Will optical communications meet the challenges of the future demands?

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The global optical network has increased its transmission capacity by a factor of 200 over the last two decades, but to meet the exponentially growing traffic demand, the capacity has to be increased about a thousand-fold over next two. Is this achievable? This presentation will analyze the fundamental limitations of the current optical-communications technology and consider possible future developments.

A network's transmission capacity is defined by (1) the network's demand for bandwidth, determined by its architecture and protocols, and (2) transmission speed, determined by the capability of the ensemble of all the physical components of the network to transmit traffic at the required rate. Developments in the logical (intelligent) networking will eventually result in a decrease in the traffic burden, but they fall outside our scope. Here we will concentrate on the physical layer of the optical network, which will have to contribute the largest portion of the transmission capacity's future growth.

At the physical layer, the transmission capacity is determined by the capacity of both the links (optical fibers) and the nodes. The theoretical limit of the transmission bandwidth of optical fiber is about 100 Tb/s at a typical long-distance span, and commercial links recently have reached 26 Tb/s. Another important figure of merit is spectral efficiency (SE). While its theoretical limit is about 9 b/s/Hz, this parameter has increased from ~0.1 b/s/Hz to ~8 b/s/Hz recently. Thus, optical fiber is approaching its theoretical limits. Though some new developments in the construction of optical transmission links have been suggested (multicore silica optical fiber being the most practical), millions of km of installed modern silica fiber will probably stay in place for another two decades; hence, economic reality suggests that the main progress should be expected and attained in the capability of the nodes.

The nodes of modern optical communications can be broken down into two categories: transmission nodes and switching nodes. The role of nodes in expanding the capabilities of the optical network can best be demonstrated by reference to the immediate past. During the 1990's, the growth in the transmission capacity of the optical network was achieved mainly through wavelength-division multiplexing (WDM) enabled by optical amplifiers. Over the last decade, we saw a bandwidth rise from 1 Gb/s to 100 Gb/s thanks mainly to coherent communications that relies on sophisticated modulation formats in conjunction with digital signal processing (DSP) of the received signal. All these advances relied on great progress in the electronic and photonic components of the optical networks, that is, the components residing in the nodes.

We will discuss the limitations and future developments of the node equipment that perform such tasks as supporting the various modulation formats, forward error correction, coherent communications, DSP, and switching and routing. We will, of course, consider technology of these nodes, such as silicon photonics and photonic ICs, again focusing on future trends and limitations of these circuits, devices and systems.

Finally, we will consider some technologies emerging from research laboratories that would break from the current approach to optical communications. Specifically, we will consider quantum (single-photon) communications and the application of plasmonics, which promises to bring nanophotonics into the optical-communication technology.

An analysis of the problems of modern optical communications and projections of potential solutions to these problems should stimulate future research and development in both the optical and electronic fields to the mutual benefits of both industries in the years to come.