Minimizing Communication Costs in Hierarchical Multi-Agent Systems

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ABSTRACT- In this paper, we consider several mathematical and algorithmic problems which arise naturally in the context of optimizing the performance of a network management system (NMS) whose architecture consists of a *distributed hierarchy* of cooperating intelligent agents.

Key Words: Distributed Hierarchy, Network Management, Multi-agent System.

1 Introduction

A network management system (NMS) must be able to coordinate thousands of network devices, and *scale* to perform well as the number of devices increases. To achieve this goal, the designers of the Optiprism [4] NMS drew upon the compelling analogies between scalable distributed computer systems and distributed human organizations, as presented by Fox [2] and others. Indeed, the architecture of Optiprism has its roots in the theory of human organizational hierarchies, as developed in the works of J. R. Galbraith [3], Mount and Reiter [5], Radner [7], Patrick and Dewatripont [6].

The Optiprism NMS is a hierarchy of (software) *managers*, each of which may act as a *supervisor* of several *subordinate* managers. State information about the network is aggregated and flows recursively upwards at each node of the hierarchy, facilitating decisions and actions which are then executed by recursive delegation of subtasks to subordinates [1, pp. 12]. In this way, decentralized information processing facilitates decentralized decision-making [8, pp. 1].

In most NMS' the human network administrator interacts with the management system using a *browser* application. For scalability, however, such a browser should not communicate with *all* of the NMS' managers at any point in time. In Optiprism, the browser application is itself a leaf node in the management hierarchy. The browser acts as "consultant", changing its position within the hierarchy, and—following Galbraith's mechanistic

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In each of these cases one can show that $C_*(t', V, U, g) \leqslant C_*(t, V, U, g)$, hence the function f minimizes C_* for the VISIBILITY-GRADED local cost function. □

6 Conclusion

In this paper, we have developed algorithms for distributing a hierarchy of network management agents in a manner which minimizes the network communication required between browsers and managers. We showed that for three different natural local cost functions, it is possible to compute a globally optimal assignment. In this work, we considered the NMS agents to be distributed across a network of machines modelled as a complete graph, and charged unit cost for communication between any two distinct machines.

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