

Chapter 8

The OVC setup in connection-oriented OPS networks

8.1 Problem description

In an OPS connection-oriented scenario, the configuration of the OVC forwarding table has a significant role to improve the network performance. In this context, a basic observation, as stated in [21], is that packets following OVCs incoming on the same input wavelength cannot overlap, because of the serial nature of the wavelength as a transmission line. Therefore such packets contend for output resources only with packets incoming on different wavelengths. As a consequence, if OVCs incoming on the same input wavelength are the only ones forwarded to the same output wavelength, contention will never arise (*conflict-free* configuration).

Figure 8.1 shows an example of a switch with $N = 2$ ports and $W = 3$ wavelengths per port. On wavelength λ_2^{in} of port n_1^{in} three OVCs are active: two (l_1 and l_2) are switched to λ_1^{out} of n_1^{out} , and the other (l_3) to λ_3^{out} of n_1^{out} . On port n_2^{in} there are three OVCs (l_4 , l_5 and l_6) coming from different wavelengths. l_4 is switched to λ_3^{out} of n_1^{out} while l_5 and l_6 are switched to λ_2^{out} of n_2^{out} . By observing the figure it is trivial to understand that packets from l_1 and l_2 will never overlap (there are subject to a conflict-free allocation), whilst packets from l_3 and l_5 may overlap with packets from l_4 and l_6 , respectively.

It is possible to quantify the influence of the overlapping to the performance of the switch. For the evaluation we use the simulation environment described in Appendix I where we also explain the meaning of the parameters. The following results have been obtained using a switch with $N = 4$, $W = 16$ and a degenerate buffer of length $B = 6$. The granularity of the FDL has been set to $D = 0.4$ because it is the optimal value for the static approach [21]. Each input and output wavelength is supposed to carry $L = 10$ different OVCs for a total of 640 incoming OVCs. We put our attention to a particular output wavelength. At different values of ρ , we carried out a set of simulations changing the relative load of the OVCs δ which is the percentage of the OVCs coming from the maximum loaded input wavelength. Formally, if the OVC i has a load of ρ_i , δ is calculated as

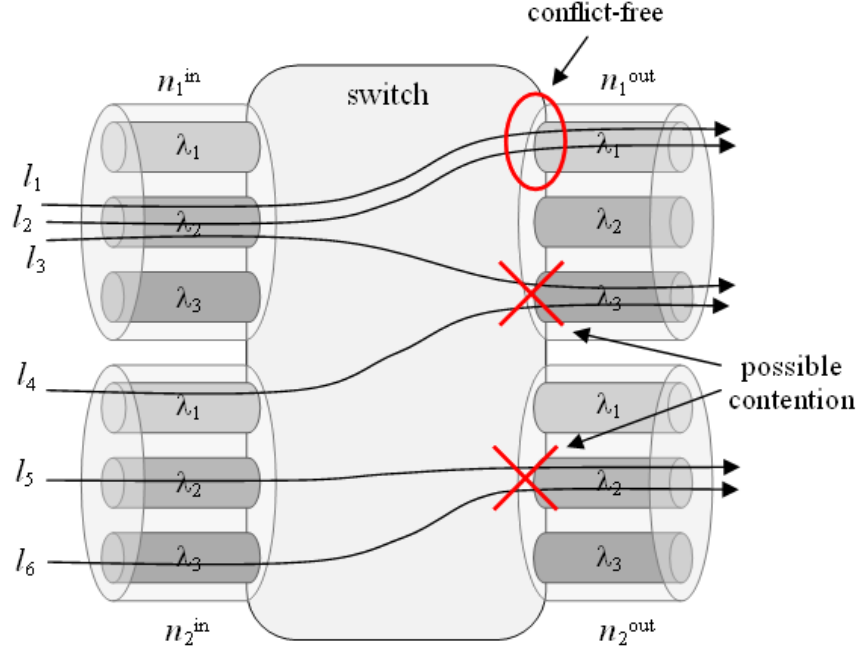


Figure 8.1: Example of OVC forwarding table configurations able to avoid and produce contentions.

$$\delta = \frac{\max_{i \in L} \rho_i}{\sum_{i=1}^L \rho_i}$$

For example, if the overall load is $\rho = 0.8$ and the relative load is $\delta = 0.5$, this means that there is an OVC which contributes with a 50% of the 0.8 load while the remaining load is uniformly provided by the other 9 OVCs.

Figure 8.2 shows the results changing the relative load from $\delta = 0.1$ to $\delta = 1$ and overall load from $\rho = 0.6$ to $\rho = 1$. It is clear that when $\delta = 1$, no contentions are possible (i.e., conflict-free configuration) and therefore the PLR is 0. Decreasing δ , the PLR increases. The increase strongly depends on the overall load. At $\rho = 1$, the curve is practically flattened with an elbow close to $\delta = 0.95$. At $\rho = 0.7$ and $\delta = 0.3$, the PLR is less than 10^{-7} .

It has to be underlined that the same behavior can be observed for whatever number of OVCs L contending for the same output wavelength. We carried out different simulations varying L from 2 to 20 and the obtained results present negligible differences.

This observation outlines that the configuration of the forwarding table has a strong impact on the switch performance. Previous works do not consider this issue and always assume an average situation where the OVCs are already established and fixed in the simulations [21] [23] [22]. But we just noticed that the OVC setup

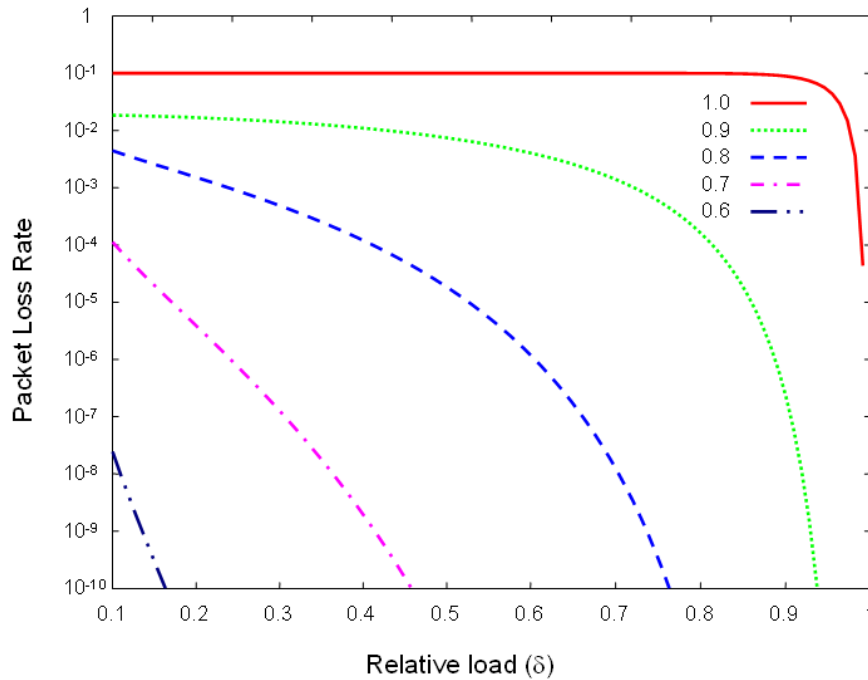


Figure 8.2: Packet loss rate as a function of the relative load at different overall load.

procedure is an interesting problem to be addressed. When a request to setup a new OVC arrives to a switch, this procedure is in charge of determining both the output port n^{out} and the output wavelength λ^{out} . While the former depends on the routing protocol, the latter may be set locally by each node using a *OVC-to-wavelength setup assignment* (OWSA) algorithm.

In the following section, we concentrate only on the OWSA problem proposing some heuristic OWSA procedures. These procedures are evaluated considering a static wavelength selection policy. However, the performance using dynamic policies is also affected since a non optimal setup continuously requires updates of the forwarding tables, moving the OVCs from the original wavelength to another. This clearly overloads the control functions, and increases the probability of breaking the correct packet sequence.

8.2 OWSA algorithms

Four different algorithms for the OWSA problem, namely **Random**, **Round-Robin**, **Balance**, and **Grouping** are suggested:

- **Random** (RND). When a request to setup a new OVC arrives, the SCL recognizes the output port n^{out} to reach the next hop and selects a random wavelength λ^{out} of n^{out} . Then, the new entry is added to the forwarding table.
- **Round-Robin** (RR). In this case, the SCL maintains a set of pointers ptr ; each one pointing to the last selected wavelength of each output port. When

a request to setup a new OVC arrives, the SCL recognizes the output port n^{out} to reach the next hop, increases by 1 the corresponding pointer $ptr_{n^{out}}$ and selects the pointed wavelength λ^{out} of n^{out} . Then, the new entry is added to the forwarding table.

- **Balance** (BLC). In this case, we assume that the setup request contains also an information on the average load of the OVC. The SCL uses this information to maintain a matrix \mathbf{V} , where each entry $\mathbf{V}_{i,j}$ indicates the overall load of the output wavelength i of output port j . At OVC setup request, the SCL determines the output port n^{out} and selects the wavelength λ^{out} with the minimum load, i.e., $\min_{\lambda^{out} \in W} \{V_{\lambda^{out}, n^{out}}\}$.
- **Grouping** (GRP). This algorithm tries to take benefit from the conflict-free configuration. At OVC setup request, the SCL recognizes the $(\lambda^{in}, n^{in}, n^{out})$ tuple of this OVC. Therefore, it searches in the forwarding table if there is another OVC l' with the same tuple. If l' exists, it selects the same λ^{out} assigned to l' . If not, it searches a wavelength λ^{out} with no assignments. If all wavelengths are already in use, SCL applies the BLC algorithm.

It has to be underlined that the idea of exploiting the conflict-free configuration has firstly been adopted in [21] to develop a dynamic contention resolution algorithm for connection-oriented OPS networks. Here we use the same concept to intelligent setup the OVC forwarding table at the nodes.

Figure 8.3 shows the steps of these algorithms. FT stands for Forwarding Table.

8.3 Performance evaluation

We carried out several simulations in order to evaluate the performance of the previous described OWSA algorithms. We set up the simulator (described in Appendix I) considering $N = 4$, $W = 16$, $C = 10$ Gbps, $L = 10$, a degenerate buffer \mathbf{Q}_6 , and $D = 0.4$ (optimal value for static approach [21]). In this case we only evaluate the PLR. Under static approach, there is no possibility to break the packet sequence (OS is always 0%) neither to change the assigned wavelength (FO is always 0%).

Figure 8.4, Figure 8.5, and Figure 8.6 shows the PLR as a function of the overall load comparing the RND, RR, BLC, and GRP algorithms using \mathbf{M}^U , \mathbf{M}^P , and \mathbf{M}^B traffic matrix, respectively.

We can see that the BLC and GRP algorithms outperform the other strategies. Confirming our expectations, the performance improves even more using the GRP algorithm.

Further simulations (not presented here), showed that either varying L from 2 to 20 or changing the traffic distribution, GRP always presents the best PLR.

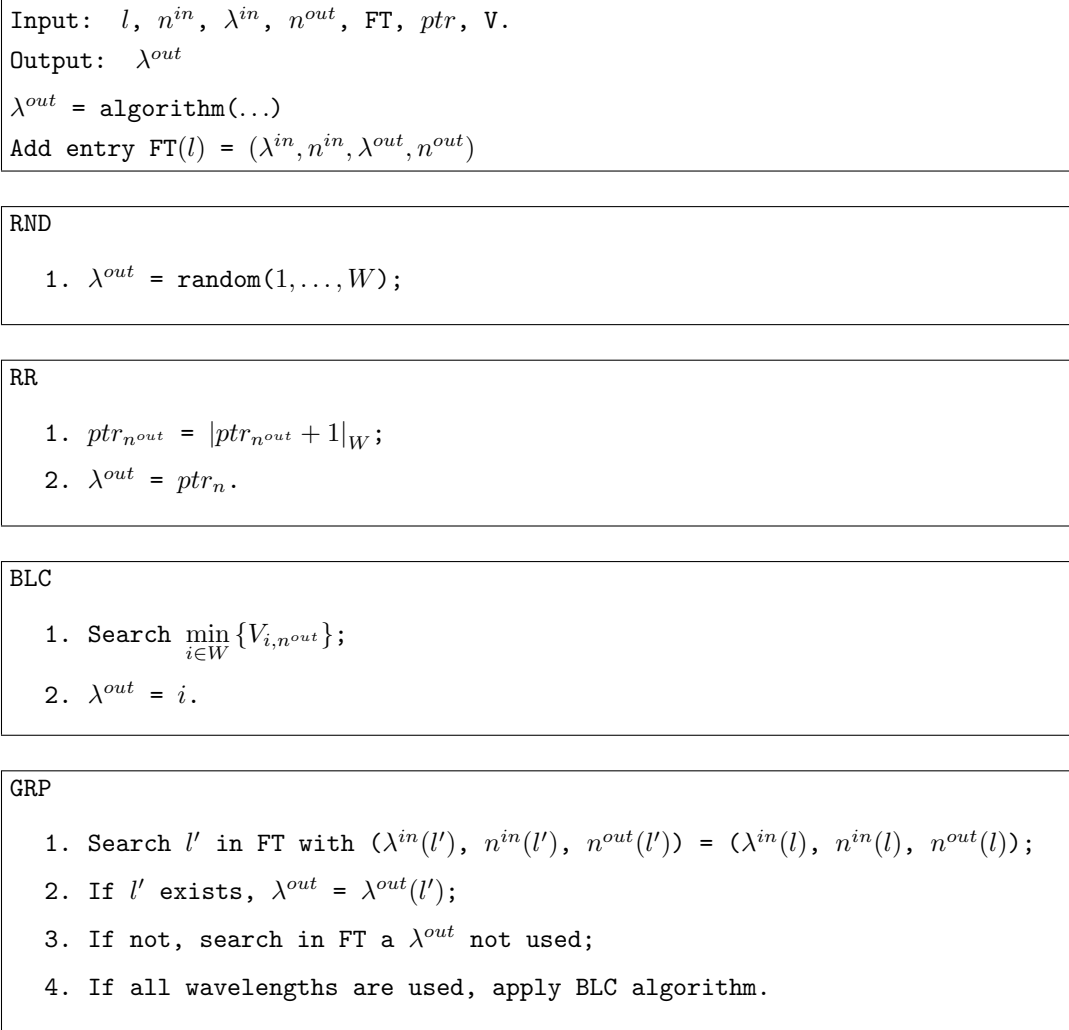


Figure 8.3: OWSA algorithms.

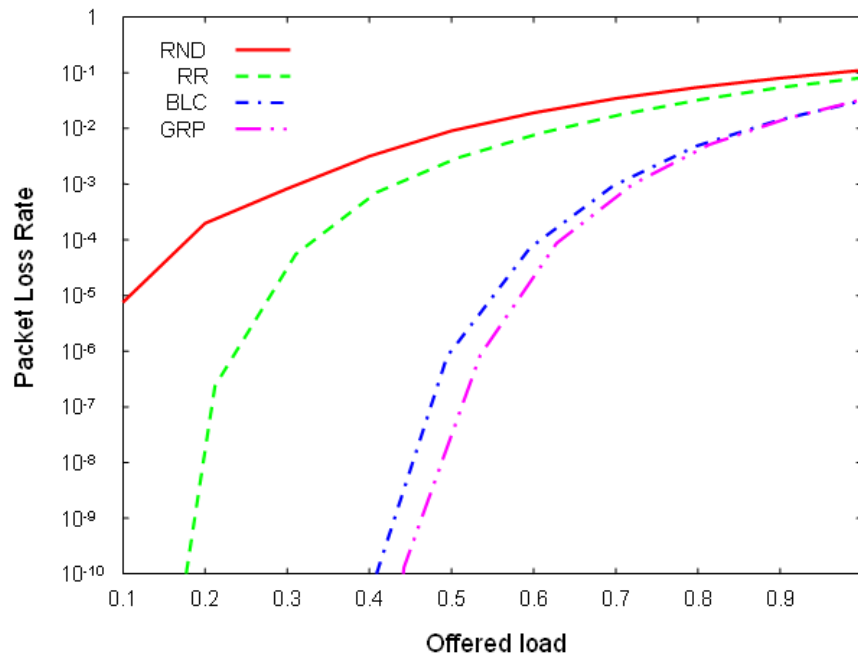


Figure 8.4: Packet loss rate as a function of the overall load comparing the RND, RR, BLC, and GRP algorithms under uniform traffic matrix.

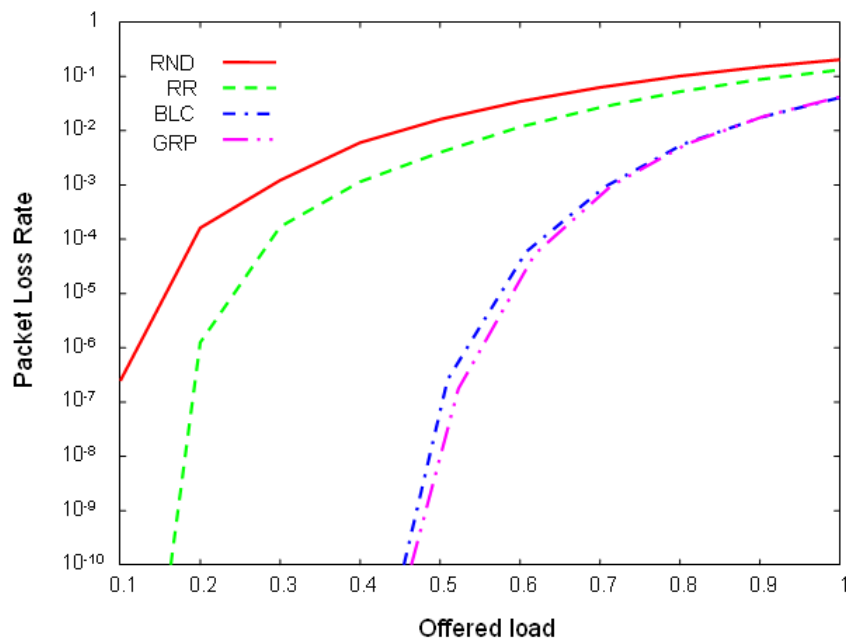


Figure 8.5: Packet loss rate as a function of the overall load comparing the RND, RR, BLC, and GRP algorithms under power-of-two traffic matrix.

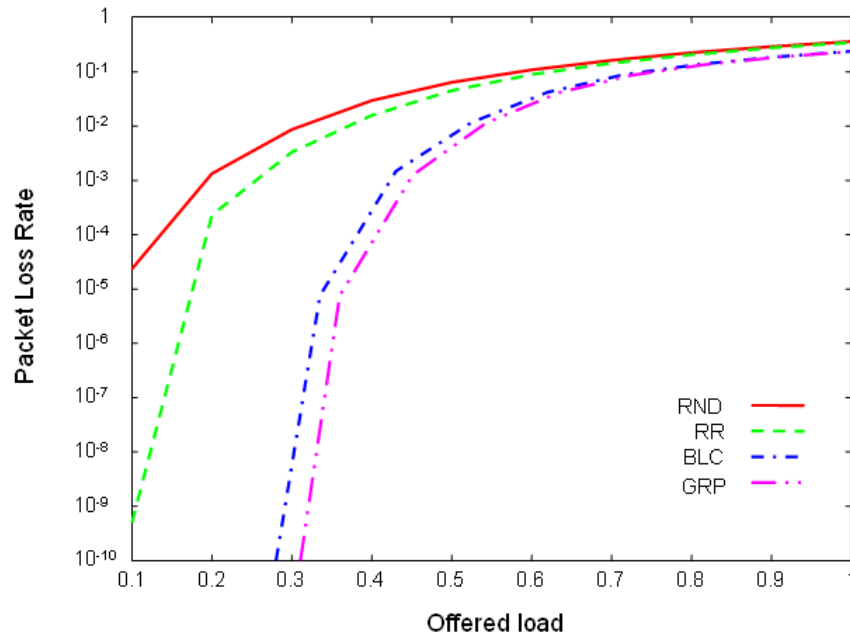


Figure 8.6: Packet loss rate as a function of the overall load comparing the RND, RR, BLC, and GRP algorithms under unbalanced traffic matrix.

8.4 Quality differentiation at the OVC setup

The previous results suggest that it is possible to obtain a clear performance improvements in terms of PLR simply applying intelligent OWSA algorithm. Basically, grouping the conflict-free flows and balancing the load yield the better results.

We can further exploit these facts to setup OVC with quality differentiation. For example let us consider that two quality OVC are available in the network, namely **High Quality** (HQ) and **Low Quality** (LQ). If a request to setup an OVC arrives to a node, we hence have two alternatives:

- If the request regards the establishment of an HQ OVC, the SCL applies the GRP algorithm previously explained since it performs the lowest PLR.
- For the LP OVC, at first, the SCL applies the first two steps of the GRP algorithm. These steps do not affect the HQ OVCs since no contentions are possible among conflict-free OVCs. If it does not find any l' with the same $(\lambda^{in}, n^{in}, n^{out})$ tuple of the new OVC, the SCL applies the BLC algorithm only between those wavelengths not used to transport HQ OVCs. If all wavelengths already transport at least one HQ OVC, the SCL applies the BLC algorithm as it is.

Figure 8.7 describes this quality differentiation setup procedure.

Eventually, it is possible to reject a request in order to not reduce the performance of the HQ OVCs already established. This possibility is not considered here and it is let to be investigated in further works.

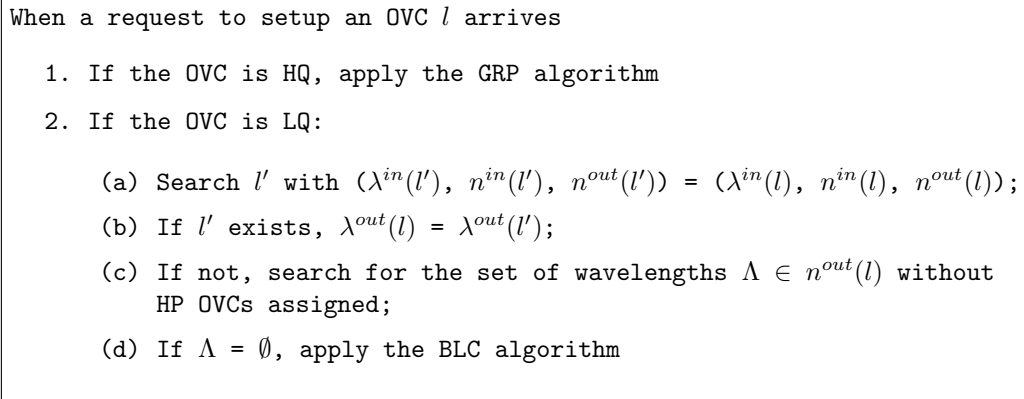


Figure 8.7: Procedure for HQ and LQ OVC.

To evaluate the performance of this procedure, we set up the simulator considering $N = 4$, $W = 16$, $L = 10$, a degenerate buffer \mathbf{Q}_6 , and $D = 0.4$ (optimal value for static approach). In this case we only evaluate the PLR. Under static approach, there is no possibility to break the packet sequence (OS is always 0) and to change the assigned wavelength (FT is always 100).

Figure 8.8 shows the PLR as a function of the overall load under uniform traffic matrix considering an HQ load of 5%, 25%, and 50% of the overall load, respectively.

We can see that there is a clear QoS differentiation between LQ and HQ. As expected, under low offered load it is possible to achieve good results. Increasing the HQ relative load, the performance gets worse, reaching 10^{-2} LQ packets losses at 0.5 load.

The same conclusions can be drawn considering Figure 8.9 which shows the PLR as a function of the offered load under power-of-two and unbalanced traffic matrix. In this case, the HP load is 25% of the overall load. In particular, we can observe that the unbalanced traffic matrix causes high performance degradations. We can suppose that this behavior is mainly due to the asymmetries of the traffic matrix which match very bad with the switch symmetries.

8.5 Summary

In this part of the thesis, we have addressed the problem of setting up the OVCs at the nodes assigning a proper wavelength to the connection.

An original policy called GRP based on grouping the conflict-free flows (i.e., flows coming from the same input wavelength) has been proposed and compared to common approach such as random, round-robin and load balancing techniques. Results have been demonstrated that considerable switch performance improvements can be obtained by this policy. For example, in the scenario studied in this work, the GRP algorithm yields a PLR one order of magnitude lower than load balancing when the switch is lightly loaded. This concept has been efficiently inferred to provide quality differentiation between two type of OVCs.

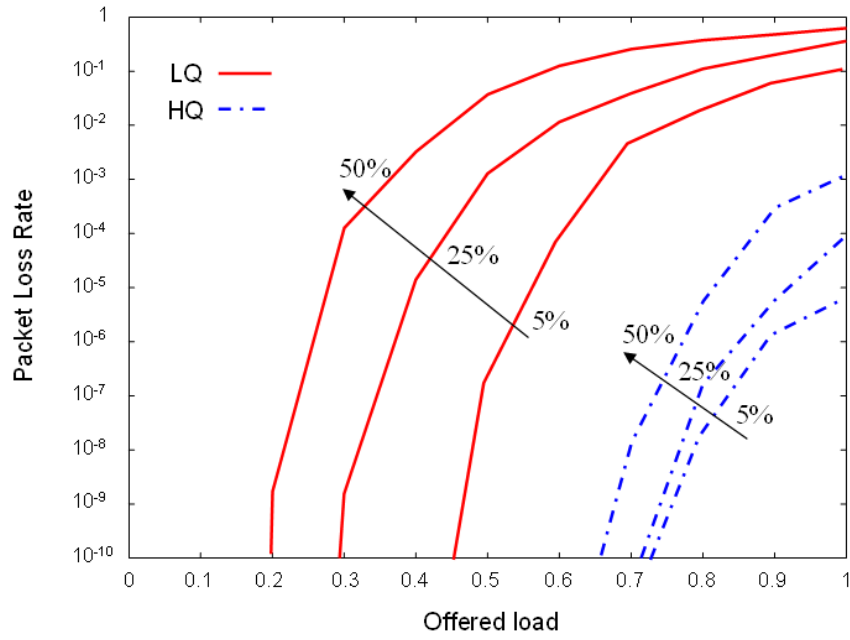


Figure 8.8: Packet Loss Rate as a function of the offered load. HQ load increases from 5% to 50% with respect to the overall load under uniform traffic matrix.

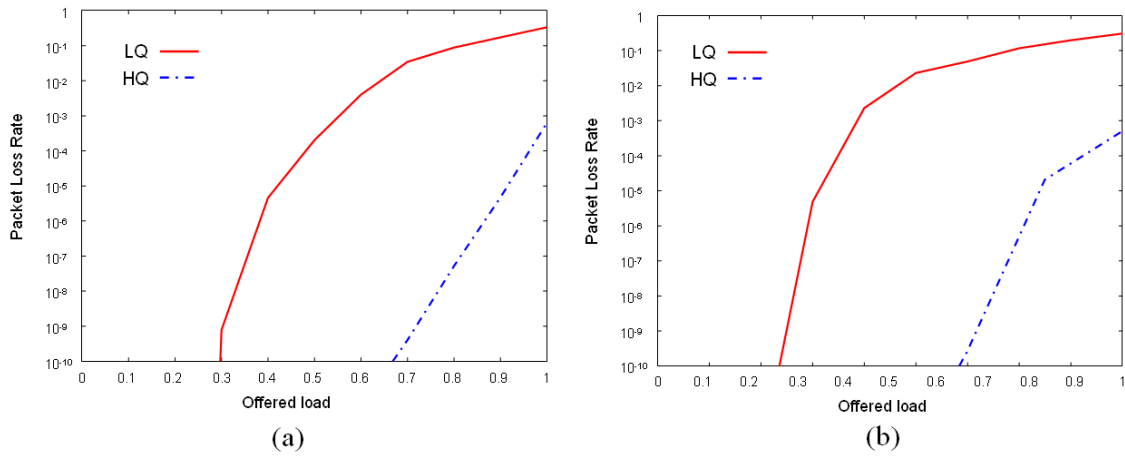


Figure 8.9: Packet Loss Rate as a function of the overall load with HQ load is 25% under a) power-of-two traffic matrix and b) unbalanced traffic matrix.

