Optical Packet Switching Meets Mythbusters

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Abstract: Despite twenty years of research, optical packet switching (OPS) struggles to find practical application. We analyze the capabilities and limitations of OPS, and conclude that OPS offers little compared with conventional electronic packet switching.
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The first research papers on optical packet switching (OPS) started appearing in the literature in the late 1980's and the early 1990's. OPS (sometimes called photonic packet switching) aims to emulate electronic packet switching by providing sub-wavelength switching at the packet level using optical rather than electronic switching devices. Since the early 1990's time there has been a steady flow of papers on OPS/PPS. These papers (including a number written by the present author) often include hand-waving introductory comments that attempt to explain why optical packet switching will be needed in future telecommunications networks. Typically, the introductory comments in OPS papers are structured as follows. First, it is pointed out that the amount of traffic on the internet has grown over the years and that this growth shows no sign of abating. This is usually followed by a statement pointing out that the ability of the network to continue to grow to meet the rising demand for more data is threatened by the limitations of today's electronic packet switching technologies. These limitations are commonly identified in terms of (a) energy consumption, (e.g. electronic packet switches are power-hungry), and (b) capacity (e.g. electronic packet switches are limited in capacity by slow and inefficient optical-to-electronic and electronic-to-optical converters, electronics is slow compared to optics, and so on). Finally it is usually asserted that optical packet switching is a promising or attractive solution to these speed and/or energy consumption problems and that optical packet switching offers advantages because of its so-called transparency, i.e. its ability to handle data with different modulation formats and data rates.

Looking back at the OPS literature over the past twenty years, it becomes clear that the introductory comments in OPS papers have not changed very much. The only significant difference is that in recent years there has been an increasing awareness of the importance of energy consumption and an increase in the number of accusations that state-of-the-art electronic packet switches are "power-hungry". After twenty years, many of the claims used to justify research in OPS remain untested and unverified. In fact many papers on optical packet switching do not make any contribution to resolving the key issues of energy consumption, capacity limits and scalability. Rather, they tend to describe new switch architectures, new devices that provide some advantage, or new limited-scale test-bed demonstrations. The data presented in these papers is generally confined to topics such as blocking probabilities, bit-error-rate curves and other issues. The centrally important topics of power consumption, throughput and scalability are often ignored.

After twenty years of research, OPS technology appears to be no closer to widespread commercial implementation than it ever was. To gain some insights as to whether OPS will ever become a reality, it is necessary to carefully analyze some of the claims that have been used in the past to highlight the promise of optical packet switching and to justify research on OPS. The purpose of this paper is to quantify some of the capabilities and limitations of optical packet switches and to make a realistic comparison of these capabilities and limitations with the capabilities and limitations of electronic packet switches. We consider in detail the energy consumption, throughput capabilities and the scalability properties of a number of OPS switch fabric technologies and compare these with the corresponding properties of state-of-the-art electronic switch fabrics. In particular, we consider arrayed-waveguide grating-based switches, semiconductor optical amplifier gate arrays, and electro-optic switches. The analysis takes into account the key contributors to energy consumption in each technology and the throughput capabilities of each technology. The analysis also takes into account the optical-to-electronic and electronic-to-optical converters required in electronic packet switches as well as the multiplexers and demultiplexers needed in electronic packet switches to bring the bit rate down to speeds that can be handled in the switch fabric. For reasons of limited time and space, we do not consider buffer technologies.

The key conclusion of this paper is that OPS offers little advantage over conventional electronic packet switching. Our analysis shows that OPS faces significant challenges if it is ever to become competitive with electronic packet switching. Without one or more major breakthroughs in optical technology, OPS is likely to remain little more than a research curiosity.