Evolutionary Algorithms for Optical Network Design: A Genetic-algorithm/Heuristic Hybrid Approach

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Summary

Multi-wavelength all-optical transport networks can potentially provide the huge bandwidths necessary for broadband services. However, they present a challenging range of difficult network design and optimisation problems. Recently, evolutionary algorithms (EAs) have attracted growing interest for use on similar complex problems in many fields, including telecommunications. However, while EAs are good general-purpose search and optimisation procedures, they are almost never the best approach for any specific problem. A powerful alternative is the development of problem-specific EAs—genetic-algorithm (GA)/heuristic hybrids. These employ both problem-specific encoding and operators, combining the best existing heuristics for the problem within an overall GA framework. Moreover, operator-probability adaptation is used so that the most appropriate blend of operators is applied at each stage in a run.

This thesis describes the application of GA/heuristic hybrids to two of the main problems in the design of multi-wavelength all-optical transport networks: mesh network topology design, and wavelength-path routing, fibre choice and wavelength allocation. It starts with an overview of EAs, a tutorial on GAs, a near-exhaustive survey of evolutionary telecommunications, and surveys of both GA/heuristic hybrids and operator-probability adaptation. A software toolset for optical network optimisation, modelling and design (NOMaD), implementing the author's GA/heuristic hybrid approach, is described, including the design-assessment metrics, overall GA framework, genetic operators and the operator-probability adaptation mechanism. Experimental results for both mesh network topology design, and wavelength-path routing, fibre and wavelength allocation are reported. An investigation into NOMaD's operator-probability adaptation mechanism is described. Finally, the successes and limitations of the research are discussed, and numerous suggestions for further work made. Overall, the hybrid approach is shown to provide excellent solutions, of comparable or higher quality than those obtained with either heuristics or simple GAs alone, and requiring less computational effort than GAs.

Contents

Abbreviations

ACO	ant colony optimisation
ACTS	Advanced Communications Technologies and Services
ADM	add drop multiplexer
BON	Business Object Notation
CS	classifier system
DCR	different common ring
DNA	deoxyribose nucleic acid
DQDB	Dual Queue Dual Bus MAN (IEEE 802.6)
EA	evolutionary algorithm
EC	evolutionary computation
EH	evolutionary hardware
EON	European Optical Network
EP	evolutionary programming
ES	evolution strategy
FSM	finite state machine
FTEL	Fujitsu Telecommunications Europe Ltd.
GA	genetic algorithm
GP	genetic programming
GUI	graphical user interface
id	identification number
LAN	local area network
LCS	learning classifier system
MAN	metropolitan area network
MCA	microcanonical annealing

NGOS	network grade-of-service
NOMaD	optical network optimisation, modelling and design
NP	non-polynomial
NWR	network wavelength requirement
OOA&D	object-oriented analysis and design
OPEN	Optical Pan-European Network
OXC	optical cross connect
PON	passive optical network
RCA	random cost algorithm
SA	simulated annealing
SGA	Goldberg's Simple Genetic Algorithm
SWP	sparse wavelength path
TS	tabu search
TSP	travelling salesman problem
VWP	virtual wavelength path
WOTAN	Wavelength-agile Optical Transport and Access Network
WP	wavelength path

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Give thanks to the LORD, *for he is good;*
his love endures for ever.

Psalm 107:1, NIV

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