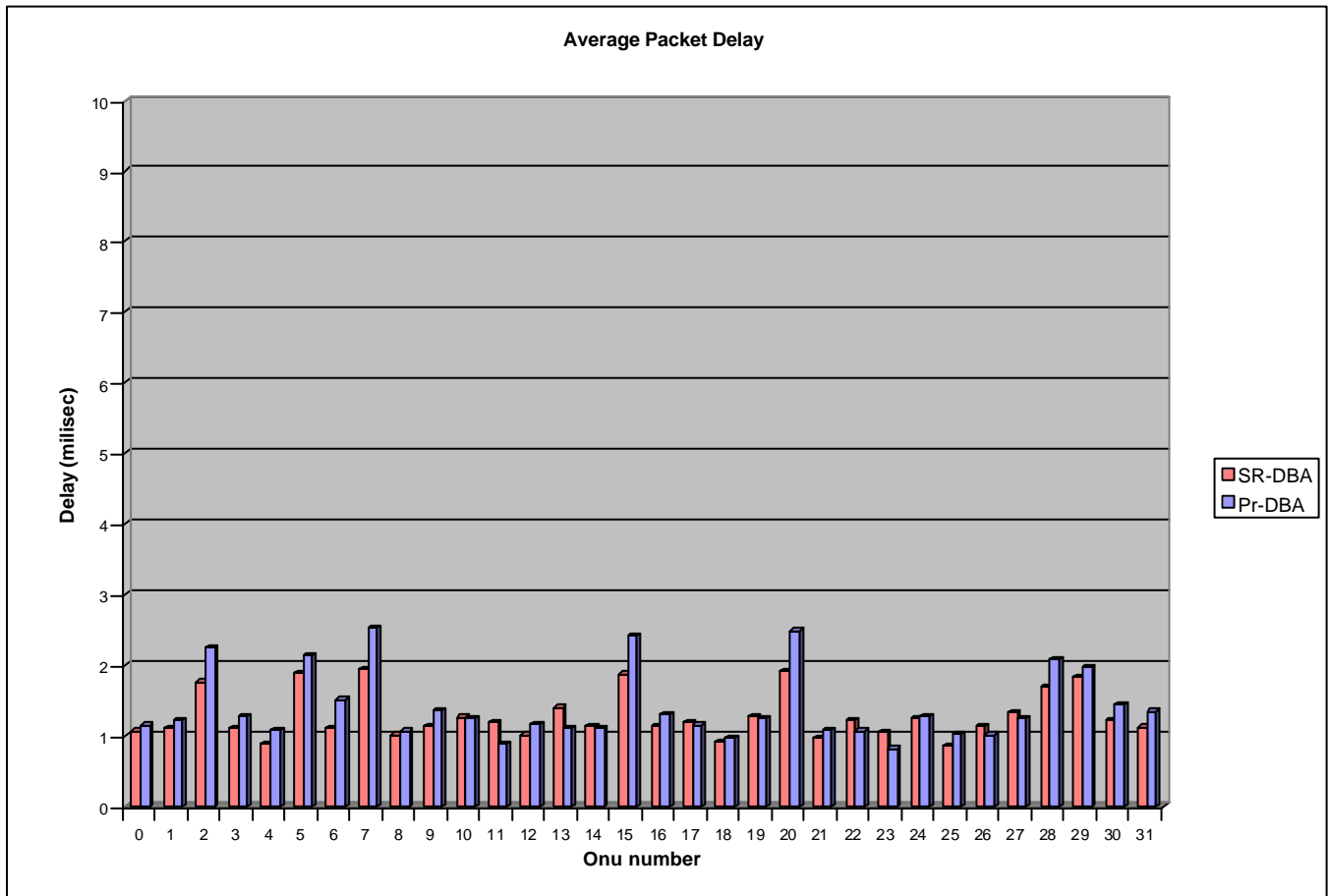
Case 1

- 7 active ONTs, 25 ONTs with very little activity
- Total link utilization:
 - SR-DBA - 24%
 - Pr-DBA – 24%
- Traffic Generator:
 - Busy time: 9 ms
 - Idle time: 11 ms
 - Effective rate per ONT:
 - Active ONTs: 4.9 Mb/s
 - Inactive ONTs: 10 Kb/s
- Average packet delay per ONT:



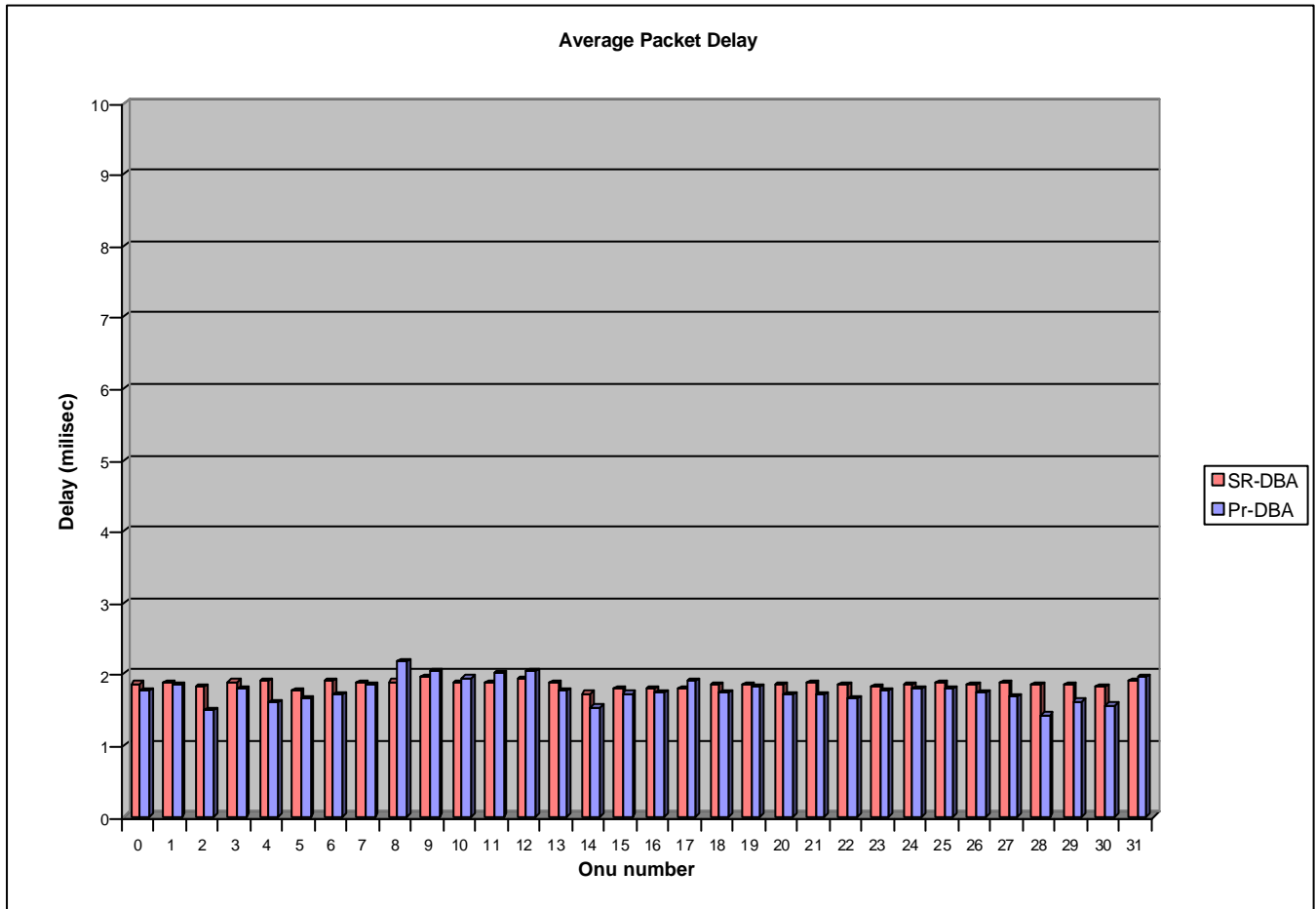
Case 2

- 7 active ONTs, 25 ONTs with very little activity
- Total link utilization:
 - SR-DBA - 52%
 - Pr-DBA – 52%
- Traffic Generator:
 - Busy time: 9 ms
 - Idle time: 11 ms
 - Effective rate per ONT:
 - Active ONTs: 11.6 Mb/s
 - Inactive ONTs: 10 Kb/s
- Average packet delay per ONT:



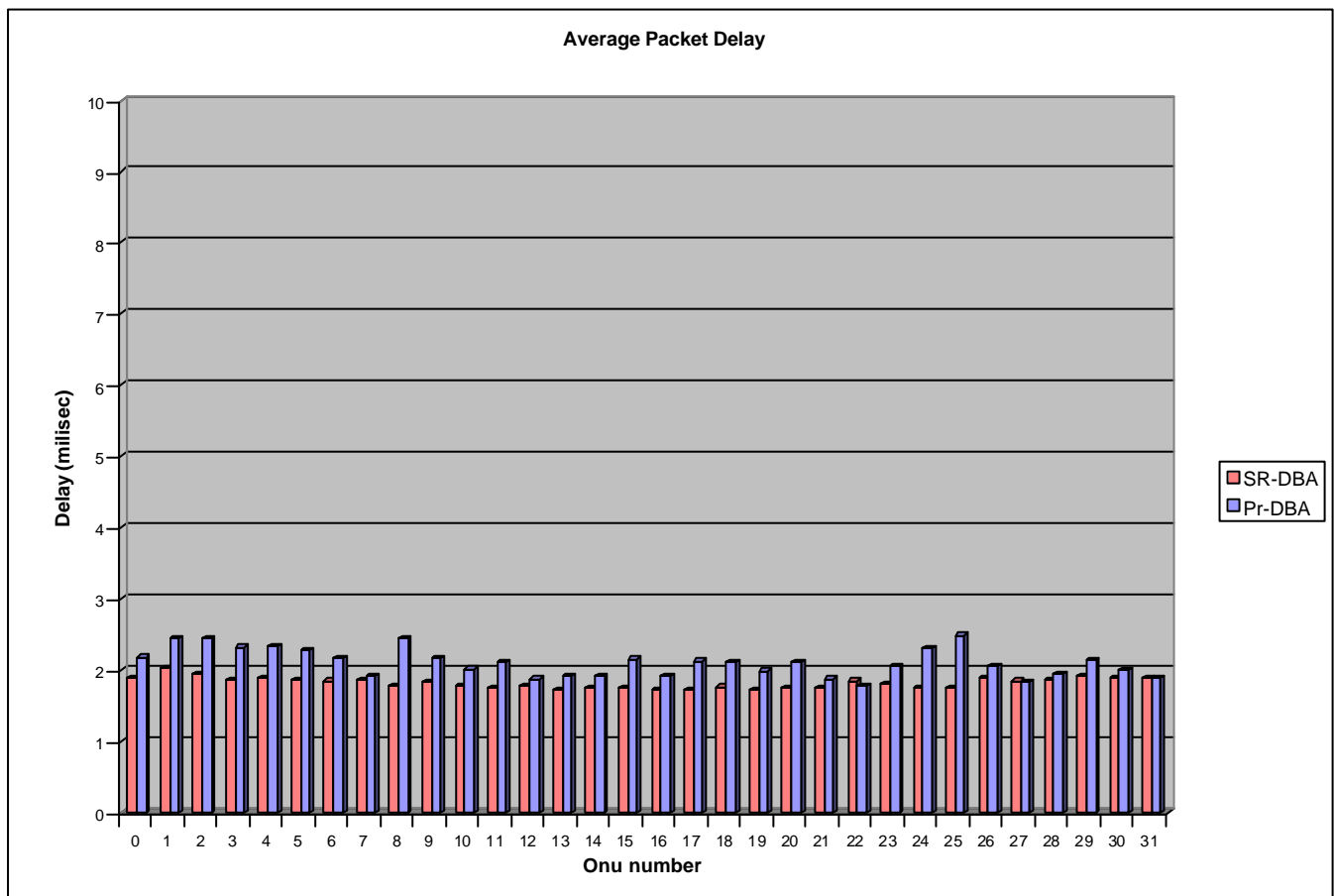
Case 3

- 32 equally active ONTs
- Total link utilization:
 - SR-DBA - 61%
 - Pr-DBA – 61%
- Traffic Generator:
 - Busy time: 9 ms
 - Idle time: 11 ms
 - Effective rate per ONT: 2.9 Mb/s
- Average packet delay per ONT:



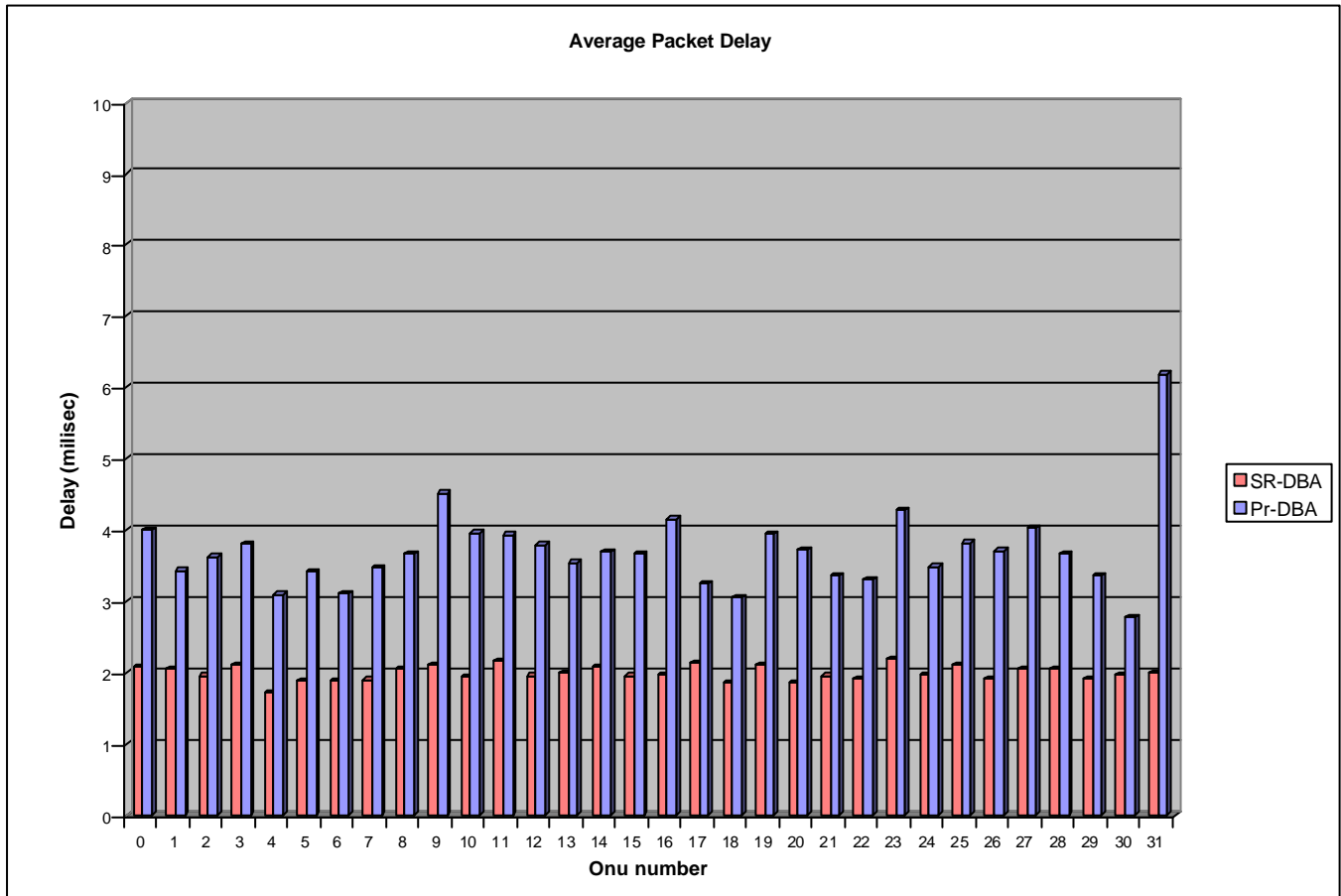
Case 4

- 32 equally active ONTs
- Link utilization:
 - SR-DBA - 61%
 - Pr-DBA – 61%
- Traffic Generator:
 - Busy time: 1.8 ms
 - Idle time: 2.2 ms
 - Effective rate per ONT: 2.9 Mb/s
- Average packet delay per ONT:



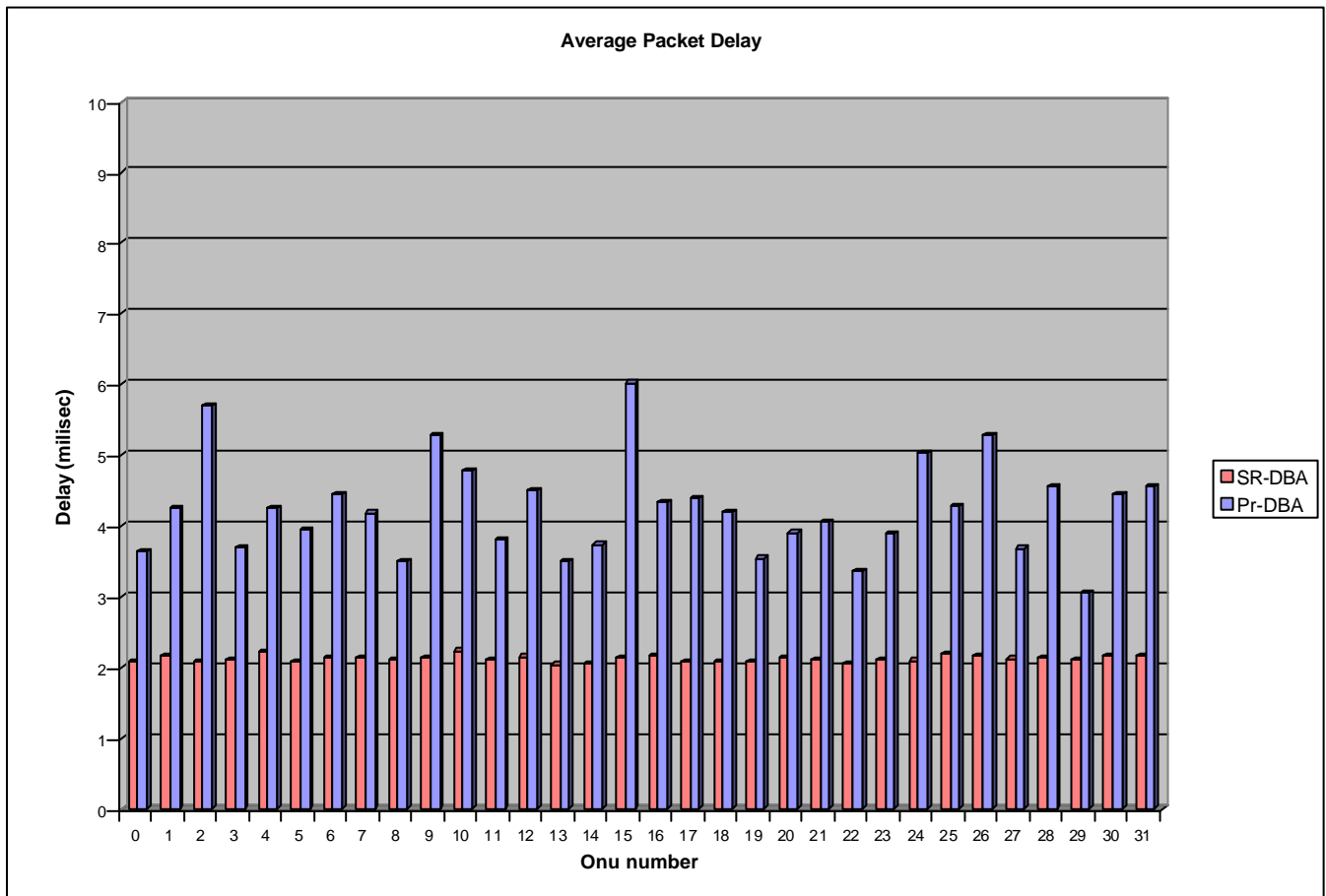
Case 5

- 32 equally active ONTs
- Link utilization:
 - SR-DBA - 61%
 - Pr-DBA – 61%
- Traffic Generator:
 - Busy time: 3.3 ms
 - Idle time: 16.6 ms
 - Effective rate per ONT: 2.9 Mb/s
- Average packet delay per ONT:



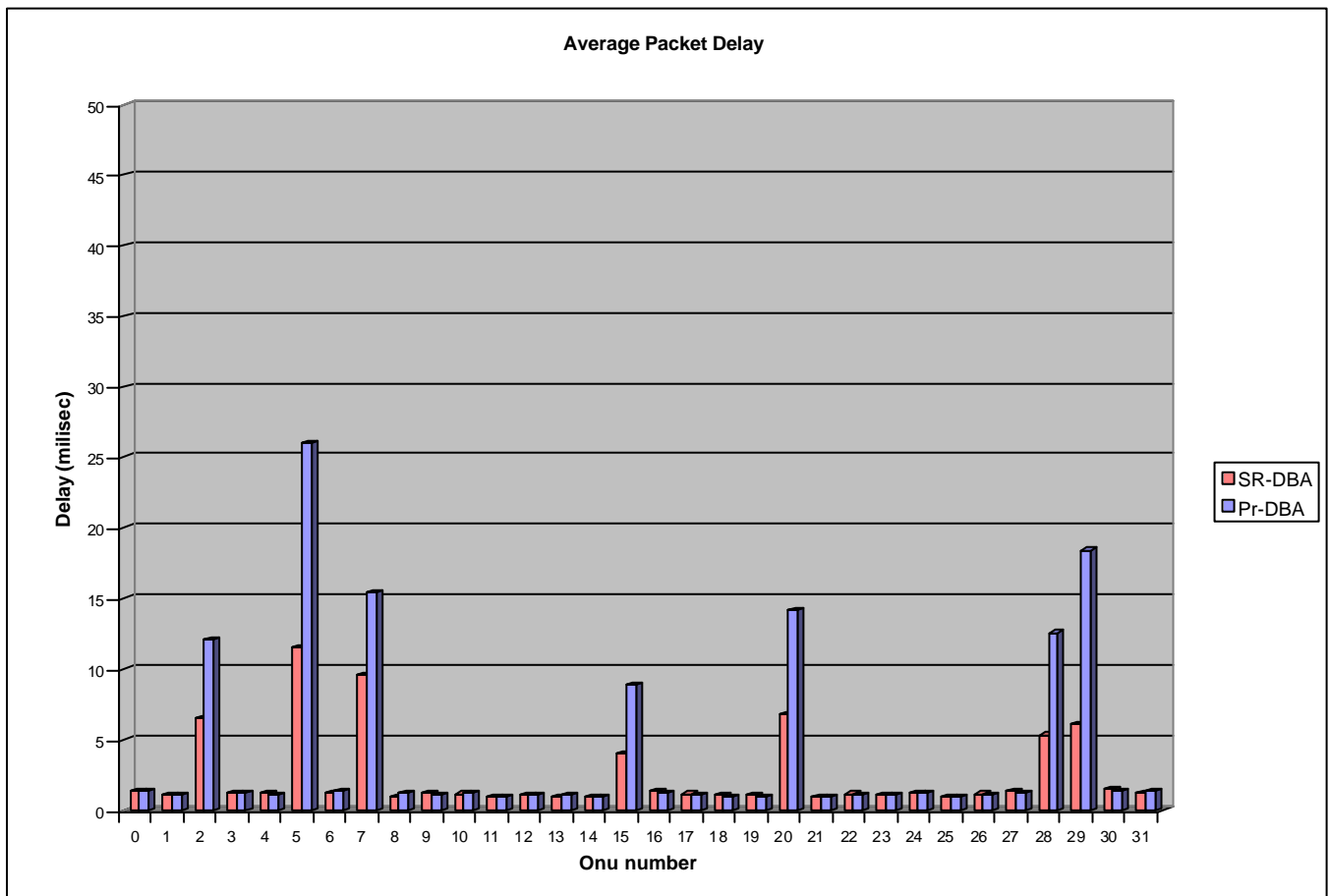
Case 6

- 32 equally active ONT s
- Total link utilization:
 - SR-DBA - 81%
 - Pr-DBA – 81%
- Traffic Generator:
 - Busy time: 9 ms
 - Idle time: 11 ms
 - Effective rate per ONT: 3.9 Mb/s
- Average packet delay per ONT:



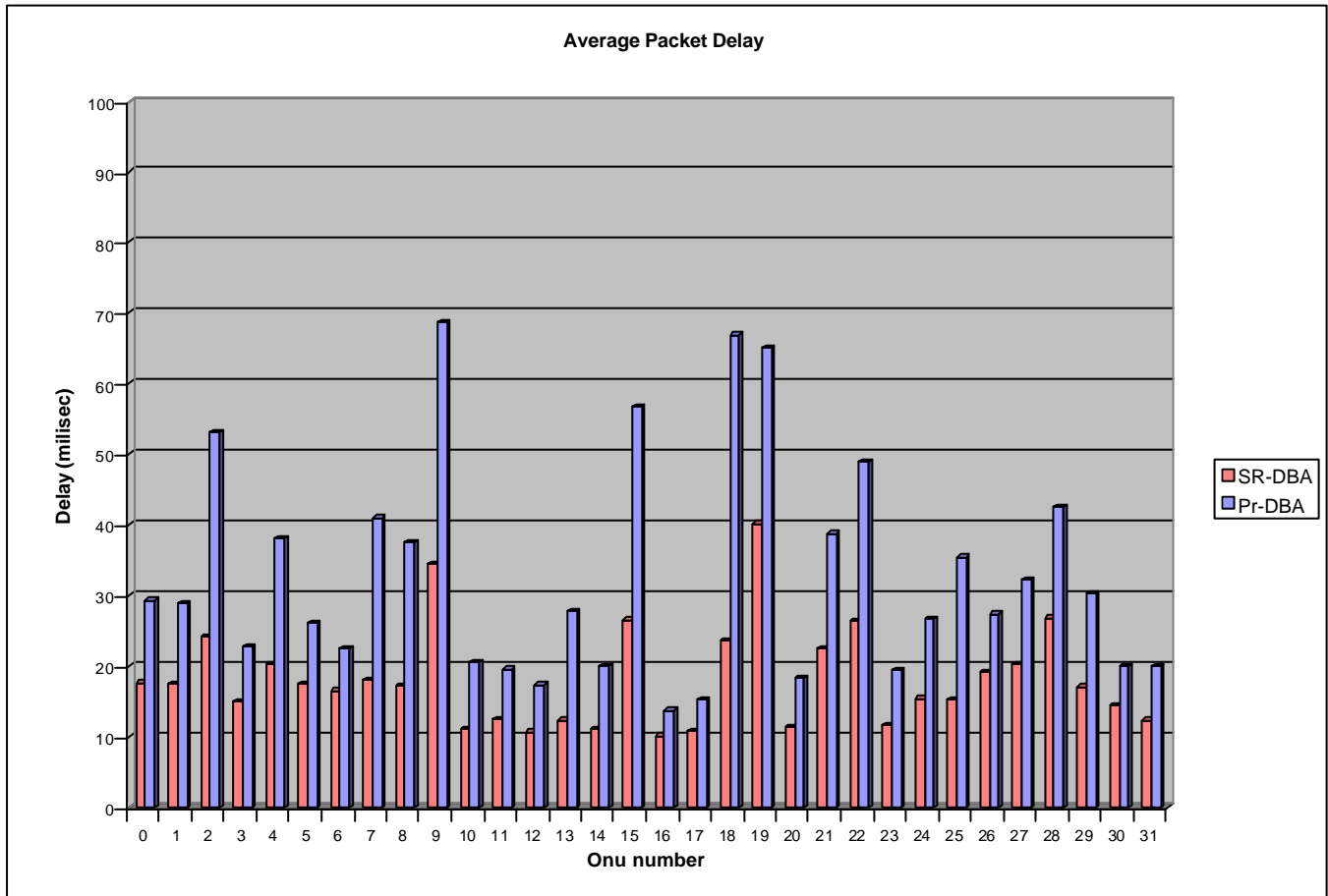
Case 7

- 7 active ONTs, 25 ONTs with very little activity
- Total link utilization:
 - SR-DBA - 88%
 - Pr-DBA – 84%
- Traffic Generator:
 - Busy time: 9 ms
 - Idle time: 11 ms
 - Effective rate per ONT:
 - Active ONTs: 19.4 Mb/s
 - Inactive ONTs: 10 Kb/s
- Average packet delay per ONT:



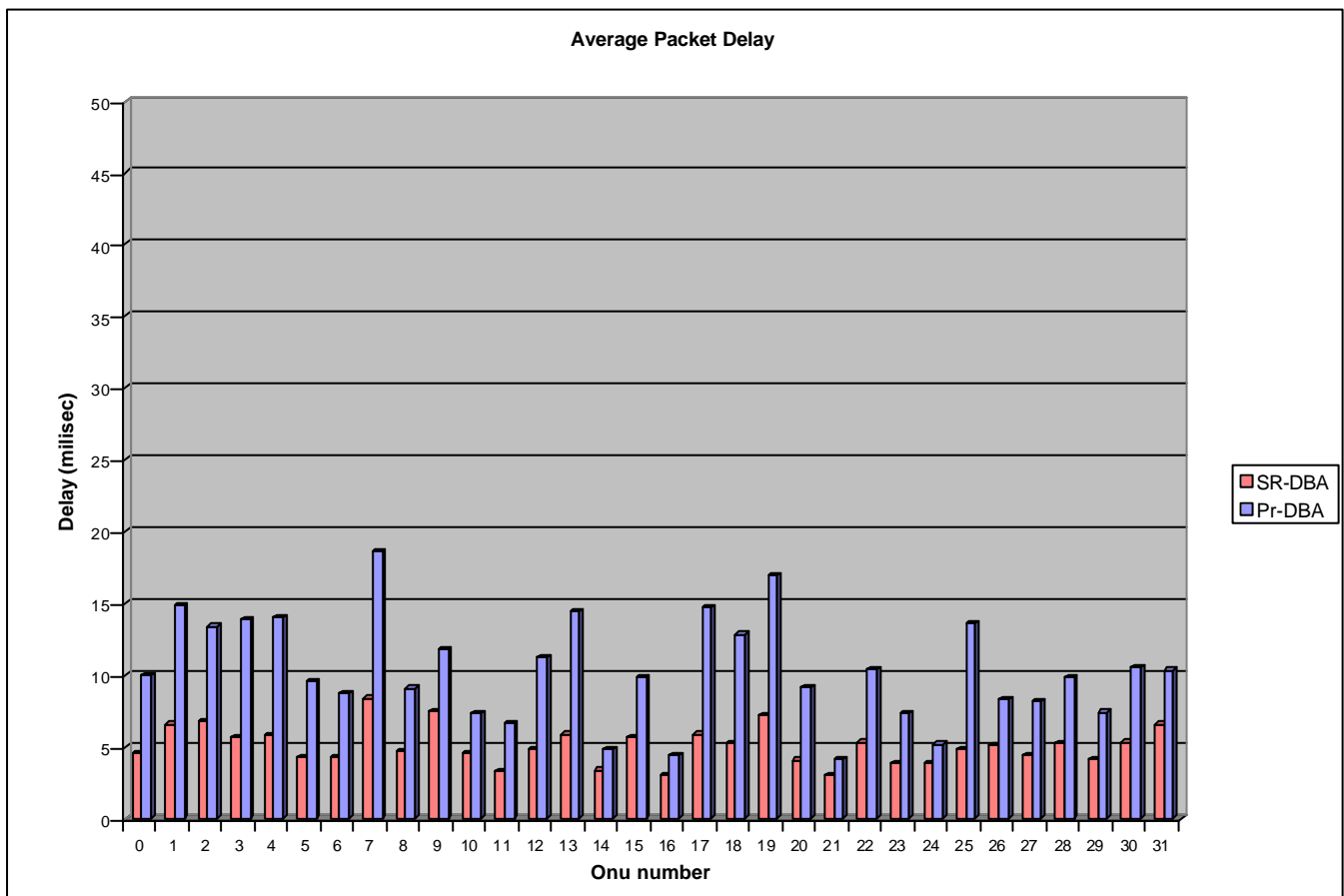
Case 8

- 32 equally active ONTs
- Total link utilization:
 - SR-DBA - 98%
 - Pr-DBA – 95%
- Traffic Generator:
 - Busy time: 9 ms
 - Idle time: 11 ms
 - Effective rate per ONT: 4.9 Mb/s
- Average packet delay per ONT:



Case 9

- 32 equally active ONTs
- Total link utilization:
 - SR-DBA - 98%
 - Pr-DBA – 93%
- Traffic Generator:
 - Busy time: 1.8 ms
 - Idle time: 2.2 ms
 - Effective rate per ONT: 4.9 Mb/s
- Average packet delay per ONT:



Case 10

- 32 equally active ONTs
- Link utilization:
 - SR-DBA - 98%
 - Pr-DBA – 94%
- Traffic Generator:
 - Busy time: 3.3 ms
 - Idle time: 16.6 ms
 - Effective rate per ONT: 4.9 Mb/s
- Average packet delay per ONT :

