Chapter 10
Wavelength and Routing Assignment in All Optical Networks Using Ant Colony Optimization

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ABSTRACT
Routing and Wavelength Assignment (RWA) in an arbitrary mesh network is an NP-complete problem. So far, this problem has been solved by linear programming for network topologies with a few nodes, and sub-optimally solved for larger networks by heuristic strategies and the application of optimization algorithms such as Genetic Algorithms (GA), Particle Swarm Optimization (PSO), Differential Evolution (DE), etc. In this chapter, the authors present the use of Ant Colony Optimization (ACO) to find near optimal solutions to the routing and wavelength assignment problem in real sized networks with up to 40 nodes and 65 connecting links. They compare their results to the lower bounds obtained by the Nagatsu’s method, finding them to be equal or very close (one wavelength over) to them.

INTRODUCTION
Optical networks using Dense Wavelength Division Multiplexing (DWDM) technology are the ideal candidates to handle the problem of the ever-increasing growth of traffic and demand for bandwidth. DWDM systems are popular with telecommunication companies because they allow them to expand their network’s capacity without laying out additional fiber. By using DWDM and optical amplifiers, companies can accommodate several generations of technology developments in their optical infrastructure without having to overhaul the backbone network. Worldwide net-
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working and communication systems and applications use high-speed optical transport networks as appropriate backbones for connecting buildings, cities and countries such as PAN EUROPEAN, NSFNET and COST optical networks (Kavian et al., 2012) and (Ramaswami and Sivarajan, 2009).

To send data from one access node to another in a DWDM network, one needs to establish a connection in the optical layer similar to the one in a circuit-switched network. This can be done determining a path in the network between the two nodes and allocating a free wavelength on all the links on the path. Such an all-optical path is commonly referred to as a lightpath and may span multiple fiber links without any intermediate electronic processing, while using one WDM channel per link. The entire bandwidth on the lightpath is reserved for this connection until it is terminated, at which time the associated wavelengths become available on all the links along the route. It is thus important to provide routes to the lightpath requests and to assign wavelengths on each of the links along this route among all the possible choices so as to optimize a certain performance metric. This is known as the Routing and Wavelength Assignment (RWA) problem. The wavelengths assigned must be such that no two lightpaths that share a physical link use the same wavelength on that link. The RWA problem is well known to be an NP-complete problem (Chlamtac et al., 1992), and the number of approaches proposed in the literature to obtain sub-optimal solutions can assess its importance. So far this problem has been analyzed by heuristic strategies and the application of optimization algorithms such as Genetic Algorithms (GA), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), etc. In (Banerjee and Mukherjee, 1996) a large RWA problem is partitioned into several smaller sub-problems, each of which may be solved independently and efficiently using well-known approximation techniques. In (Navarro and Sinclair, 1999) ACO is used to analyze the RWA problem, considering wavelength conversion. (Somani and Azizoglu, 2000) addresses the wavelength assignment issues in interconnecting optical Local Area Networks (LANs) in which a wavelength cannot be reused for local connections. In (Banerjee and Sharan, 2004) a formulation of the static RWA problem in optical networks as a single objective optimization problem is presented and solved in a novel way using a genetic algorithm. Similar to it, (Rao and Anand, 2006) presents the use of a PSO algorithm to obtain near-optimal solutions to the NP-complete RWA problem in optical networks, without a wavelength conversion capability. In (Hassan and Phillips, 2008) a heuristic approach inspired by PSO is proposed for solving the static RWA problem and a new encoding scheme for members of the swarm population is proposed. The results from (Hassan and Phillips, 2008) are compared to those from (Rao and Anand, 2006) and (Banerjee and Sharan, 2004) showing an improvement both in terms of the number of iterations required and in the Average Path...