OPTIPRISM: A Hierarchical Distributed Network Management System for All-Optical Networks

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***Index Terms*— Network management, optical network, multi-agent system.**

***Abstract*— This paper describes the design and implementation of Optiprism, an agent-based network management system (NMS) providing configuration and fault management services for all-optical networks. Optiprism is designed to support (1) a scalable architecture consisting of a distributed hierarchy of software agents, or managers (2) the ability to alter the hierarchy as the network evolves by adding, removing or upgrading managers (3) reorganization of physical deployment for better responsiveness (4) an innovative browser agent providing scalable end-user interaction with the distributed NMS.**

I. Introduction

Traditional network management software implementations have used centralized paradigms based on SNMPv1 or SNMPv2c, or weakly distributed hierarchical paradigms based on SNMPv2, RMON, CMIP, or CMIP derivatives such as TMN [15, p. 5]. While these approaches are feasible in small networks, their communication costs grow linearly with the number of devices [19, p. 4]. Wavelength division multiplexing (WDM) networks present additional difficulties since the central problem of routing and wavelength assignment (RWA) [18] is NP-complete [20] and even heuristic approaches to it are computationally expensive [4, 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 agents [15, p. 9] or "managers" would yield significantly reduced processing requirements at the client-side. These managers would maintain aggregated information such as route availability and fault reports about recursively smaller sections of the network. Moreover, if the network's state was hierarchically distributed, then management applications would not need to establish direct connections to every network element. Instead, the administrator would interact with high-level supervisory managers. Control operations (e.g. lightpath provisioning and teardown) would be issued to these high-level managers, which would compute routes and delegate partitioned connection requests to their subordinate managers. Monitoring of alarms and alerts would operate in the reverse direction: subordinate managers would report fault conditions to their supervisor. A management application would only need to communicate with high-level supervisors in order to manipulate and monitor the optical network. The next sections describe the design and implementation of such a network management system.

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II. Design

In designing Optiprism, we adopted a distributed architecture because it enabled us to meet four important objectives. The most critical is *scalability*. In large networks, the processing of management requests (e.g. route selection) presents computational burdens that would ultimately choke a centralized NMS. In contrast, a distributed architecture can amortize this computational overhead against a set of processes distributed throughout the computational environment [10, p. 1]. Second, a distributed architecture is *maintainable* because it is easier to augment as the network grows. Third, a distributed architecture permits computations to be closer to information sources, reducing latency and total control traffic [7] [12], thereby yielding better *responsiveness*. This benefit is amplified if the architecture supports dynamic re-distribution of managers, since then the NMS can adapt to circumvent computation and communication hot-spots in its environment [11, p. 32]. Finally, adopting a distributed architecture makes it possible to develop end-user management applications which exhibit *scalable interaction*, i.e. applications that interact with only a scalable subset of the NMS at a given time. We now describe how the design of Optiprism strives to meet these objectives.

A. Scalability

An effective optical NMS must able to coordinate the control planes of hundreds of optical switches. This objective led to the choice of a hierarchical architecture. In Optiprism, each manager can be a *supervisor*, composed of several *subordinate* managers. Conversely, each manager—with the exception of a unique "root"—is subordinate to some supervisor. In a supervisory role, each manager provides an interface to the services it can implement using the functionality of its subordinates. Two managers are called *peers* if they have the same supervisor.

Complications arising from this design choice include: (i) higher level managers may experience greater load and (ii) failures at higher levels may have non-local negative side-effects on the NMS. Presently these concerns are addressed by assigning high-level managers to more reliable machines that have larger memory and processing power. We are investigating the possibility of addressing both issues through replication and clustering of managers.

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