The Munich Network Management Team

Prof. Dr. H.-G. Hegering (LMU, TUM, LRZ)

July 1998

1 Who we are

The Munich Network Management Team (aka MNM Team) is a group of researchers from the University of Munich (LMU), the Munich University of Technology (TUM) and the Leibniz Supercomputing Center (LRZ) commonly headed by Professor Dr. Heinz-Gerd Hegering. It consists of approx. 15 permanent researchers and several associated researchers persuing their Ph. D. thesis plus approx. 30 graduate students. Our research interests center around integrated management of distributed computing environments. For several years, comprehensive work has been done on architectures for integrated management and on implementations of distributed management solutions for dedicated management areas, e.g., configuration, accounting, and fault management. The work is based on practical experiences and knowledge gained from intensive cooperations with providers of large heterogeneous networks and developers of integrated management solutions as well as scientific research in the institutions of the MNM team.

2 Our Research Area

With the rise of distributed computing along with client-server concepts for the provision of computing services, classical mainframe-based computing has been losing more and more of its importance. Integration of telecommunication and data communication, flexible and adaptable communication structures (intelligent networks, virtual workgroups and networks, mobile communication), new services (teleservices, multi-media communication, corporate networks) and the ever increasing dependence of distributed applications on these services makes management of the overall environment a complex and vital task. It poses new challenges not only to organizations but also to scientific research.

Management of distributed computing environments as a whole consists of the following areas: According to the kind of resources to be managed, one can differentiate between *network management*, *systems management*, and *application management*. These disciplines focus on managing network devices, end systems resp. distributed virtual systems and different modules of distributed applications. *Enterprise Management* is related to the overall structuring of the organization that aims at providing data communications or telecommunications services.

The tasks of the first three management disciplines can be classified according to the following functional areas:

- *configuration management*: adaptation of resources to the distributed environment
- *fault management*: detection, localization, and correction of faults
- *performance management*: ensuring the quality of transmission and quality of service
- *accounting management*: determination of resource utilization and allocation to users, and
- *security management*: protection of distributed systems from intruders and misuse

The growing heterogeneity of resources and services not only necessitates a management based on sets of tools that are interconnected in an open standardized manner but also furnishes the need for an integration of the different management disciplines: network, systems and application. This integration needs to be based on common management architectures, such as Internet (aka SNMP), OSI, CORBA management facilities, as well as software solutions (e.g., *management platforms*) that allow a lego-like combination of different modules.

The major challenge lies in the design and development of integrated management solutions for heterogeneous network and system environments in a manner that enables a truly "open" management, i.e., a management that is independent of any particular product or manufacturer. Open management must build on standardized management architectures in the development of which the MNM team is playing an active role. Integrated management that spans all areas of management is the key for the realization of the strategies mentioned above in a heterogeneous environment. Objectives of an investigation are the modeling of resources to be managed, management procedures and methodologies, as well as the conception of generic management tools. Among others, the projects mentioned below are being performed in close cooperation with various companies (e.g., Siemens, SNI, HP, IBM, BMW, ICS, Wacker-Chemie, Cabletron) as well as universities and other research institutions (GMD Focus, IBM Research Labs Zurich, IBM European Networking Center). However, the day-to-day management tasks at the Leibniz Supercomputing Center (LRZ), which is the network and computing services provider for public research institutions in Southern Bavaria (their network currently consists of more than 18.000 interconnected nodes and is rapidly growing), provide for the single most important source of input in terms of research and practical experiences.

The rest of this paper will describe the research topics and some of the results in more detail.

2.1 Network Management

Effective management of the communications infrastructure underlying a distributed environment is of central importance for new data processing supply structures.

Event Correlation

A severe problem of today's network, systems and application management is the inappropriate management of events: If a problem occurs in the managed system, the administrator is often confronted with an overwhelming number of (in most cases) meaningless events indicating some symptoms of the problem. Classical event filtering mechanisms have little impact on this. The aim of the event correlator currently under development is to reduce the number and enrich the meaning of the events shown to the administrator. Ideally the event correlator is able to condense the received events to a single event exactly indicating the problem in the managed system. Current work focuses on the methods to gain a dependency graph of the managed system, which is needed by a powerful event correlator.

Virtual Networks

Another research activity in the area of network management concerns virtual networks, namely logical subnetworks built upon shared physical networks according to the organizational structure of an enterprise. The management requirements evolving from the application of the virtual network paradigm are investigated and new management concepts are proposed to meet these requirements. Main factors include the modeling of management relevant parts of the enterprise, the logical and the physical network along with the definition of functions to map the organizational structure to the logical network and the underlying physical network.

Customer Network Management

The project dealing with the introduction of a Customer Network Management (CNM) for the B-WiN needs particular mention. B-WiN is the national research network, operated by DFN, that provides communications services (IP, ATM and X.25) mainly to scientific institutions. It is based on one of the ATM networks provided by DeTeSystem. CNM refers to the controlled transfer of information from the service provider to the customers. This enables the customer to logically integrate the management information concerning the parts relevant for him of the public network in his own network infrastructure. For the communications services provided by B-WiN corresponding CNM services from the areas of fault, performance, configuration, accounting and security management need to be realized. They should provide the connected institutions with information and functionality related to their connectivity and the services they have subscribed for. Goal of this project is the development of a service management platform required for these purposes. Problems of distribution are being handled through an object-oriented development method and a Client/Server architecture. In order to handle the heterogeneity of the customer infrastructure the implementation is based on technologies such as CORBA and Java.

2.2 Systems Management

The wide use of distributed client/server infrastructures consisting of workstations and PCs introduces significant problems with respect to the number as well as the diversity of installed systems. In order to resolve these problems, techniques from network management are investigated with respect to their adaptability and applicability. Besides researching *trends* that minimize management costs, i.e. network computing based on "thin" clients, we are studying solutions for the following areas:

Management of Nomadic Computing Systems

The increasing appearance of nomadic computing systems in traditional networks poses new challenges on their management. So far, most existing management systems consider the dynamic effects arising from nomadicity as more or less severe faults or disruption of normal operation. Besides providing for nomadicity in management systems, solutions for the infrastructure supporting nomadicity of systems and users are also being developed. If integration of these systems is to go beyond simple network connectivity a management relationship has to be established between the local and the home management system, as well as the mobile node. Topics being covered more thoroughly, i.e. discovery and exploitation of available computing services and resources, licence management, etc., relate mostly to configuration, security, and accounting issues. Our research on this subject also examines current management architectures and standards in regard to their applicability to different usage scenarios for nomadic systems. Architectures focused on the Internet management as well as other related standards from the Internet and telecommunications area.

Security Concepts for Flexible, Distributed Management

The high degree of distribution and dynamics in existing distributed systems also requires the application of distributed, flexible management systems. The concept of delegation of functionality among management entities aids in meeting both of these requirements. Delegation of management functionality refers to the removal of part of the functionality traditionally realized in the centralized management station and its realization on distributed agents running on selected managed systems. The idea is to execute management tasks in any place at any time.

This approach may be applied to different areas and scenarios including systems, application and service management. Such a flexible, distributed management system provides a seamless and transparent execution of management tasks which are performed at the most appropriate point in place and time.

However, security is a critical subject; it may play a decisive role in terms of acceptance and applicability of a flexible, distributed management. Often systems management presupposes the capability to control resources and to have full access on the managed systems. Delegated management functions can, therefore potentially, cause severe damage. Because of that it is necessary to examine security and potential threats with the objective of developing a security architecture for flexible, distributed management.

In the course of the project the security aspects of distributed systems, application and service management with intelligent agents are being analyzed. The goal is to protect both — the delegated management functionality and the environment where this functionality is to be executed — from each other. Furthermore the components of the management system as well as the hosts have to be protected and safeguarded from hostile attacks.

Therefore, security requirements for delegation of management functionality and for entities of the distributed system — manager, mobile agents and (simple) agents — have to be identified. Additionally potential threats for the whole system or single components have to be examined. Our research identifies security requirements of a flexible, distributed management system and develops security concepts which fullfill these requirements.

Using Neural Networks for Network Analysis

Modern management solutions are characterized by the absence of a uniform, adequate model of the managed system. The difficulties arise from the heterogeneity, complexity and dynamics of current distributed systems. Therefore products only deal with single aspects of the management instead of providing integrated solutions. Methods from the area of neural computing can cope with systems even without a complete system model being known. The missing pieces are filled with information learned from monitoring the system. This work is focussed on learning an end systems behaviour by analysing logs being almost ignored today.

Systems Management Agents

In this project SNMP based systems management is realized via a number of agents that perform not only monitoring of specific parameters but also active intervention in the operation of the system. For the comfortable control of the agents a management application has been developed.

In contrast to existing commercial solutions generally based on a bottom-up approach, we focused on covering typical tasks of Unix system administrators. This top-down analysis revealed the need for supporting multiple issues: The creation and deletion of user accounts and groups, the management of user quotas for system resources like storage or printer usage, the mount/unmount of filesystems and functions for starting and stopping processes. It is easy to see that the capabilities of the agent are beyond the usual monitoring tasks by permitting the execution of actions on behalf of the systems. The transfer of management information is done through the SNMPv2 management protocol.

The analysis led to the development of a UNIX workstation MIB and to the implementation of a systems management agent running on different platforms (HP-UX, IBM AIX, Sun Solaris, SunOS). The MIB contains the following groups: Memory (main memory, swap-space, etc.), Devices (CPUs, printers, storage disks and filesystems, etc.), Processes (owner, status, resource usage, etc.), Users (passwords, groups, quota, etc.)

In order to cope with the large heterogeneity of the four supported operating systems and to enable the adaption of the agent to new provider requirements, the agent has been implemented in a modular way: Every way of accessing a

MIB variable is represented by a different procedure. This means that every MIB variable has been implemented in a separate module and has either one or two interfaces, depending on whether the variable is readonly or read- and writeable. This modularity supports porting the agent's functionality to other management architectures, such as OSI and CORBA. Additional agents for other areas of systems management, such as DHCP, are under development.

2.3 Enterprise and Application Management

Besides network components and end systems, integrated management has to deal with databases scattered throughout the enterprise and with applications running in distributed environments. Modeling concepts from network management are applied and respectively extended towards information systems, applications, and work flows.

Availability of Distributed Applications

Distributed applications are defined as complex pieces of software which are distributed across various, heterogeneous end systems in a network. Mostly, they rely on the provision of other applications.

Since adequate methods for testing the availability of distributed applications do not exist, it is necessary to determine it based on the availability of the involved components (other applications, end systems, network nodes). Availability of end systems and network nodes is tested by using and extending the testing functionality of existing management tools. Another aspect necessary to deal with are dependencies between applications. In respect to that, we propose a service graph for the description of functional dependencies and extend it to a parameterized availability graph to describe the involved devices, and to give calculation rules. In practice, though most dependencies are described during the design phase, some of them can be recognized only during operation. To deal with this, user trouble reports about unavailability of services are used to enhance the testing methods as well as to improve and refine the availability graph.

Service-oriented Fault Management

Given the increase in heterogeneity, complexity, and distribution of communication resources, services and applications, the difficulty of managing such a complex environment increases (at least) proportionally. The consideration of user trouble reports, like problems with email, file transfer, referred to as service-oriented symptoms, and the increasing specialization of personnel involved in fault recovery impose new requirements to fault management. Some of the resulting problems in the current state-of-the-practice are

- to diagnose the same fault multiple times, and
- to misdiagnose a complex fault because more and more specialized problem-solving expertise is hidden in the "heads" of few experts not sharing a common diagnosis support tool.

By providing an informational infrastructure for documenting the network behaviour and maintenance activities, trouble ticket systems enable the development of novel concepts for the correlation of service- and device-oriented symptoms, and for a general access to problem-solving expertise. Our research is concentrated on the development of these concepts, and the integration of correlation and fault diagnosis in order to increase the efficiency of fault recovery.

Systems and Application Management based on ODP concepts and CORBA

The existence of different management architectures is a negative factor concerning integration. The application of a so-called "Umbrella" management is strongly influenced by the lack of adequate management models for distributed applications, management services and concepts for management gateways between these architectures. In this context models are developed to enable integrated management of different management applications. They are semantically rich to meet the requirements of enterprise management and at the same time flexible enough to be applicable for different applications on various operating systems or management architectures.

The abstraction from the specifics of individual systems platforms is supported by the use of new middleware architectures such as CORBA. The goal of the current work is among others to evaluate CORBA in terms of its application in systems management, its integration in management platforms and the use of object-oriented design methods for the top-down development of management systems.

We believe that applying the CORBA concepts (with the advantage of isolating applications from language dependencies and from the details of data distribution mechanisms) is essential in today's management since the need to obtain an integrated view over corporate networks is continually growing. Furthermore, it is difficult to fulfill the complex requirements of large network providers with currently available SNMP-based management platforms. Therefore, a CORBA-based approach to systems and application management seems promising.

However, the question "what are the characteristics of distributed applications from a management point of view?" is still a current research topic. Compared to other management areas, there is still a lack of common understanding of this issue. In order to describe these characteristics, we first of all need a framework for management objects. This framework must allow us to describe relevant aspects of any distributed application in a way that is suitable as a basis for all areas of management.

Today, there seems to exist only one standard model that is comprehensive enough to address all management issues — the ODP Reference Model. It is not only standardized but also of growing practical importance due to, among others, the cooperation between the OMG and the ISO. Therefore, we propose to take it as a basis for the definition of the necessary framework for management objects.

The MNM team creates and implements concepts for the deployment of object-oriented systems and application management. Major aspects of this project are:

- developing a conceptual view of CORBA-based systems and application management,
- establishing object models for end systems and applications based on ODP concepts,
- implementing concepts for interoperability between management architectures,
- evaluating compilers which translate from Internet SMI or OSI GDMO to CORBA IDL, and
- building a prototype implementation based on current and soon-to-be middleware and network management platforms.

Service Management

Providing complex services, e.g. operation of a complete corporate network, to a customer generally involves a number of providers arranged in a hierachy of customer-provider-relations. Managing the services leads to a situation where each of these relations introduces the need for a customer network management.

Efficient establishment and maintenance of such a hierarchy of management relationships today is still an unsolved problem. Open questions include the appropriate technical interfaces between heterogeneous management platforms and systems, the integration of different management workflows, e.g. alarm escalation procedures, as well as adequate management information and models for resources and security issues, e.g. ensuring the nondisclosure of information that is related to a certain customer.

The project will address these issues and focus primarily on Web-based interfaces between the management systems of customers and providers as well as appropriate database schemas that can be used in common within the different levels of the customer-provider-hierarchy, thereby supporting efficient and seamless integration of the management systems and paradigms.

Corporate Operations Framework

Integrated management solutions should provide an efficient deployment of distributed systems as well as support the service provider in achieving a high and sustainable quality of services. For this purpose, we have extended the TMN business and service model to a four-level model. The *Corporate Operations Framework* describes a hierarchy of services, tasks, procedures and management tools. The *service* level describes provided services which can be decomposed into *tasks* that are carried out by qualified staff. To fullfill these tasks efficiently, *procedures* have to be described within an organisation. The procedures use different management *tools*. Describing a provider's business along these levels allows a structured description of the mapping from offered services down to management tools. By applying the Corporate Operations Framework to the organisation of several in-house providers in large German enterprises the framework has been refined and brought to its current state.

IN Service Management

With the deregulation of the telecom markets comes along the need for the telecommunications providers to offer cheaper and better services with a reduced time to market. This goal can only be achieved with a service management that allows to deploy, configure and monitor these services in a uniform way.

The management requirements of telecommunications services are mostly equivalent to those classical distributed applications have. Since the distinction between telecommunications services and distributed applications is due to historical reasons, we try to contribute to the unification of these two areas by modelling IN services as distributed applications. That way the use of well-known application management concepts is possible to fulfill the requirements of the IN services. That means there's no need to develop special tools for the management of IN services but use the tools already in place for the management of traditional distributed applications instead.

3 Cooperations

Our qualification is strongly supported from applying the results to the day-to-day management tasks in the Leibniz Supercomputing Center (LRZ), which is the network and computing services provider for public research institutions in Southern Bavaria.

Besides cooperating with the LRZ on practical research and implementation issues we are closely collaborating with other universities and research institutions (GMD Fokus, IBM Research Division–Zurich Research Labs, University of Pretoria, University of Frankfurt), manufacturers of hardware and software (Siemens, SNI, Hewlett-Packard, IBM, Cabletron, Genias, Intelligent Communication Software), as well as network providers and users (BMW, BASF, Rohde&Schwarz, German Telekom).

There are different kinds of cooperation, e.g. financing industry-related practical students' work and master theses, sponsorship of research positions for Ph.D. students, hardware and equipment grants etc. Each work that is done by students is additionally supervised by a full time researcher of the MNM-Team.

The management platforms currently deployed comprise HP Openview, IBM NetView for AIX, IBM NetView TMN Products and Cabletron Spectrum.

Of course, institutions interested in joint research and implementation are always invited to contact us:

Prof. Dr. H.-G. Hegering
University of Munich
Department of Computer Science
Oettingenstr. 67
D-80538 Munich, Germany
Phone: +49-89-28928702
Fax: +49-89-2809460

or send an email to *hegering@lrz.de*. For additional information you are invited to visit our web-pages containing a detailed list of publications and a lot more (*http://wwwmnmteam.informatik.uni-muenchen.de/*) .