

Michael Smirnov (Ed.)

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Autonomic Communication

First International IFIP Workshop, WAC 2004
Berlin, Germany, October 2004
Revised Selected Papers



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Michael Smirnov (Ed.)

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First International IFIP Workshop, WAC 2004
Berlin, Germany, October 18-19, 2004
Revised Selected Papers

Volume Editor

Michael Smirnov
Fraunhofer FOKUS
Kaiserin-Augusta-Allee 31, 10589 Berlin, Germany
E-mail: smirnow@fokus.fraunhofer.de

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Preface

The first IFIP Workshop on Autonomic Communication (WAC 2004) was held 18–19 October 2004 in Berlin, Germany. The workshop was organized by Fraunhofer FOKUS with the help of partners of the EU-funded Autonomic Communication Coordination Action — IST-6475 (ACCA), and under technical sponsorship of IFIP WG6.6 — Management of Networks and Distributed Systems.

The purpose of this workshop was to discuss Autonomic Communication—a new communication paradigm to assist the design of the next-generation networks. WAC 2004 was explicitly focused on the principles that help to achieve purposeful behavior on top of self-organization (self-management, self-healing, self-awareness, etc.). The workshop intended to derive these common principles from submissions that study network element's autonomic behavior exposed by innovative (cross-layer optimized, context-aware, and securely programmable) protocol stack (or its middleware emulations) in its interaction with numerous, often dynamic network groups and communities. The goals were to understand how autonomic behaviors are learned, influenced or changed, and how, in turn, these affect other elements, groups and the network. The highly interactive and exploratory nature of WAC 2004 defined its format — six main sessions grouped in three blocks, each block followed by a panel with all speakers of the previous block as panellists and session chairs as panel moderators.

The first panel aimed to highlight the main principles guiding research in algorithms, protocols and middleware; the second panel investigated grand challenges of network and service composition; the third panel had to answer the question “How Does the Autonomic Network Interact with the Knowledge Plane?”. Panel reports were compiled by panel moderators and conclude this volume.

The emphasis of the workshop was on the long-term research agenda with a broad interdisciplinary approach to explore concurrently multiple paradigm spaces. Along with regular sessions the workshop offered two invited talks. Prof. I. Chlamtac, IEEE and ACM Fellow, known for outstanding achievements in optical and mobile networking, shared his views on bio-inspired communication. Prof. A. Fradkov, IEEE Fellow and IFAC member, known for his fundamental works on non-linear and adaptive control, presented a novel network control paradigm based on a cyberphysical approach. Both talks are published in this volume in full length in the invited program section.

The motivating vision of autonomic communication is that of a self-organized Internet that will be able to sense its environment, to perceive its changes and to understand the meaning of these changes, thus facilitating new ways to perform network control, management, middle box communication, service creation, etc. This might be based on universal and fine-grained multiplexing of numerous policies, rules and events which, while autonomously performed, can facilitate the desired behavior of groups of network elements. In line with this vision papers were

solicited on topics including policy-based communication and policy multiplexing, group communication for the control and management plane, network evolvability design, self-organization for re-configurability, management of nomadicity, autonomic communication calculi and theoretical foundations of autonomic network control, mobile code and network programmability, generic network-level service composition at run-time, context handling, theoretical foundations of rule-based systems, security, immunity and resilience of autonomic communication, and its application to QoS, traffic engineering, routing, etc. The workshop received 45 submissions from all over the world; the TPC selected 18 papers constituting the main body of this volume.

WAC 2004 was the foundational event for the autonomic communication initiative and this volume is believed to be the first collective publication solely dedicated to the investigation into its principles. The initiative emerged from the series of brainstorming and consultation meetings started at the EU Commission premises in July 2003 and organized by the IST Programme Future and Emerging Technologies (FET) to address Communication Paradigms for 2020. WAC 2004 was followed by the foundation meeting of the ACF — Autonomic Communication Forum (<http://www.autonomic-communication-forum.org>), and by the publication of FP6 Call for Projects within the proactive initiative on Situated and Autonomic Communication. At the time of writing ACF had close to 200 members from industry and academia. WAC 2005 is being organized in Athens, Greece; WAC 2006 is planned for Paris, France.

To give the authors the opportunity to revise their papers based on the workshop discussions, to allow panel chairs to discuss and to prepare panel reports, and to allow invited speakers to publish their presentations as full papers, this LNCS volume was published as a postproceedings of the workshop.

Finally, it is a pleasure to record here our high appreciation of the efforts of many people in the successful launch of WAC: to all the authors who submitted, presented and revised their papers, or agreed to present their papers as posters, regretting that it was not possible to accept more papers for WAC 2004; to all the attendees for highly interactive participation in the discussions; to the Program Committee members and to all associated reviewers for thorough and motivated assessment of submissions; to partners in the Autonomic Communication Coordination Action for acting as promoters and helpers for WAC 2004; to the EU Commission FET officers for the continuous support of WAC and ACF; to IFIP TC6 members for accepting this foundational workshop, especially to IFIP WG6.6 for technical hosting of WAC; and last but not least, many warm thanks go to the employees of Fraunhofer FOKUS, who dedicated much effort in making the event professionally organized and socially enjoyable.

About This Book

This is the postproceedings of the 1st IFIP TC6 WG6.6 International Workshop on Autonomic Communication (WAC 2004); it includes 18 full papers presented at WAC 2004 and revised by the authors based on the workshop discussions, and full texts of the two invited talks and three panel reports.

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An Infrastructure-Based Approach to Support Dynamic Networks with Mobile Agents

Arndt Döhler, Christian Erfurth, and Wilhelm Rossak

Computer Science Dept., Friedrich-Schiller-University,
Jena, 07743 Jena, Germany

{arndt.doehler, erfurth, rossak}@informatik.uni-jena.de
<http://swt.informatik.uni-jena.de/>

Abstract. With the growing size of distributed systems and the higher number of available resources and services in networks dynamical aspects become more and more important in systems engineering. We believe that there is a real need for decentral, self-organizing structures to cope with the upcoming challenges. In this paper we describe a framework which provides a self-organizing infrastructure that allows to link otherwise autonomous elements in a flexible way and adapts dynamically to changes in the underlying network. This framework is implemented as an extension of the mobile agent system Tracy, which is also a product of our university. The Tracy Domain Management module is part of the framework and provides the basis for segmenting the infrastructure. Another module we are going to discuss in this paper facilitates autonomous and proactive routing of mobile agents. Agents form the application layer of the system. Routing is triggered by the needs an agent inherits from its owner and then matched to the resources and services available in the network in an iterative fashion. We describe concepts, design issues and first results of our work with Tracy and the use of these additional Tracy modules.

Keywords: Distributed systems, self-organization, rule-based behavior, proactive navigation of mobile agents, mobile agent systems.

1 Introduction

In the context of networked environments, mobile agents can be seen as a new paradigm for the implementation of fully distributed software systems with a balanced peer-to-peer concept [1]. During the last years at Friedrich-Schiller-University Jena (FSU), we have developed our own mobile agent system (MAS) Tracy [2, 3]. Tracy is a Java2-based middle-ware that supports the efficient migration of mobile agents over several protocols and migration strategies. So called agencies (Tracy agent servers) are the specialized execution environments for mobile agents. In our approach, every Java-enabled device in the Internet can be such a network node. Currently, we work on additional system components on top of the basic middle-ware layer to network mobile agencies by a self-organizing

mechanism, to improve scalability and flexibility, and to provide an information base for mobile agents that supports their pro-activity and adaptability. Especially interesting is the case where the network provides a dynamical environment [4], e. g. if mobile network nodes and services appear and disappear, and where agents act as intelligent entities by determining their own path at run-time dynamically in the continuously changing landscape.

The movement of mobile agents is based on a logical network view, i. e. mobile agents discern agencies only. The cooperation of normally autonomous and independent agencies is essential to network agencies on such a logical level. The first part of this paper covers that issue and describes a self-organizing network of agencies.

The second part of the paper addresses the routing service which improves the movement of mobile agents in such networks and supports their autonomy. On an agent's journey, it visits only those agencies which provide a resource or service of interest. Furthermore, the agent tries to use a fast path through a network based on known infrastructure characteristics (as QoS). Finally, an agent optimizes its transmissions between agencies with the help of several migration strategies described by Braun [5]. All information necessary for the agent's navigation in the network and the related calculations are provided by the routing service module.

2 Concepts of the Basic Infrastructure

2.1 A Logical Network

A node with an agency is the basic element of our infrastructure. All networked agencies form a logical or virtual application-level network. Every agency offers services managed by local stationary agents. Mobile user-task agents (application-agents) can use these services by local message exchange with the stationary agents. To use remote services on other agencies, a mobile agent must migrate to the desired agencies for local communication with the stationary agents. This approach is typical for a strictly defined MAS and has been described e. g. in Braun [5].

In this context an autonomous decision of a mobile agent is based on a couple of basic capabilities each agency must exhibit: Knowledge regarding the existence of other agencies and theirs offered services is essential, the propagation of this information through the network is desirable, and the infrastructure must be enabled to handle network changes.

The problem is, that in the worst case every agency would have to hold information regarding every other known agency and, thus, a fully intermeshed virtual network comes into being. Since fully intermeshed networks aren't a scalable solution in industrial size networks, we decided to separate the network into manageable and interrelated chunks.

2.2 Topology – The Domain Concept

The basic idea of our approach is to split the whole MAS network into *domains* (see Fig.1), which are limited to IP-subnetworks. All agencies within a domain register at a single agency called *domain manager*. In our approach all agencies have basically fully equal rights and basic capabilities since the *DomainInformationAgent*, the domain management component of Tracy, is present on each agency. So we have a peer-to-peer system. By launching an agency as a domain manager it takes on a specific role and offers the relevant domain management services. From the network management view this role-based behavior can be seen as a client-server behavior, where the domain manager plays the role of the server.

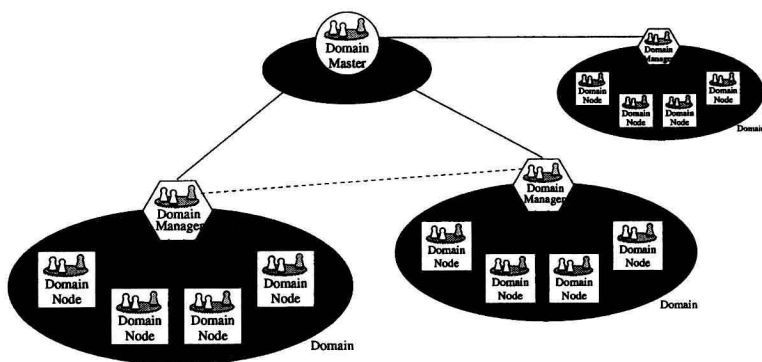


Fig. 1. Domain Concept: A structured network of agencies

The domain manager is responsible to manage all other agencies in a domain called *domain nodes* and to hold connections to other domains. Every domain node has its unique domain manager, and the domain manager knows all domain nodes that are currently active in its domain. If an agency starts or stops, it has to register respectively check out with the domain manager node.

The domain manager holds the complete information of its domain nodes and of itself. It propagates this information to all domain nodes inside its domain, but not beyond. Thus, all agencies within the domain know each other, and form again a fully intermeshed network of a limited size. In practical applications we have learned to expect not more than 60 agencies per domain.

To re-integrate the whole logical agent system network, domains have to be linked together. For that reason domain managers contact a unique *domain master*. The master is a specialized domain manager which manages only other domain managers and interconnects them with each other. In future, we plan some more domain masters to prevent the single point of failure problem. On this level, only summarized information are exchanged.

Since it is possible to launch more than one domain, this approach is capable of handling very large networks in a piece by piece fashion, while it allows for

scalability at the same time. Only inside a domain information and resources are fully intermeshed. In-between domains the mesh is broken. This makes it, of course, necessary for a mobile agent to move into a domain before it can access its resources.

2.3 Valency of a Node – Priority Concept

A Tracy domain is a self-organized basic cell of the infrastructure. When a Tracy agency is launched, it checks the presence of other agencies by sending a UDP-multicast first. If a domain manager answers, the agency must register with the domain manager by sending a mobile agent. In the case of absence of a domain manager the agency becomes domain manager itself. If several agencies were launched simultaneously or a domain manager breaks down, agencies compete to become the domain manager according to the first-come-first-serve principle.

To influence the role allocation according to importance of an agency, a priority value can be assigned to every agency [6]. The priority is modeled as a byte value and ranges between -128 and $+127$. It should correspond to the performance, the quality of the network connection, and the reliability of a node. Currently the priority value has to be fixed before the agency starts. After the launch it can't be changed.

With the concept of priorities, the launching process of a domain information agent changes slightly. When a domain manager receives registration messages from other nodes, it now compares their priorities with its own value. If its own priority is lower than one of a new node, that node becomes the new domain manager.

The drawback of this solution is the fixed assignment of priority values. Furthermore, the programmer has to know the absolute valency of his device or the valency in ratio to the other agencies before its agency starts. This leads to an arbitrary or appraised allocation of the priority value.

2.4 Valency of a Node – Dynamical Priority Assignment

Our new approach is, therefore, to dynamically assign proper priority values during the runtime of an agency. Launching an agency happens as described before, but after registration with the domain manager respectively become domain manager itself an agency performs performance measurements (computing power, memory size and others) by some sensors. The performance measurements reflect the performance of the node and form an abstract view on the local capabilities of the system environment of the agency.

The Map Module which will be discussed in section 3.1 provides information on known services and on network connection qualities. Together with the performance measurement results as an information base (see Fig. 2) it is now possible to calculate a proper priority value to support an automated and useful choice of a domain's manager.

Performance measurements can be regularly repeated and the time interval can be dynamically adapted to the current network situation with the help of