Integrated IT-Management in Large-Scale, Dynamic, and Multi-Organizational Environments

Markus Garschhammer
Munich Network Management Team
Leibniz Computing Center
Barerstr. 21
D-80333 Munich
Germany
garschha@mnm-team.org

Michael Schiffers
Munich Network Management Team
Ludwig Maximilian University Munich
Oettingenstr. 67
D-80538 Munich
Germany
schiffer@mnm-team.org

Abstract

Integrated IT-management has been a challenging research topic for several years now. However, integrated management of today's large-scale, dynamic, and multi-organizational IT-systems is still in its infancy. To overcome the difficulties management solutions for such environments have either been re-done from scratch or simply ignored. It would be desirable to re-use well-established management solutions as far as possible. But it is not at all clear, when to re-use, how and what to re-use, or what to re-do from scratch. One of our research goals is a respective decision support. Based on two real scenarios we propose as a first step a methodology for systematically analyzing management approaches for the purpose of determining re-usability. In a two-dimensional portfolio, management cases can be positioned, and thus categorized, and their deficiencies when evolving towards other environments can be analyzed. We demonstrate the technique for an example.

Keywords

Management Strategy, Service Management, Virtualization, Virtual Organization. Management Automation

1 Introduction

IT-Management has classically been summarized as all means necessary for an effective and efficient operation of a distributed system and all its resources corresponding to a given set of business objectives. A commonly agreed goal is an integrated approach to IT-management where *integration* means standardized concepts for a global management database, an integral approach to different management aspects, consideration of organizational aspects (e.g. domains), the support of heterogeneity, and the provision of open programming and user interfaces [8].

Since its beginnings we have been witnessing a tremendous progress in integrated IT-management from linking separated management islands, like isolated LANs, to common management platforms as fundamental integration bases. Examples of the latter range

from early OSI management efforts [14, 15] to Internet/SNMP management schemes [1], CORBA and the Object Management Architecture (OMA) [16], and the work-in-progress at the Organization for the Advancement of Structured Information Standards (OASIS) regarding both management of and management using Web Services [11, 12]. However, in spite of all these promising efforts there are still a lot of unsolved problem areas. One such area is that of 'co-managing' resources in dynamic virtual organizations where a resource may belong to several management domains simultaneously.

The co-management problem, as an example, is induced when 'going virtual'. A typical approach when dealing with large-scale, highly dynamic, and multi-organizational environments like Grid Computing [4], Web Services orchestration [13], unbounded networks [2], and even ad-hoc sensor networks [3]. The management challenges in Virtual Organizations (VO) are enormous [5, 6]. In order to overcome these difficulties a common approach would be to re-use or migrate some of the well-established management concepts into this new environments. However, it is not at all clear, when to re-use, how and what to migrate, or what to re-do from scratch. Neither is clear what the trade-offs are when combining different approaches. One reason is that most known integrated management solutions have been suffering from proven applicability to large-scale, dynamic, multi-organizational environments. Either do they lack fundamental mechanisms (e.g. for overcoming the heterogeneity of managed objects) or the community did not require it because of rather small scenarios. However, with the emergence of Grid Computing, Web Services Technologies, and Autonomic Computing, the importance of adequate management solutions is increasing.

One of our research goals is overcoming these difficulties. As a first step we will investigate in this paper the adequacy of existing management solutions for the emerging environments. In section 2 we will use two scenarios (a Web-Hosting Service at the Leibniz Rechenzentrum (LRZ) and the DEISA Grid) for discussing the respective in-adequacy of traditional management solutions. We do this from two different perspectives: (i) their suitability when evolving real organization into virtual ones, and (ii) their suitability when establishing virtual organizations from scratch. As our intentions are neither to solve all the questions nor to propose specific techniques and migration methodologies, we will instead draft a framework for further studies in this context. We do this in section 3 by arranging management scenarios in a portfolio and deriving generic management concepts from the portfolio. The portfolio then serves for discussing some of the challenges mentioned before. Finally, section 4 concludes the paper and presents further work.

2 In-Adequacy of Existing Management Solutions

When analyzing management concepts as they are realized today we observe that integrated management generically builds on transparency and virtualization concepts for dealing with complexities and heterogeneities. Examples are physical resources that have been virtualized for abstracting away their heterogeneity (as in VLANs and VPNs). Accordingly, transparency in Grid services is achieved by virtualization of these services [6] and Web Services are being standardized for management purposes [12, 11]. Although

these concepts are well understood in single domain, small-scale, and mostly static environments, it is still an open issue in the more complex scenarios we are aiming at.

This section gives some examples regarding management challenges in virtual organizations by examining two scenarios and discussing the reusability of well known tools and concepts therein. In the first example we investigate a well known web service provisioning scenario discussing the question 'What would management look like if this service was implemented within a virtual and not a real organization?'. The second example describes a grid-like scenario where management definitely is exposed to a virtual organization. Regarding that scenario we investigate the question 'Are common, well known concepts (of management in real organizations) reusable?'.

2.1 Extending service provisioning to virtual organizations - Web-hosting going virtual at the LRZ

The LRZ is the computing center of all scientific institutions in the Munich metropolitan area. The LRZ operates a web server farm to host its own web site as well as about 300 virtual servers of various institutions in the Munich scientific network. Servers are configured redundantly to ensure smooth operation even if one of the components fails. All servers and components belong to the LRZ acting as a real organization (RO).

In the following we will give some examples about what may happen, which additional features in management concepts and tools would be needed, if that service were provided in a virtual organization (VO). We see a VO as an organization aggregating more than one RO to form a new organization with its own business objectives and policies. Each RO contributing to the VO grants access to (parts of) its resources to the VO. As an RO may contribute to various VOs, resources a VO is built upon are always shared - not between users as in typical operating systems but between VOs.

Figure 1 shows a resource-oriented view on the web-hosting scenario as described above. As can be easily observed, redundancy yields a complex infrastructure which implies complex management tasks.

Configuration Management and Fault Management In order to create a highly available web-service provisioning solution an adequate configuration was chosen to reflect redundancy requirements. In case of the LRZ acting as a RO, configuration decisions mainly are concerned with the components' performance. The solution chosen to enable redundancy resembles a common concept and uses well known and well established network components.

If the LRZ were to be a VO, configuration decisions would get a lot more complex because no common concepts exist to establish high availability in VOs. Resources (e.g. switches, servers) are strictly dedicated in an RO but shared in VOs. Note that in today's implementations sharing is performed without any guarantees.

A high availability solution built in a VO would require development of a customized solution taking into account availability requirements of every virtual resource integrated. Conducting specialized SLAs for each resource used is eventually needed, too.

Accounting The technical solution established by the LRZ to enable highly available web-service provisioning uses 12 servers built as two redundant blocks to host about 300 virtual web servers. In case of the LRZ acting as an RO, accounting of compute

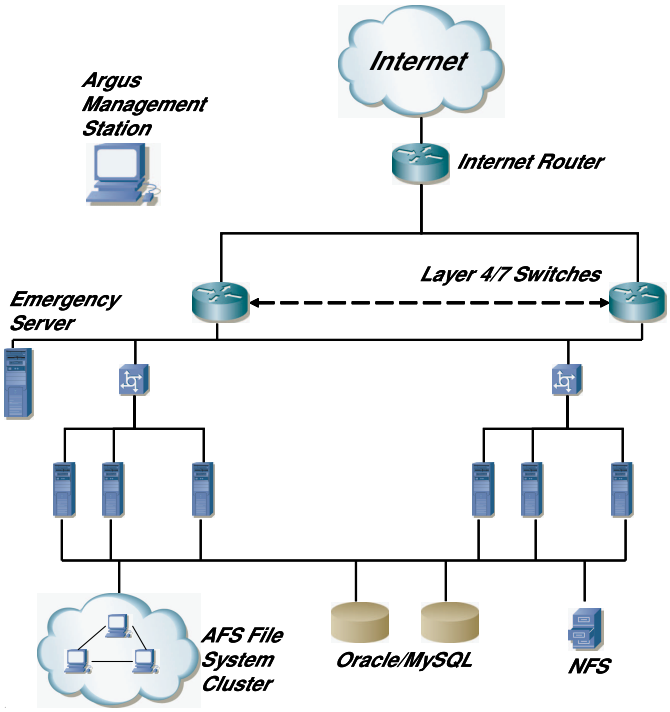


Figure 1 The LRZ Virtual Web Service

resources needed to provide each web site (technically a virtual server) could easily be achieved by summing up the times each server process consumes. Even if it is moved to a mirror machine values would be comparable because of the homogeneous server environment the LRZ uses.

If all servers used in this solution were provided by different organizations and the web-hosting service was realized in a VOs accounting procedures cannot assume measures to be comparable anymore because there are no dedicated servers anymore. What is provided instead, is simply 'computing power'. As accounting always was done within an RO, concepts generating measures comparable across organizations are just evolving.

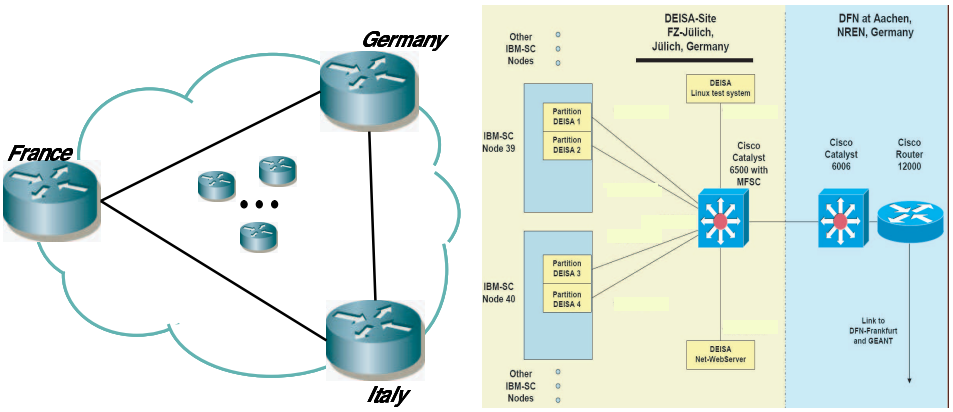
Security As indicated in figure 1 the LRZ uses different kinds of databases to provide dynamic web pages. For security reasons, these databases are protected by access lists. This approach is sufficient as long as the web server processes resided on dedicated servers which can easily be added to these lists.

An access list should grant access to a service (more technically a process). But to ease implementation complexity, in many cases it is granting access to a server. If the implicitly statical relation between a service and the server hosting that service becomes dynamic in the environment of a VO this security concept fails and needs to be re-implemented from scratch. In a VO one could not anticipate which server is

hosting which service because resources are not dedicated to a specific service anymore and this assignment can dynamically change as well.

2.2 Re-using common concepts in virtual organizations - management challenges in DEISA

The Distributed European Infrastructure for Supercomputing Applications (DEISA) (http://www.deisa.org) integrates 11 supercomputing centers from all over Europe to both deploy and operate a persistent, production quality, distributed supercomputing environment with continental scope and to enable scientific discovery across a broad spectrum of science and technology. Each DEISA-site connects their supercomputer(s) to the dedicated DEISA network. Thus, DEISA members share computing power among each other. Data sharing is realized using a high performance file system (GPFS) spanning the whole network. Various National Research and Educational Networks (NREN) from all over Europe are involved in the provisioning of the DEISA network. Provisioning is coordinated by the European scientific network GEANT, a collaboration between 26 NRENs across Europe (see figure 2).



(a) Global Connectivity *(b) A Typical DEISA-Site*

Figure 2 The DEISA Super Cluster

DEISA definitely forms a Virtual Organization (VO). In the following we examine this scenario from a management point of view discussing briefly whether and how common management concepts and tools could be re-used. We present some examples of how management in VOs differs from management in real organizations (RO) and give reasons for these differences.

The dedicated high performance network is one of the core building blocks of DEISA. Every service (core or application) depends on that network. Thus, network management ensuring performance and enabling instant reactions on faults is essential. From this point of view, DEISA resembles any company offering highly reliable network services to its employees (or users). A lot of network management tools are available today to ease

the various corresponding network management tasks. Therefore, an obvious approach would be to apply one or more of these tools for network management in DEISA, too. Unfortunately, however, this approach fails in the context of DEISA as explained below.

Performance management Switches and routers building the DEISA network belong to different European NRENs. In most cases the DEISA network is implemented as a Virtual Network sharing components with other services (e.g. IP-connectivity the NRENs offer in their own countries). Thus, management of these components from a (anticipated) DEISA Control Center is not possible due to the NREN's autonomy. Reusing existing management tools in DEISA would require access to SNMP interfaces of each component. Even if this access were read-only, NRENs would deny it because of privacy issues (the whole local configuration would be visible to DEISA). Even worse, to enable purposeful, active network management going beyond monitoring, SNMP write access would be needed, too.

The challenge with DEISA is that existing device management solutions (SNMP-Agents) do not know any role concept. This implies the impossibility of (role-based) access policies which would enable the NRENs to grant access to only those parts of a device MIB which are relevant to the VO the device is co-managed by. Existing solutions assume a device to belong to a single organization and therefore be managed by only one manager. Ironically, the well known concept of fine grained, user based access rights has been implemented in operating systems and files systems where sharing is a fundamental requirement. Apparently, the concept of resource sharing has (not yet) been reflected in management solutions.

Fault Management The configuration of the DEISA network is complex because of the flock of providers contributing to the network. This becomes evident when faults (e.g. broken links, network partitions) occur in the network. As the network implementation is transparent to DEISA, problems in connectivity are only noticed if a service depending on that connection fails. Current event correlation techniques [7] would automatically report connectivity problems if a device failure was noticed. Quite similar to the performance management problem (see above), the typical correlation solutions are not sufficient for DEISA because all events/traps a device triggers are sent to the NRENs Network Operations Centers (NOC) only. In the case of publishing events, device management solutions are not aware of the fact that resources are being shared and a more sophisticated management approach is required. If a device (e.g. a router of the DEISA network) would sent its traps to all organizations (be they virtual or real) sharing that device, each of them would probably have implemented some fault management tools and concepts enabling an inner-organizational fault management.

Application Management The fundamental purpose of the DEISA infrastructure is running bigger and more demanding applications than the ones that can be run today on each isolated national infrastructure. The way DEISA does this is based on load balancing the computational workload across national borders. Huge, resource-demanding applications are run by re-organizing the global operation in order to allocate substantial resources in one site.

Hence, it is essential to comprehensively monitor the entire community-critical application environment which implies an extensive automation of the respective change

management and identity management/access management tasks, the quick isolation of the root cause of problems to minimize costs, the resolution of problems before they impact the community, and the seamless shift of resources from maintenance to production innovation.

One could argue to use such tools like Nagios, HP OpenView or IBM Tivoli for application management in VOs. However, the implicit assumption of these tools is the single management domain typically found when dealing with management issues in Real Organizations. Thus, when application topologies are stable, these tools are an option. However, 'dependencies' in Grids are not always 'network dependencies'.

2.3 Gap analysis - facing a new paradigm shift

When carefully analyzing the above scenarios we recognize the management objectives to be generally identical. The major differences, though, relate to the organizational scopes of the required management solutions (single domain versus multi-domain, single organization versus multi-organization), the organizational perturbations (dynamic domains versus static domains), and the responsibilities (strict provider autonomy) induced by such organization networks. Among others we especially identified the following deficiencies of existing management solutions:

- There may be more than just one actor playing the role of a manager potentially leading to management conflicts. Common management concepts implicitly assume exactly one manager (role) and do not provide any mechanisms to cope with this 'multi-manager' problem.
- Dependencies are no more static and do not relate to networks only. Instead, dependencies may cover all management layers across organizational boundaries. Visualizing, analyzing and manipulating these dependencies requires an adequate tool support.
- Implicit dependencies between different layers of abstraction (e.g. a server and a service) have to be made explicit to the management. Management systems must not rely on 'legacy' (i.e. implicit) dependencies any more but have to cope with dynamically changing, explicit, dependencies instead.
- Events and traps resources are sending out must be intelligently correlatable to those users who are sharing these resources to enable an adequate fault management.
- There is a significant requirement for re-building well-established hardware solutions like load balancers, firewalls, etc. as software solutions to enable their seamless integration into VOs.
- Fault tolerance mechanisms based on resource redundancy may not work anymore because availability becomes unpredictable in shared environments unless stable sharing mechanisms (apart from best effort) enabling guarantees (e.g. response time, bandwidth, max. execution time) are established.
- Common well-established accounting concepts generate measures highly depending on the hardware used in service provisioning. As hardware becomes virtual in VOs these concepts have to be reconsidered to provide comparable measures across virtual resources.

Even though our presentation of open issues presented above is based on two example scenarios only, it already generates a whole list of problems to be solved when enabling

management in Virtual Organizations (VOs). At first glance, one might argue that almost every management task needs to be reconsidered or even re-implemented from scratch to enable an integrated management in VOs.

Management concepts are facing a paradigm shift from real to virtual organizations lifting the concept of sharing, well known within real organizations, to temporary groups of organizations. Reviewing the last 20 years of IT-management, paradigm shifts are quite common: First there was the shift from homogeneous to heterogeneous resources managed in an integrated way. Then network management shifted to service management. Now we are entering the next stage. But unlike the shifts to integrated management and to service management which were more or less observed only, the shift to virtual organizations is predicted and already envisioned in the first Grid projects with their generalized, integrated management requirements. This yields the question, from a retrospective point of view, how paradigm shifts were carried out in the past and which concepts may be re-usable in the shift we are facing today.

3 How to Cope with a Broadening Scope of IT-Management

In this section we introduce a portfolio scheme to visualize the trends IT-management is facing today and to denote concepts already used or only envisioned to cope with these trends. The scenarios we introduced in section 2 will be categorized using this management portfolio and thus showing which trends they reflect.

3.1 Trends in IT-management

Among others, IT-Management has to face two major trends, the growing diversity in infrastructures and the growing inter-organizational dependencies. The latter one can be observed in the example scenarios we introduced whereas the first one can be observed since the very beginning of IT (management). In the following we give some examples supporting this observations.

Growing diversity in infrastructures

Despite various approaches to simplify IT infrastructures the diversity of resources is still growing. In recent years, service oriented architectures emerged and introduced services as high level resources into management. New technologies like fiber-optical devices were developed without replacing existing technologies. With the World Wide Web coming up as an almost uniform infrastructure, a new platform to deploy and operate services has been built which put Web servers, databases and other resources into a new service provisioning environment.

Growing inter-organizational dependencies

Inter-organizational dependencies came up first when companies started to outsource parts of their IT infrastructures. Consequently, a service provided to an end-user was not provided by exactly one company anymore. This trend intensified with the Internet maturing to a base infrastructure for application service provisioning. The idea of Grid Computing where resources are shared between organizations rather than between users is the latest evolution step supporting this trend.

Both observations outlined above broaden the scope of IT-management. To represent this graphically we arrange the trends along the axes of a two-dimensional grid as depicted

in figure 3 (a)). This allows us, for the purpose of our investigations, to partition the world of IT-management and to position the management cases as exemplified in figure 3 (b)). The portfolio can thus be used two-fold: (i) to position/categorize management cases, and (ii) to leverage common management approaches when traversing the portfolio from one partition to another. Both applications of the portfolio are described in the following.

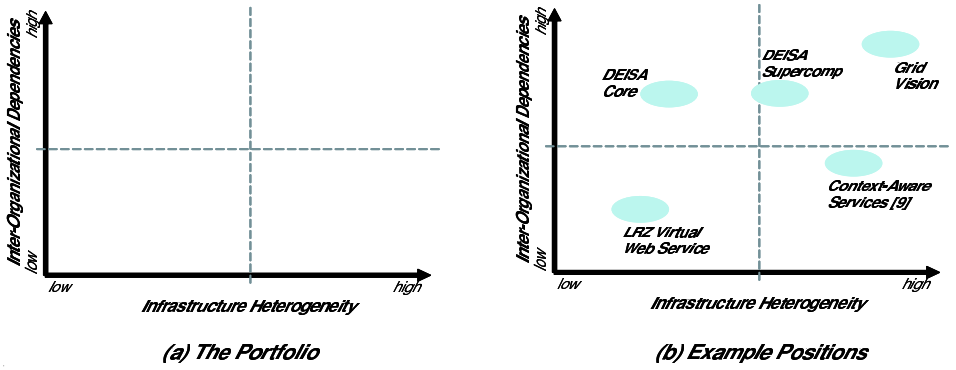


Figure 3 The Management Portfolio

3.2 Categorizing present and future management cases

Cases to be managed are variously driven by the two major trends in IT-management denoted above. This offers the chance to position cases in the portfolio according to the shapes of the trends. Accordingly, cases belong to portfolio partitions implying a respective categorization. In the following we position both example scenarios introduced in section 2 and two future scenarios for demonstrating the categorization effect. Figure 3 (b)) reflects this.

LRZ Web-Hosting

The LRZ uses common, almost homogenous hardware to build its Web-Hosting-Service. The service is provided without the assistance of any further organizations (even the network used to connect the sites to the Internet is provided by the LRZ itself). Accordingly, this scenario is positioned in the lower left partition of the portfolio which indicates a low level of inter-organizational dependencies as well as a low level of heterogeneity in the infrastructure used in this management case.

DEISA

The core sites of DEISA all use identical hardware to provide computing resources but they share these resources among each other. All other sites involved in DEISA contribute to the project various kinds of supercomputers. We therefore exhibit two DEISA-cases: DEISA Core in the upper left partition indicating the usage of homogeneous resources by the core sites, and DEISA Supercomp right to DEISA Core representing a further step into common grid scenarios with heterogeneity in both infrastructures and organizations (see figure 3 (b)).

Context-aware services
In [9] management challenges implied by pervasive computing environments have been explored. The scenarios envisioned there can also be placed in the management portfolio. Pervasive computing environments integrate a flock of heterogenous resources and infrastructures (e.g. different type of networks, various devices like PDAs, notebooks). Services in such environments are provided by various organizations (e.g. context providers, network providers, etc.) Although inter-organizational dependencies exist in such kinds of scenarios they primarily affect the service management aspects. We therefore position such a management case near the mid-level as far as inter-organizational dependencies are concerned and far right regarding the heterogeneity of the infrastructure.

The Grid vision
The vision of Grid computing already reveals its effects in IT-management. Grid computing as a future scenario has to be placed in the upper right corner of the portfolio indicating both a high level of inter-organizational dependencies and a high level of heterogeneity. DEISA Supercomp is placed lower and more left because it does not fully implement the Grid vision. The ratio behind this is that the number of organizations joining DEISA is a priori well known and not changing during production. Additionally, although the resources are heterogeneous, they are predetermined since the participating (real) organizations are completely known beforehand.

3.3 Approaches broadening the scope of IT-management

The portfolio we introduced above and the positioning of present and future scenarios already reflects the evolution of IT and the respective IT-management. Obviously, the lower part of the portfolio groups scenarios well understood today from a management point of view. The upper part groups management cases typical for virtual organizations where management concepts are just being developed.

The evolution of information technology started in the lower left corner of the portfolio and is now moving to the upper right corner. As IT-management is required to provide adequate solutions for an evolving information technology, the management portfolio presented in figure 3 reflects this by depicting the respective concepts that are observed. Following the evolution of scenarios means traversing partitions within the portfolio. Figure 4 (a) shows these transitions as arrows crossing the partition borders. Furthermore, the basic concepts applicable when following the transitions to the upper or righter regions are shown. The transition possibilities depicted in figure 4 (a) are described in the following. This decpription also includes a short discussion of the maturity of the approaches.

Integration and standardization
The common concept to cope with an ever growing heterogeneity in infrastructures is that of *integeration and standardization*. This concept is well studied and practiced in scenarios with low or middle degrees of inter-organizational dependencies where the idea of virtual organizations is not deployed.

[8] presents a detailed survey of that concept of 'integrated management'. Standardization techniques like SNMP exist as well as tools to support most of the managment tasks (see e.g. various management platforms or ITIL [10] to standardize management

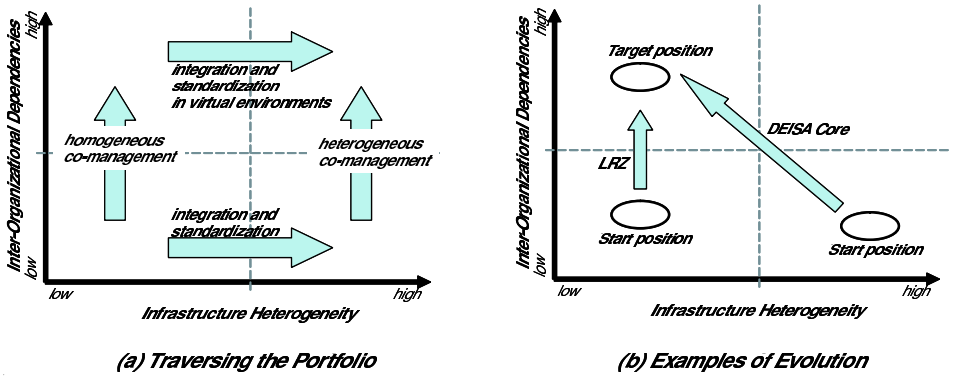


Figure 4 Management Portfolio with Different Traversing Paths

processes). Thus, 'integration and standardization' can be labeled as well established and mostly tool-supported.

Homogeneous co-management

Early Grid projects, like the DEISA Core, implement the idea of virtual organizations based on homgeneous resources. Corresponding scenarios reside in the upper left partition of the management portfolio. In our opinion, the management concepts needed to cope with the heterogeneity of organizations using a homogeneous infrastructure must be based on a well-established co-management concept.

We show that kind of *homogeneous co-management* as an arrow pointing upward in the rigth part of the management portfolio. The idea of co-management is alreay established in the management community but deployable concepts are just emerging in the various grid projects. A common toolset, however, is still missing because management tools are developed particularly for the scenarios they are used for.

Heterogeneous co-management

The concept of co-management can also be deployed when moving to virtual, higly interdependent organizations in a heterogeneous environment. However, co-management in that kind of scenarios has to be deployed with respect to the heterogeneous infrastructure used. We label that concept as *heterogeneous co-management*.

Simmilar to homogeneous co-management this concept is just evolving and tools are missing. Even worse, the community expects heterogeneous co-management to be more complex than homogenous co-management. Most projects dealing with co-management today try to ease management issues through unifying infrastructures as will be discussed in section 3.4.

Integration and standardization in virtual environments

As mentioned above, the concept of integration and standardization is well implemented and studied as long as no virtual organizations are involved or the degree of inter-organizational dependencies is not growing too high, respectively.

In our opinion this concept has to be leveraged in the future to enable *integration and standardization in virtual environments*. Developement of this concept is an open resarch topic and needs further investigation.

3.4 Traversing the world of management

Above, we have shown different concepts for traversing the management portfolio. In the following we discuss paths usable or used today. Doing so, we show a further application of the management portfolio and highlight emerging research topics.

LRZ Web-Hosting in a virtual environment

In section 2 we introduced the LRZ-Web-Hosting scenario and discussed what would happen if this service was implemented in a virtual organization. With the management portfolio we are able to graphically trace that evolution of the scenario.

Re-implementing the LRZ-Web-Hosting with identical hardware spread over different organizatons in terms of the management portfolio simply means moving upward starting from the LRZ-scenario already indicated (see figure 4 (b)). Regarding the approaches introduced above in section 3.3 and shown in figure 4 (a) from a management point of view we see that a corresponding co-management concept is required, as has already shown in the gap analysis in section 2.3.

Paths to travers the portfolio

The discussion of a further development of the LRZ-Web-Hosting scenario raises the question which path should be used for a suitable traversion of the management portfolio and which paths have already been established.

As figure 4 shows each partition of the portfolio could be reached in two ways when combining corresponging approaches. A 'natural' way, however, would be to follow the IT-development in the past and for the future by using 'integration and standardization' followed by 'integration and standardization in virtual environments'.

As already mentioned some scenarios built today (like DEISA Core) leave the natural path and move backward through strictly unifying infrastructures but still implementing the idea of virtual organizations. The reason for this approach is mainly due to the missing pieces along the 'right' path. This 'way back' is shown together with the evolution of the LRZ-Web-Hosting in figure 4 (b)).

4 Conclusion

When investigating the opportunities and issues of re-using existing management strategies in emerging dynamic environments, the management portfolio we provided is a first step towards systematically analyzing the challenges resulting from an integral management approach. Based on two detailed scenarios, we presented a portfolio that not only allows the positioning of existing and future management cases within an organizational dependencies/infrastructure heterogeneity diagram. The advantages of the portfolio are three-fold:

- a management case, once positioned, can be categorized by a set of criteria characterizing the respective partition
- a management case is positioned relative to other cases making them somehow comparable as far as used concepts, tools, and management applications are concerned
- traversing the portfolio indicates the general deficiencies related to the transition, which is especially important when 'following' paradigm shifts as these provoke a discussion on what to re-use and what better not.

Although first experiences demonstrate the general applicability of the technique, we are still at the beginning. The work presented here thus serves as a roadmap for further research activities. We are very confident the methodology, once mature, will contribute to solve (at least some of) the problems regarding managing the management (meta-management) which is of increasing importance in Grid Computing and similar dynamic environments.

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Biography

Markus Garschhammer received his diploma in computer science (M.Sc.) from the Munich University of Technology (TUM) in 1999. Since then he is a member of the MNM Team. He was working at the University of Munich (LMU) as a research and teaching assistant achieving his Ph.D. in 2004. Since 2005 he works at the Leibniz Computing Center in Munich. His work focuses on management in all flavours, especially on evolving concepts and tools.

Michael Schiffers received the diploma (M.Sc) in Computer Science from Bonn University in 1977. He is a member of the MNM team and a research assistant at the Department of Informatics at the Ludwig Maximilian University, Munich, since 2002. Before that he hold several positions in the international IT–industry. His current research interests cover Grid Computing and service management. He is a member of the Gesellschaft für Informatik (GI) and ACM.