Towards an Agent-based Distributed Hierarchical Network Management System for All-Optical Networks

Bilal Khan* Dardo D. Kleiner† David Talmage*
Center for Computational Science, Naval Research Laboratory, Washington D.C.
http://www.nrl.navy.mil/ccs/project/public/DC/web/
{bilal,dkleiner,talmage}@cmf.nrl.navy.mil

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Abstract— **We describe the design and implementation of Optiprism, an agent-based network management system (NMS) providing configuration and fault management services for all-optical networks. Optiprism provides support for**

1) **a scalable architecture consisting of a distributed hierarchy of intelligent mobile software agents, or managers,**
2) **the ability to adapt as the network evolves by adding, removing or upgrading managers and restructuring the hierarchy,**
3) **manager mobility services permitting reorganization of physical deployment for better responsiveness,**
4) **an innovative browser agent which provides a scalable solution to the problem of end-user interaction with a large distributed NMS.**

Optiprism has been developed and tested on the Multi-wavelength Optical Network (MONET) switches of the Advanced Technology Demonstration Network.

I. Introduction

Traditionally, network management software has been based on centralized paradigms using on SNMPv1 or SNMPv2c, or weakly distributed hierarchical paradigms using SNMPv2, RMON, CMIP, or CMIP derivatives such as TMN [24, p. 5]. While these approaches are feasible in small networks, their communication costs grow linearly with the number of devices [31, p. 4]. In many such architectures, as network size and complexity grows, the manager's workstation becomes burdened with resource intensive *micromanagement* operations [5, p. 2]. Wavelength division multiplexing (WDM) networks present additional difficulties since the central problem of routing and wavelength assignment (RWA) [30] is NP-complete [35] and even heuristic approaches to it are computationally expensive [6, p. 2].

An effective optical NMS must thus address the core problem of scalability. We contend that a *strongly distributed* deployment of a hierarchy of *cooperating* intelligent mobile agents [24, p. 9] or *managers* would yield significantly reduced processing requirements at the client-side.

∗ Advanced Engineering & Sciences, ITT Industries.
† Computer Integration & Programming Solutions, Corp.

The architecture of our NMS is inspired by theories of organizational hierarchies, as developed in the works of J. R. Galbraith [16], Mount and Reiter [26], Radner [29], Patrick and Dewatripont [27] and others. We draw upon the compelling analogies comparing distributed computer systems with distributed human organizations, as presented by Fox [15], et al. In particular, our NMS employs the idea of vertical integration within a hierarchy of managers: state information is condensed and flows recursively upwards at each level of the heirarchy to facilitate the analysis of state and the making of decisions. This process can result in actions which are executed by a recursive downward flow of subtasks to subordinates. Within the NMS, managers maintain aggregated information such as route availability and fault reports about recursively smaller sections of the network. The two flows facilitate both decentralized decision-making and decentralized information processing, respectively, in a manner described by Van Zandt [34, pp. 1]. Because the network's state is hierarchically distributed, management applications do not need to establish direct connections to every network element. Instead, the administrator interacts with high-level supervisory managers. We draw on Galbraith's mechanistic model of organizational design theory, incorporating the strategy of permitting *lateral relationships* between managers across groups. This model of planning achieves integrated action and reduces the need of continuous communication between interdependent sub-units. Within the NMS, control operations, such as lightpath provisioning, are issued to the high-level managers, who then compute routes and delegate partitioned connection requests to their subordinate managers. Monitoring of alarms and alerts operates in the reverse direction: subordinate managers report fault conditions to their supervisor. Depending on the task, the management application communicates with some subset of the managers to monitor and manipulate the network. The next sections describe the design and implementation of the Optiprism network management system.

II. Design

In designing Optiprism, we adopted a distributed architecture because it enabled us to meet four important objectives. The most critical of these is *scalability*. In large networks, the processing of management requests (e.g. route selection, alarm filtering) presents computational burdens that would ultimately

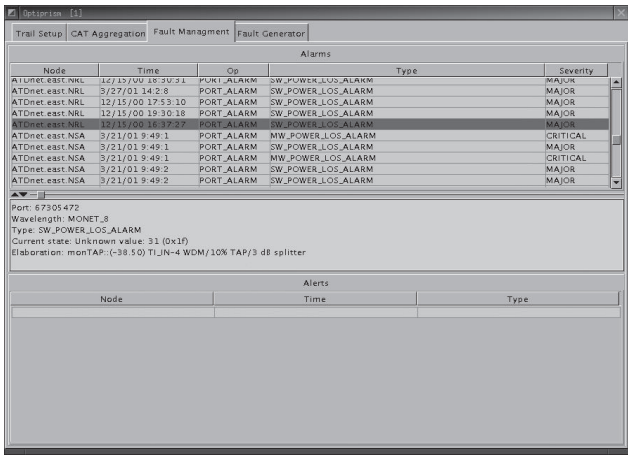

Fig. 10. Fault management dialog.

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