Optical networking, employing wavelength division multiplexing (WDM), is seen as the technology of the future for the Internet. This dissertation presents novel algorithms and new approaches to improve the performance of optical circuit switching (OCS) and optical burst switching (OBS) networks. Extensive simulations and analytical modeling are both used to evaluate the effectiveness of the proposed algorithms. The simulation tests were performed over a variety of optical network topologies including the ring and mesh topologies, the NSF-Net topology, the U.S. Long-Haul topology, the Abilene high-speed optical network used in Internet 2, the Toronto Metropolitan topology and the European Optical topology.

Optical routing protocols previously published in the literature have largely ignored the noise and timing jitter accumulation caused by cascading several wavelength conversions along the light-path of the data burst. This dissertation has identified and evaluated a new constraint, called the wavelength conversion cascading constraint. Extensive simulation results have conclusively demonstrated that the presence of this constraint causes significant performance deterioration in existing routing and wavelength assignment (RWA) algorithms. Two constraint-aware routing algorithms are proposed for OCS networks. The two algorithms perform source routing using link connectivity and the global state information of each wavelength. Effective proactive routing and preemptive channel scheduling have also been proposed to address the cascading constraint in OBS environments. Extensive comparative simulation results have illustrated that by limiting the negative cascading impact to the minimum extent practicable, the proposed approaches can dramatically decrease the blocking probability and improve the transmission fairness among bursts with different hop counts. The dissertation has also developed a suite of three fairness-improving adaptive routing algorithms in OBS networks. The adaptive routing schemes reduce the overall burst loss probability and resolve the intrinsic unfairness defect of existing popular signaling protocols. The extensive simulation results have shown that the proposed schemes generally outperform the popular shortest path routing algorithm and the improvement could be substantial. A two-dimensional Markov chain analytical model has been developed and used to analyze the burst loss probabilities for symmetrical ring networks. The accuracy of the model has been validated by simulation.

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