Innovations in optical communications are expected to transform the landscape of global communications; internet and datacenter networks. This dissertation investigates several important issues in optical communication such as fairness, throughput, blocking probability and differentiated quality of service (QoS). Novel algorithms and new approaches have been presented to improve the performance of optical circuit switching (OCS) and optical burst switching (OBS) for long haul and short reach datacenter optical networks.

In the first contribution, two new schemes are proposed for long haul networks to improve throughput and hop count fairness in OBS networks. The idea is motivated by the observation that providing a slightly more priority to longer bursts over short bursts can significantly improve the throughput of the OBS networks without adversely affecting hop-count fairness. The results of extensive performance tests have shown that the proposed schemes improve the throughput of optical OBS networks and enhance the hop-count fairness.

The second contribution presents two routing and wavelength assignment schemes in multimode fiber networks for long haul networks. First scheme is aimed at alleviating the hop count fairness problem in OBS networks using wavelength-division multiplexing as well as mode division multiplexing without affecting system throughput while the second scheme aims at achieving higher throughput as well as improving hop count unfairness.

The third contribution attempts to optimize the bandwidth and maximize the throughput of datacenter networks. An extension of TCP called multipath-TCP (MPTCP) has been evaluated over an OBS network in densely interconnects datacenter topologies and a significant performance gain has been established in throughput and reliability.

In the fourth contribution, a service differentiation scheme using MPTCP over OBS for datacenter traffic is developed. The scheme is evaluated over mixed workload traffic model of datacenters and is shown to provide tangible service differentiation between flows of different priority levels.

The fifth contribution proposed an adaptive QoS differentiation architecture for software defined optical datacenter networks using MPTCP over OBS. This scheme prioritizes flows based on the current network state through an SDN controller.

The extensive simulations tests conducted to evaluate the above proposed schemes have demonstrated the effectiveness of these schemes and revealed the significant performance gain they achieved. These simulation tests were performed over a number of network topologies such as ring, mesh and U.S. Long-Haul, some high processing computing (HPC) topologies such as 2D and 6D mesh torus topologies and modern datacenter topologies such as FatTree and BCube.

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