PS-29. Multi-slice Traffic Engineering Method for Optical Packet / Path Integrated Networks

Masayasu Yamaguchi, Daisuke Ishii, Satoru Okamoto, Naoaki Yamanaka, and Eiji Oki†
Keio University and †The University of Electro-Communications, E-mail: myama@educ.cc.keio.ac.jp

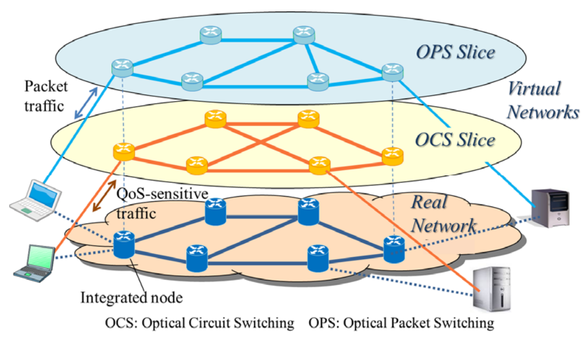
Abstract

This paper proposes a novel traffic engineering method for improving the throughput characteristics of optical packet forwarding in an optical packet / path integrated network. This method is based on bypassing optical packets rejected from a highly-loaded optical packet switch onto one of the adjacent packet switches via an optical path to increase the network throughput. Since the formation of a bypass is equivalent to sharing the buffers of two or more optical packet switches, the packet loss rate can be reduced even by the same buffer length. Or the buffer length can be reduced to achieve the given packet loss rate.

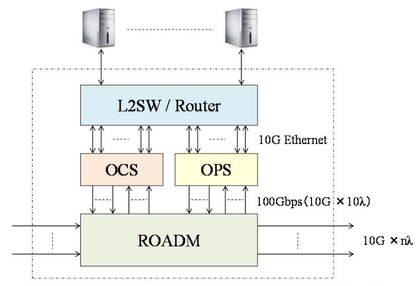
Background

-Rapid increase of the Internet traffic and power consumption
→ Introduction of optical technologies
-Needs for flexible traffic handling of both best-effort and guaranteed services
→ Integration of packet and path switching technology

Optical packet / path integrated networks have been studied.



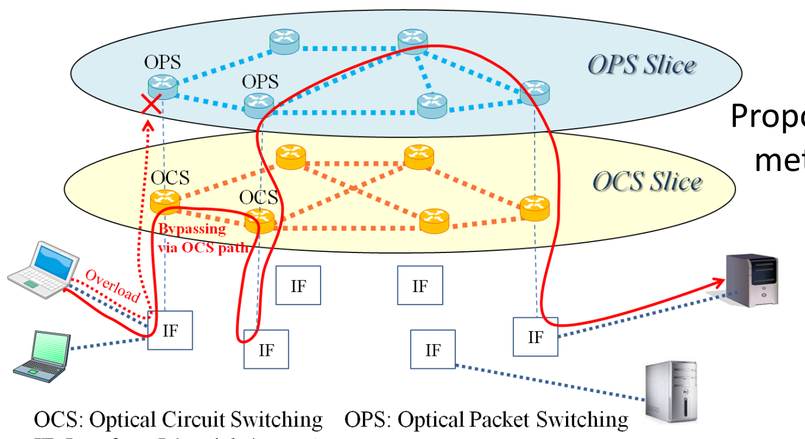
Logical structure of the optical packet / path integrated network.



Structure of an optical packet / path integrated node

Packet forwarding issue and approach

-**Issue:** To achieve a high throughput under highly-loaded conditions in photonic switching networks (← Limited buffering capabilities in optical domain) → Needs for traffic engineering
-**Approach: Proposal of packet bypassing method via the OCS slice**

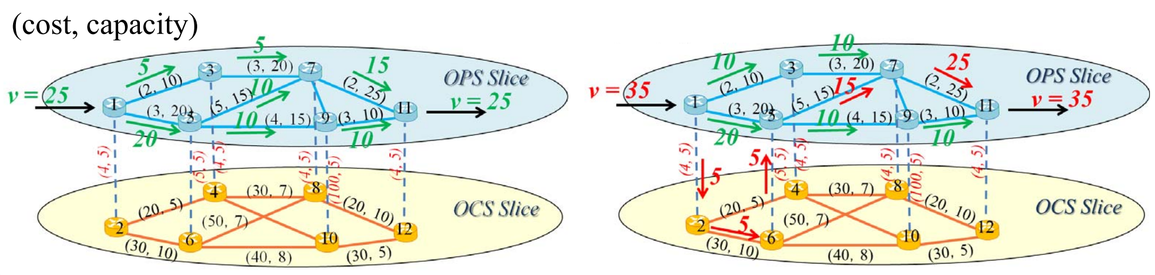


Proposed packet bypassing method via the OCS slice.

OCS: Optical Circuit Switching OPS: Optical Packet Switching
IF: Interface (L2 swich / router)

Example of path finding results

-Routes from node #1 to node #11
-Route & volume of each flow are calculated by the integer linear programing (ILP) as a minimum cost flow problem.
(cost = power consumption per link, capacity = link capacity)
$v \leqq 25$: all of packets are forwarded on the OPS slice (green arrows)
$v > 25$: overflowed packets are bypassed through OCS slice (red arrows)



(a) V = 25 (low load) (b) V = 35 (low load)

Merit & issue of bypassing packets via OCS slice

Merit

-Packets can bypass a crowded node and can reach a vacant node via the OCS slice.
→ reduce packet losses at crowded nodes
→ improve network throughputs
- Excessive resource allocation can be reduced by cutting peak traffic in OPS slice.

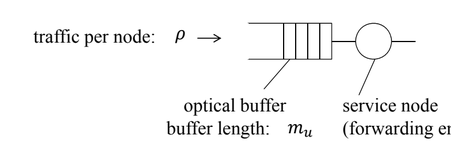
Issue

-Bypassing via OCS slice increases power consumption per packet.
→ Route and volume of bypassing traffic should be optimized to minimize the increase of power consumption.

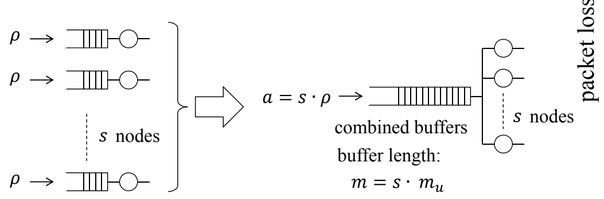
Traffic model and packet loss calculation

-Bypassing scheme integrates buffers in all nodes in OPS slice.
→ A virtual single buffer produces a statistical multiplexing effect
→ Reduces packet losses as a whole

Traffic model of OPS nodes.



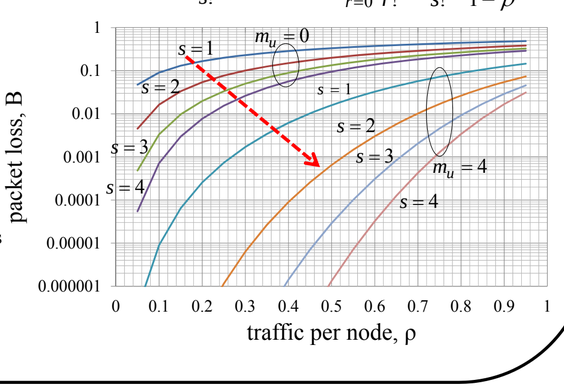
(a)A single OPS node model



(b) Approximate model of s OPS nodes

An example of packet loss calculation.

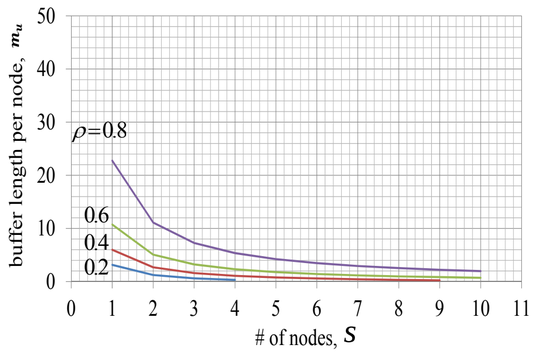
$$B = P_0 \frac{a^s}{s!}\rho^m \qquad P_0^{-1} = \sum_{r=0}^{s-1} \frac{a^r}{r!} + \frac{a^s}{s!}\frac{1-\rho^{m+1}}{1-\rho}$$



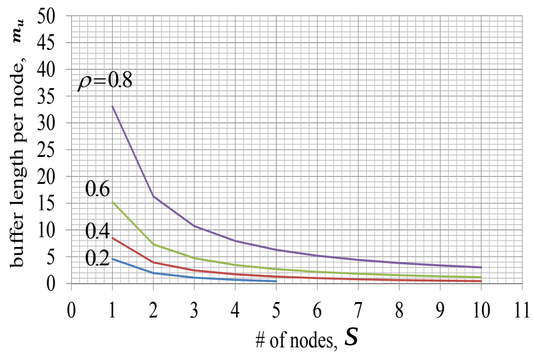
Buffer size reduction

-The integration of buffers can reduce the buffer length per node m_u for a given packet loss B, down to about 1/s by connecting s nodes.

Relationship between buffer size per node and the number of nodes.



(a) $B = 0.001$



(b) $B = 0.0001$

Conclusion

-Proposal of a multi-slice traffic engineering method for optical packet / path integrated networks
-Traffic analysis indicated that bypassing packets via the OCS slice can reduce packet losses or buffer length per node.

Acknowledgement

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References

[1] H. Harai, “Optical Packet & Path Integration for Energy Savings toward New Generation Network,” International Symposium on Applications and the Internet, SAINT 2008, pp.389-392, Jul.-Aug. 2008.
[2] H. Furukawa, T. Miyazawa, K. Fujikawa, N. Wada and H. Harai, "Control-message exchange of lightpath setup over colored optical packet switching in an optical packet and circuit integrated network," IEICE Electronics Express (ELEX), Vol.7, No.14, pp.1079-1085, Jul. 2010.
[3] H. Furukawa, N. Wada, and T. Miyazaki, “640 Gbit/s (64-Wavelength × 10 Gbit/s) Data-Rate Wide-Colored NRZ-DPSK Optical Packet Switching and Buffering Demonstration”, J. Lightw. Technol., vol.28, no.4, pp.336-343, Feb. 2010.