A Self-Management Framework for Efficient Resource Discovery in Pervasive Environments

Abstract
When considering resource discovery in pervasive environments, issues such as the diversity of application requirements, different classes of Quality of Service (QoS), device and network heterogeneity should be addressed. In these cases, static solutions prove to be ineffective since the desired characteristics of resource discovery mechanisms are constantly changing. To alleviate such problems, a promising direction involves self-management approaches that allow for adaptation of the monitoring mechanisms and their automatic reconfiguration. Accordingly, we present our ongoing work on a context-aware, policy-based framework to support the autonomic management of pervasive environments’ monitoring mechanisms that rely on dynamic, bio-inspired P2P overlays.

Categories and Subject Descriptors
C.2.3 [Network Operations]: Network Management; C.2.4 [Network Operations]: Distributed systems

General Terms
Management, Performance, Algorithms, Experimentation

Keywords
Resource Discovery, Overlay Networks, Autonomic Network Management

1. INTRODUCTION
An integral part of every pervasive environment is its resource discovery mechanisms, namely the ability to efficiently locate and retrieve resources, e.g. information or device profiles. Most relevant approaches rely on overlay structures that are built on top of underlying networks in order to abstract their complexity and maintain topologies with desired characteristics, such as compliance to QoS properties or support for semantics. In our work, resource discovery is possible by means of a self-organized, multi-layer bio-inspired overlay [1]; ant-like agents roam the network collecting and disseminating connectivity and neighborhood information and thus assist in creating and managing overlay topologies optimized in terms of different metrics.

However, pervasive environments are built on top of networks that are characterized by heterogeneity, dynamicity, ad hoc or mesh connectivity and lack of centralized management. Their increasing popularity despite these adverse features relies on the provision of context-aware, user-friendly, personalized applications and services to users. Nonetheless, their inherent dynamic nature and the constantly changing user and application requirements both diminish the proper operation and performance of such environments. In this respect, adaptive mechanisms emerge as a necessity in order to address the evolving needs and the variety of QoS features and metrics that are expected to be satisfied [2, 3].

We present here our ongoing work on a self-management framework for the adaptive and optimal reconfiguration of the aforementioned bio-inspired resource discovery mechanisms. The framework considers context information from the network and the applications and based on policies automatically triggers the appropriate adaptation of the overlay structures to ensure the satisfaction of particular goals, e.g. increased robustness or higher responsiveness. We conducted experiments that validate the effectiveness of our approach to adapt to evolving dynamic situations.

The remaining of this paper describes the architecture of the proposed self-management framework in Section 2 along with a brief evaluation of its practical aspects, while Section 3 concludes the paper and gives insight to our future work.

2. SELF-MANAGEMENT FRAMEWORK
Figure 1 illustrates the architecture of the self-management framework to enable the adaptation of resource discovery mechanisms that operate on top of the multi-layer overlay structures that are constructed by our ant-inspired algorithms. Our focus is on pervasive environments, which are built on wireless mesh networks. The architecture is modular and comprised of a series of components. Every node of the network will carry an instance of this architecture and hence support its functionality.

The first layer of our modular architecture refers to resource discovery. Pervasive applications issue their requests for resources to the Query Handler component that receives requests and their associated quality preferences (e.g. minimum response delay) and responds back with the results when they have been resolved. The Query Processor stores queries locally in the Query Repository for caching and log-
ging, while its main functionality involves translating the high-level requests to low-level resource requests that can be executed directly on the overlay. The latter are passed to the Information Discovery component that executes the resource discovery algorithm that we have presented in our previous work [1].

The network management layer of the architecture is responsible for adapting the overlay operation in order to optimize it according to the quality metrics expressed in the resource discovery queries. To benefit from its flexibility and extensibility, policy-based management making use of context information is the foundation of this layer. In this respect, standard components of policy-based management are utilized, namely the Policy Repository that stores the policies, the Policy Decision Point that monitors context information and conditions expressed as quality requirements and the Policy Enforcement Point that executes the necessary policy-driven configuration actions locally on every node. The translation between high-level policies and low-level overlay configuration commands is the responsibility of the Adaptation Engine. Information regarding the status of the overlay is collected by the Data Collection component by communicating with the Network Monitor component, which keeps track of the dynamically evolving overlays and the currently executing queries. By adding semantics the Context Engine converts the network information to context that can be handled and understood by the Policy Decision Point after having been stored in the Context Repository.

With the use of the described architecture two types of overlay networks’ adaptation are possible that both lead to optimization of their performance. First, since in our approach we concurrently maintain multiple overlay layers each optimized towards a different QoS metric the architecture selects the most appropriate overlay to perform resource discovery by taking into account the quality requirements expressed by resource queries. Second, configuration changes that enhance the operation of the overlay structure are performed in accordance to policies allowing for example to reduce the overhead of the overlay to adjust to the available bandwidth or reduce its diameter to ensure limited hop coverage. Figure 2 indicatively shows the benefits of adaptation of the overlay on the generated traffic overhead: by dynamically adjusting the ratio between the different families of ant agents (details omitted due to space limitations) the framework is able to automatically maintain the generated overhead at desired levels even under dynamic conditions (1 node joining and one leaving every 2 steps). The results refer to an overlay optimized in terms of short average path lengths for a random network topology of 1281 nodes.

**Figure 1: P2P overlay self-management framework**

**Figure 2: Dynamic adaptation of overhead traffic**

3. **CONCLUSIONS**

The cornerstone of successful deployment of pervasive environments relies on efficient resource discovery mechanisms. In this respect, we presented here a modular framework for the adaptive reconfiguration of such mechanisms in order to address the diverse and evolving needs of users and applications. Our approach is based on ant-inspired, self-organized overlays and exploits context information and policies to manage the monitoring needs of the latter in an autonomic fashion, satisfying continuously changing requirements and leading to optimal operation. Further experimentation of the proposed framework and its realistic deployment on our lab testbed rank amongst our future research plans.

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5. **REFERENCES**

