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A Study of Optical Fiber Network Capacity Escalation due to Localized Extreme Traffic Increase

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Abstract
Optical fiber network capacity escalation along the traffic increase was studied. Due to localized extreme traffic increase, the required capacity of the local line might be affected significantly while whole network capacity is not affected.

Introduction

A vast traffic of the broadband internet has penetrated in the commercial communication system, and the optical fiber network has become the infrastructure of such system. As the traffic is still growing in a steady pace, the capacity of the network should be expanded regularly to keep the acceptable network performance. One of the most important measures of the performance is the congestion of the network, and it can be quantitatively evaluated by the number of packet losses or the packet loss ratio. The network operators need to maintain the service level of the network keeping the packet loss ratio to be smaller than the target level, and they should introduce additional capacity for the network when the recorded packet loss ratio is approaching the target level.

When the traffic in the network is growing in uniform, the network operators can expect the network congestions based on the historical trend, and they can estimate required additional capacity to reduce the congestions. On the other hand, service providers will launch new services such as movie broadcasting [1], and it will cause localized extreme traffic increase in the network. Such an event will impact on the network congestions, and the network operators might require more network capacity than they are planning.

In this paper, the escalation of the optical fiber network capacity was studied and compared with the uniform traffic increase and the localized traffic increase. A numerical simulator was used to evaluate the optical fiber network. The results showed that the localized traffic increase might not cause significant impact on the whole network capacity, but it could cause significant increase of the required local line capacity of the network.

System model

Figure 1 shows the optical fiber network model used for this study. The topology of this model is based on NSFNET backbone [2].

The traffic in the model was assuming the packet traffic. In the initial condition, the average traffic was set to be the same between any nodes. The number of packets was randomly generated, and its distribution was Gaussian. In addition, the packet length was also random, and its distribution was Gaussian. The routing of the traffic adopted the shortest path method, and two diversity routes were pre-assigned in case for the line congestion. The initial line capacities between the nodes were set to satisfy the entire traffic only by the shortest path.

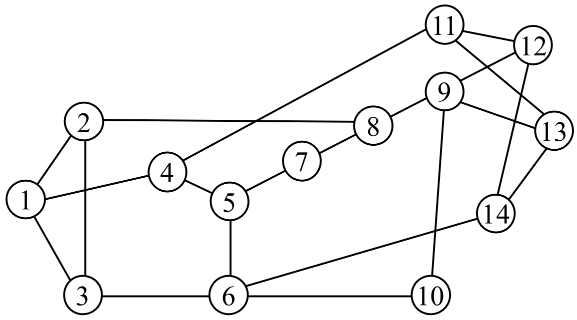


Figure 1 Network topology used for the simulation

A Monte-Carlo method was used to evaluate the network performance. Each simulation conducted 100,000 times random assignment of the traffic. In case when congestion was occurred, the traffic was automatically diverted to the pre-assigned routes. The packet loss would occur when all diversity routes were congested, and numbers of the lost packets were recorded to evaluate the packet loss ratio.

The escalation of the network capacity required to maintain the service level was evaluated using this simulation model. The traffic between the nodes was increased for each simulation, and it resulted in the increase of the packet loss ratio. When the packet loss ratio between certain nodes exceeded the target level, the capacities of the lines transferring the traffic between the nodes were automatically increased. The criterion of the packet loss rate was targeted to 5 x 10^{-3} in this simulation. By repeating this process, the escalation of the network capacity along the increase of the traffic was obtained. To increase the capacity of the line, a granularity of the additional capacity was adopted in the simulation, because the actual network would introduce additional capacity by the wavelength basis, and it should have a certain granularity. In this simulation the granularity was set to be the same as the initial traffic between the two nodes.

Results and discussions

The network capacity escalation was evaluated for the uniform traffic increase and the localized extreme traffic increase. For the uniform case, the traffics between the nodes were increased by 5% for each simulation. For the localized case, the traffic from and to a specific node was increased by 10% while the other traffics were increased by 3.8% in order to keep almost identical total network traffic with the uniform case. In addition, for the localized case, two different nodes were arranged as the specific node, and they were node number 6 and 1.

Figure 2 shows the increase of the total network capacity for the uniform traffic increase and the localized traffic increase. Horizontal axes shows the time of the simulation, and the vertical axes shows the relative capacity assuming the initial capacity as 1. As seen in the figure, there were not so significant differences between three cases.

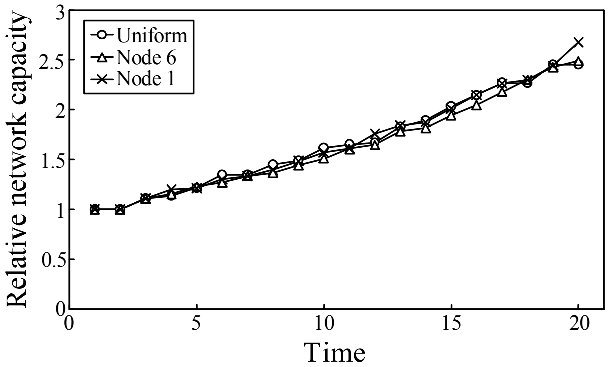


Figure 2 Evolution of the total network capacity

Figure 3 shows the transition of the packet loss ratio for the entire network. As seen in the figure, the loss ratio repeats increase and decrease, because the simulation program automatically increased the line capacity when the loss ratio exceeded the target rate. For the uniform case, the loss ratio did not keep exceeding the target rate. On the other hand, it sometimes kept exceeding the target rate for the localized case. This implies that the increment of the line capacity for the localized case might not be enough for this simulation.

Even though the total network capacity did not differ so significantly for three cases, local line capacity showed the significant difference. Figure 4 (A) and (B) show the difference of the line capacity escalation for node 6 and node 1. In this figure, the capacity is normalized by the granularity of the capacity increase unit. As seen in the figure, the difference of the line capacity between the uniform case and the localized case for node 6 was relatively moderate, and it was 8% to 42% after 20 times of simulation. On the other hand, the difference was larger for node 1, and it exceeded 80%. These results showed that the localized extreme traffic increase could cause significant impact on the local line capacity escalation.

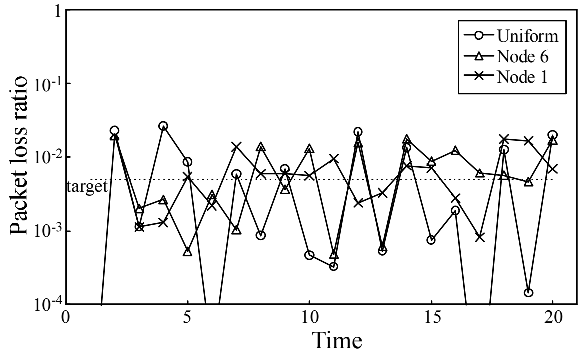
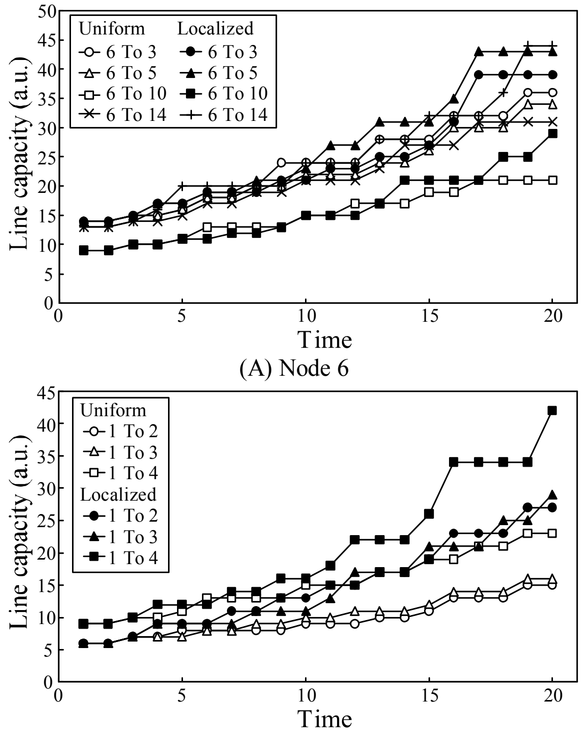


Figure 3 Transition of the packet loss ratio



(A) Node 6

(B) Node 1

Figure 4 Escalation of the local line capacity

Conclusions

Network capacity escalation due to the localized extreme traffic increase was evaluated through the simulation. The results showed that even when the total network capacity became almost identical, the local line capacity could suffer significant impact, and this might cause some problems upon the planning of the network operator, because the escalation is far beyond the expectation.

References

[1] http://www.youtube.com

[2] http://www.ece.arizona.edu/~medenis/hw1/nsf_net.htm