Abstract

Wavelength Division Multiplexed (WDM) optical networks are increasingly being deployed to support the future broadband communication networks. One of the important concerns facing the network operators is to minimize their Total Cost of Ownership (TCO). The best way to achieve this is by managing the resources efficiently and effectively. In our work, we classify the Resource Management (RM) issues confronting WDM backbone service providers into following two main categories:

1. RM at Fiber Level (FL), and
2. RM at Central Office (CO)

Though a considerable amount of work has been done to manage resources at FL, very few works have focused on minimizing the Capital Expenditure (CAPEX) considering the overall cost of electronic components such as Add/Drop Multiplexers (ADMs) and Cross Connects. One of the fundamental design problems for WDM networks is Wavelength Assignment (WA). For setting up several lightpaths that share a fiber, the bandwidth of the fiber needs to be partitioned into several channels. In each channel, the allotted bandwidth can be used at a unique wavelength which can be shared by many non-overlapping lightpaths. WA problem can be defined as an assignment of wavelengths to the lightpaths satisfying the wavelength continuity constraint with an objective of minimizing the number of wavelengths required. But, according to the latest Federal Communications Committee (FCC) report, only 42% of the fibers deployed are being currently lit. In a WDM ring supporting multiple Synchronous Optical Network (SONET) rings, SONET ADMs are needed to terminate lightpaths. Every lightpath requires two ADMs, one at each end of the lightpath. Cost of an ADM lies between $100,000 and $500,000. This has necessitated the need for WA algorithms with the objective to minimize ADMs rather than wavelengths. This WA problem has been conventionally formulated as a set covering problem. We have proposed two novel state spaces for it and solved it optimally using two algorithms, namely Uninformed Best First Search (UBFS) and A*. We have also proposed two heuristics, H-I and H-II, for solving small sized problems (upto 75 lightpaths). We have also suggested an order

independent version of Breadth First Least Interference (BFLI) heuristic to overcome the input order dependency problem of the original BFLI algorithm.

Routing is an important part of the WA problem and we show how routing can help service providers in saving ADMs. We formulate Routing and Wavelength Assignment (RWA) as a set covering problem and solve it for four different types of routing, namely Clockwise, Anti-clockwise, Shortest Path and Hybrid. We propose two novel techniques, namely M3AIW (Minimum Average Minimum Intersection Minimum Weight) and M3AWI (Minimum Average Minimum Weight Minimum Intersection), to solve the problem. The experimental results suggest that M3AWI and M3AIW, under Shortest Path routing and Hybrid routing, on an average, saves 12% in the number of ADMs when compared to the Clockwise and Anti-Clockwise routing techniques. A proper routing strategy can save up to 30% in the number of ADMs which can immediately reduce the CAPEX by a few million dollars for ring networks of bigger sizes (Ring size N=32,40).

RM at CO is a growing phenomenon where not much work has been done. It is believed that the Operating Expenses (OPEX) in COs contribute a significant part of TCO that operators face. Switching load optimization is a crucial problem in COs where trunks with common traffic are clustered to a single switch so that traffic flow between the switches is minimal. We call this Trunk to Switch Assignment (TSA) problem. We have formulated TSA as a set partitioning problem and proposed a state space search formulation along with a heuristic (H-III) for TSA. We have used two heuristic search techniques, namely Iterative Deepening A* (IDA*) and Block Depth First Search (BDFS), to solve this problem. BDFS is found to outperform IDA* on various performance metrics, such as nodes generated, nodes expanded and execution time, for various trunk sizes and traffic flows. An important issue in this context is the need for real-time decision making by service providers is increasingly being felt during the post-deployment stage. The main concern is to make minimal changes to the existing configurations and get maximum Return on Investment (ROI). Thus, a real-time version of BDFS is proposed to make optimal changes to the existing networks under user

defined time constraints. The suggested technique is able to give an optimal solution in almost 50% of the time, for most the problem instances.

In summary, the thesis has attempted to solve two important problems facing the WDM backbone service providers. The main strength of the thesis, however, lies in its potential in applying the suggested techniques to solve broader range of problems in WDM network design and planning. We hope that our results will encourage others to consider using heuristic search techniques to develop practical solutions to other industrial problems too.