Optical Flow Switching[1]

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Abstract. *Present-day networks are being challenged by dramatic increases in bandwidth demand of emerging applications. We will explore a new transport, "optical flow switching", that will enable significant growth and cost-effective scalability of next-generation data networks.*

Summary

In the early days of the Internet, the most precious resource was long-haul transmission capacity. The electronic packet switching (EPS) architecture was designed to use this resource as efficiently as possible Figure 1. The problem with the EPS architecture, is its scalability: to keep apace with the unfolding exponential growth in data network bandwidth demand. Even electronic processing advancing with Moore's Law will not be able to avert a crisis in electronic-based switching.

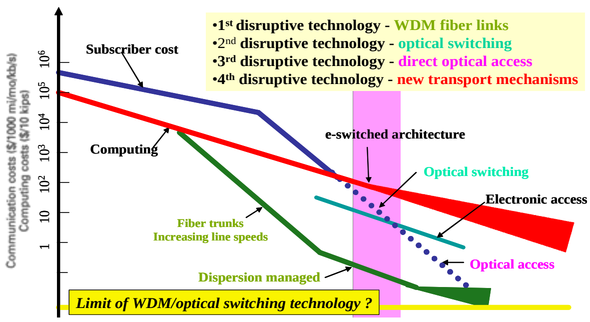

Figure 1. Network cost reductions owing to disruptive optical technologies **Error! Reference source not found.**.

In recent works, we explored the use of an optical network transport mechanism, Optical Flow Switching (OFS), in the quest for lowering network cost by the same order of magnitude as anticipated future increases in data volume per transaction (two to three orders of magnitude). OFS is a scheduled, all-optical, end-to-end service in which connections are established in response to flow-based requests by client-layer IP network schedulers (e.g., routers) for direct access by individual users, Figure 2. To use network resources efficiently, service holding times of wavelength channels are required to be on the order of hundreds of milliseconds or longer. Scheduling of flows with a time horizon of several transactions also help to achieve high network utilization albeit with some queueing delay at the entrance of the network usually in the form of holding the user from transmission until the network is ready for the transaction. However, there are specialized applications that have stringent time deadline and would not like to wait in a queue but will be willing to pay for more expense to use the network. In this paper we will focus on network physical architecture and cost of providing the OFS transport mechanism. We will also explore a fast OFS for stringent time deadline services. This fast flow switching architecture is highly efficient and economical for on-demand high data rates transfers, distributed sensor data ingestion, as well as distributed computing and processing with short time deadlines and bursty, high-volume data transactions.

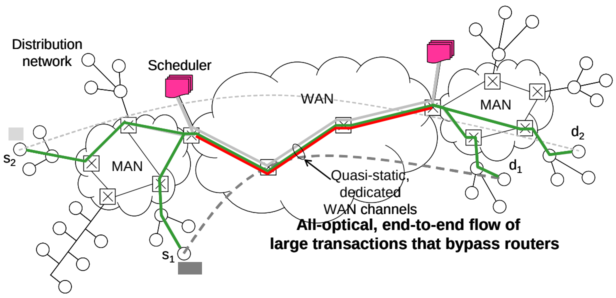

Figure 2. OFS with transparent, end-to-end data flow between users.

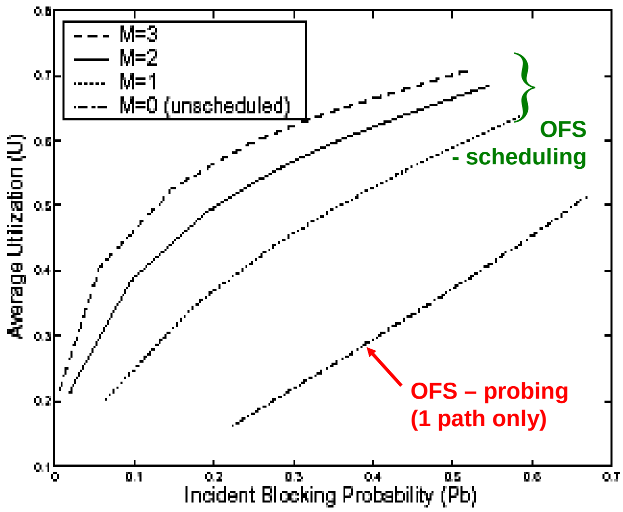

Figure 3. OFS with and without scheduling horizons, [29], showing increased utilization with increasing scheduling horizon (M transactions) for the same blocking probability performance.

[1] The materials of this paper are excerpted from the list of references given below, particularly [1-7, 15-26]

There is a tradeoff among three observable network performance parameters: delay, blocking probability, and wavelength utilization. The key to high utilization of backbone wavelength channels – a precious network resource owing to the necessity of optical amplifiers and dispersion management – is statistical multiplexing of large flows from many users in a scheduled fashion. Thus, high network utilization can be achieved if the users are willing to wait for service according to a schedule (incurring delay) or accept high blocking probability upon request for service. Figure 3 shows the increase in utilization for the same blocking performance as the scheduling horizon increases.

The results of the throughput-cost comparison are given in Figure 4. OFS is the most scalable architecture of all when the average user data rate is high and the number of users in the network is large; EPS is most sensible at low to moderate data rates with a small number of users; the GMPLS architecture, which is conceptually intermediate to EPS and OFS, is optimal at moderate user data rates with a moderate to large number of users; and, finally, there does not exist a regime of optimality for TaG since the low cost of scheduling in OFS yields great performance benefit relative to the otherwise identical TaG architecture.

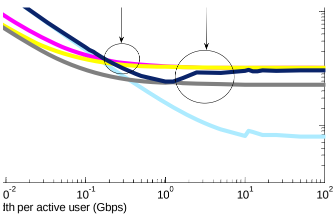

Figure 4. Cost/user/bit as a function of user rates for different transport mechanisms.

Transport mechanisms such as OFS, together with network physical topology design which exploit the strengths of optics to serve large transactions, will likely enable order(s) of magnitude cost reductions. The consequence of such a shift towards optical networking technology is that most architectural elements of networks – from the physical layer to higher layers, as well as network management sn control – must be rethought at the most fundamental level.

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