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Solving ring loading problems using bio-inspired algorithms

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ABSTRACT

In the last years, several combinatorial optimisation problems have arisen in the communication networks field. In many cases, to solve these problems it is necessary the use of emergent optimisation algorithms. The Weighted Ring Loading Problem (WRLP) is an important optimisation problem in the communication optical network field. When managed properly, the ring networks are uniquely suited to deliver a large amount of bandwidth in a reliable and inexpensive way. An optimal load balancing is very important, as it increases the system's capacity and improves the overall ring performance. The WRLP consists on the design, in a communication network of a transmission route (direct path) for each request, such that high load on the arcs/edges is avoided, where an arc is an edge endowed with a direction. In this paper we study this problem in two different ring types: Synchronous Optical NETworking (SONET) rings and Resilient Packet Ring (RPR). In RPR the purpose is to minimise the maximum load on the ring Arcs (WRALP). In SONET rings the purpose is to minimise the maximum load on the ring Edges (WRELP). The load of an arc is defined as the total weight of those requests that are routed through the arc in its direction and the load of an edge is the total weight of the routes traversing the edge in either direction. In this paper we study both problems without demand splitting and we propose three bio-inspired algorithms: Genetic Algorithm with multiple operators, Hybrid Differential Evolution with a multiple strategy and Hybrid Discrete Particle Swarm Optimisation. We also perform comparisons with other algorithms from literature. Simulation results verify the effectiveness of the proposed algorithms.

1. Introduction

Nowadays Synchronous Optical NETworking (SONET) rings are widely used in telecommunications. In a SONET ring, nodes (typically telephone central offices) are connected among them by a ring of fiber. Nodes send, receive and relay messages by means of a device called an Add-Drop-Multiplexer (ADM) that determines the actual bandwidth available along any edge of the SONET ring (Goralski, 2002). An important optimisation problem arising in this context is the Weighted Ring Edge-Loading Problem (WRELP). Given a network and a set of communication requests, a fundamental problem is to design a transmission route (direct path) for each request such that the high load on the edges will be avoided. The load of an edge is the number of routes traversing the edge in either direction. In general each request is associated with a non-negative integer weight, and the load of an edge is defined as the total weight of those requests that are routed through the edge in both directions. The weight of a request can be interpreted as a traffic demand or the size of the data to be transmitted (Bernardino et al., 2008, 2009a; Cosares and Saniee, 1994; Dell'Amico et al., 1999; Goldschmidt et al., 2003; Karunanithi and Carpenter, 1994; Lee and Chang, 1997; Myung et al., 1997; Myung and Kim, 2004; Schrijver et al., 1998; van Hoesel, 2005; Wang, 2005).

Resilient Packet Ring (RPR), also known as IEEE 802.17, is a standard, designed to optimise the transport of data traffic through optical fiber ring networks (Davik et al., 2004; RPR Alliance, 2004; Yuan et al., 2004). The RPR aims to combine the appealing functionalities of Synchronous Optical Network/Synchronous Digital Hierarchy (SONET/SDH) networks with the advantages of Ethernet networks.

The load balancing model for RPR differs from the SONET ring loading in a number of significant aspects. Namely, SONET demands are bidirectional and demands assigned to go clockwise compete for common span capacity with the demands assigned to go counter-clockwise. In RPR two distinct rings occur (clockwise and counter-clockwise) and the demands do not compete for the common capacity. In SONET the demands are "circuit-switched", and deterministic, while the RPR is based on "packet" stream technology with Multi Protocol Label Switching (MPLS) like "tunnels", statistical multiplexing and different level of service.

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