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A Policy Framework including Trust and Reputation in Grid Environments

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1. Introduction

A Grid defines a particular type of technological and organizational interaction within a computational network, describing supply and demand for computational or data services[1]. However, Service providers usually have more information about quality or availability of the services they provide, than their potential users (consumers). This case of asymmetrically distributed information usually leads to suboptimal results due to occurring uncertainty on the consumer side, and thus to a inferior usage of the Grid in total. Not only providers, but also consumers, can cause asymmetrically distributed information. Both transaction participants have to deal with uncertainty caused by environmental factors (e.g. network failures as a result of natural disasters). According to our comprehension of a Grid, there is no difference between a Grid market and other imperfect markets like a second-hand car market. Effects which can be observed in physical markets can be found in Grid environments as well. Managing the asymmetrical distributed information depends on the organizational form of the Grid. Enterprise Grids, used by local participants in the same organization, can be controlled by company policies. Larger Grid systems, which form e.g. virtual organizations with many service demands and offers in parallel, are more difficult to control. As long as incentives for strategic behaviour exist (e.g. by introducing payment for on-demand service usage), asymmetrically distributed information can be exploited by strategically acting participants. Without regulating and coordinating mechanisms the Grid may suffer from low quality of service (QoS) due to asymmetrically distributed information.

Because of these economic issues, policies have to be defined to overcome these shortcomings. As these policies are not enforceable in all Grid physiologies, we propose to use trust and reputation concepts, similar to those used in e-commerce applications. However, our understanding of trust extends the prevalent technical-oriented views in Grid environments. Secure communication and digital certificates are necessary, but not sufficient to generate trust both in the system and to other participants.

The paper investigates in economic theory driven approaches in order to reduce uncertainty in automated micro decisions like a single service selection. Three different forms of relations between Grid Service providers and customers make it necessary to differentiate mechanisms reducing asymmetric distributed information. Therefore we develop a framework to depict the importance of trust and reputation concepts to reduce this uncertainty in different grid environments. This framework should help to define the policies keeping a grid system running in dependence of the corresponding environment.

We begin our discussion by introducing three spheres for describing Grid systems (see figure 1): the technological infrastructure, the business infrastructure and the policies infrastructure [2]. That implies a holistic approach which is necessary to understand the economic implications.

1. The computing technology infrastructure describes the underlying technological progress, comprising hardware and software as well as the engineering process.
2. The business sphere is the starting point for the development of new services and products. Having the technology in place is a basic prerequisite, but does not generate innovation by itself. In the business sphere, existing technology enables innovative business models, using corresponding economic logic.
3. Businesses, however, need rules, for protecting participants' rights and properties. The policies infrastructure describes possibilities and measures in order to dispose of uncertainty and fraud. This requires a joint understanding and acceptance of rules, norms and laws, as well as agreed-on measures to regulate and enforce compliance.

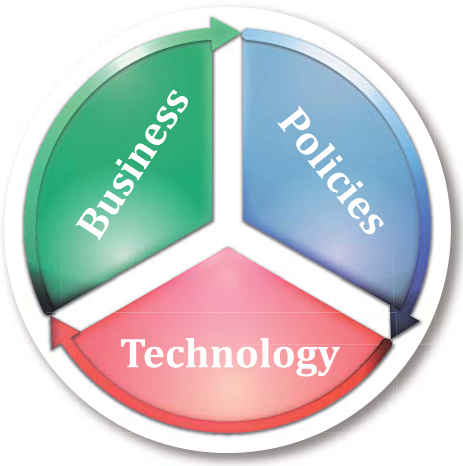

FIGURE 1. Infrastructure Spheres

The spheres may not be considered independently of each other. Without technology, there are no services and products to be invented. Without business models, no policies are needed to regulate their actions.

If understood as a positive feedback loop, the relation becomes even clearer: the availability of new technology (Overlay networks, SOA) allows the development of new innovative business models (on-demand or utility computing, the Grid). New business models lead to the existence of new software-based services and products. In the next step, normative institutions like norms, policies and contracts need to be applied to protect markets, providers and consumers from fraud and wrongdoers. A world without contracts or rules leads to uncertainty and prevents entities from making rational decisions (e.g. early P2P networks [3]). A world in which people interact needs human-readable rules; an environment of artificial agents requires machine interpretable rules. This again leads to technological development. Considering technological inventions as a present, constant flow of innovating ideas and concepts of computer scientists, the research challenges for management will mainly lie in the business and the policies infrastructure [4].

Dividing our research field into infrastructure spheres allows us to abstract from technology and business models, and to focus on policy details. This abstraction allows us to define necessary policy rules for each Grid coordination form.

The article is organized as follows: section 2 describes the related work in the domains of Grid economics and reputation-based trust. In section 3 we will establish the connection between reputation, coordination forms and the infrastructure spheres, which then leads to our final framework. Section 4 presents three stages of Grid Systems, distinguishable along the dimensions of the framework, and with examples to illustrate the practical application. The conclusion is presented in section 5.

2. Related Work

Our approach focuses on Grid coordination forms and the necessary reputation concepts. Our proceeding is top-down, from the economic models to the infrastructure requirements. The technical view on Grid Systems is only a small part of our framework. Related work can thus be found in the domains of taxonomies for Grid economies, reputation-based Grid resource allocation, and is based on the classification of reputation in institutional economics. The combination of these domains leads to a recent field of research, Grid Economics (see figure 2).

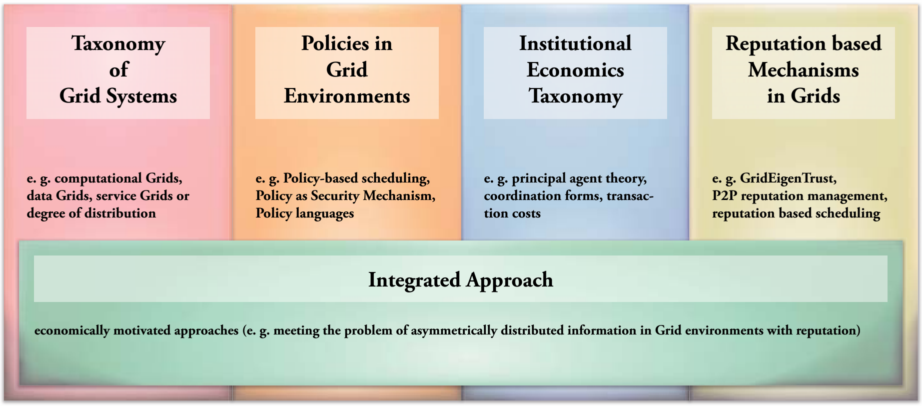

FIGURE 2. Classification of related work

The taxonomies for Grid economies focus on the technical properties of Grid Systems. Krauter et al. [5] identify architectural properties to survey different Grid approaches. They differentiate between Computational Grids, Data Grids and Service Grids. The computational Grids have a higher computational capacity as every single machine on its own, whereas the Data Grids are focused on providing an infrastructure to manage data from data repositories. The third category is represented through the Service Grids. They are built for services that can not be provided by single machines. Another taxonomy for dynamic resource allocation in Grid Systems is presented in [6]. He analyses dynamic task scheduling solutions. A further taxonomy for resource scheduling in Grid economies can be found in [7]. In contrast to these approaches, the taxonomy of Buyya et al.[8] focuses more on economic aspects. Buyya's paper does not include reputation aspects, but it proposes economic models to allocate resources in a more efficient way and provides pricing strategies for service providers.

The understanding of Policies in Grid Systems cover a wide range of definitions. Policies are increasingly used for automated system management [9] and to control the behaviour of complex systems. Policies can be changed to adapt the system's behaviour without modifying any source code. To define such system-wide policies the understanding of each participant has to match. Therefore, different languages have been introduced (see e.g. [10] for an comparison of three different languages). Policies can also be used to define service and resource selection strategies in Grid Systems [11]. In a different understanding, policies can be seen as a kind of security mechanism (e.g. [12]). Our understanding of policies is a superset of all kind of rules, languages, mechanisms all participants have to follow. As you can see in the following sections, not all types of Grid environments allow the enforcement of these policies. If an environment does not allow enforcing rules, other mechanisms have to be found. Therefore, we propose repuatation mechanisms to ensure that.

Institutional economic theories investigate the exchange of scarce goods between economic subjects. Thereby the way of exchange, the coordination of the economic subjects, is of great importance. The transaction cost concept [13] was enhanced by Williamson [14], who compiled a pattern of determining attributes for the transaction costs' amount, see [14, p. 40]. The economical concept of transaction costs can be divided into two parts [15]: motivation costs and coordination costs. Motivation costs describe the agents' motivation to align their interests, e. g. the costs of cheating or opportunistic behavior [14] or the agency costs among owners, managers, and debt holders [16]. Coordination costs are the charges of exchanging products or services as well as the indirect production expenses. There are three different types of efforts to coordinate the actions between specialized agents: obtaining information, cost coordination and costs of measurement. Stigler identified costs of obtaining information [17]. Costs of coordinating input in production have been identified by Alchian and Demsetz [18] and Barzel noted costs of measurement [19].

Also being ingrained in Multi-Agent research, there is already some work considering trust and reputation-based approaches in Grid Computing. The differentiation of trust can be found in [20]. The authors distinguish between two steps of trust: verifying the identity of an entity and what that identity is authorized to do and as a second step the monitoring of entities' behavior. Like the authors, in this paper we concentrate on the behavioral trust which is amended through reputation information. In [21] the authors present a comparison of different trust mechanisms and their applicability for task scheduling in Grid Systems. Alunkal et al. [22] present their GridEigenTrust framework to manage trust and reputation in a Grid System. Therefore they extend a common P2P reputation management mechanism, called EigenTrust. In contrast to the work of Alunkal et al., our framework focuses on the necessarity of reputation regarding the Grid characteristic.

Illustrated in figure 2, our aim is to integrate these research areas and generating an integrated approach. This economically motivated approach meets the problem of asymmetrically distributed information in Grid environments with help of reputation where necessary. The idea of using markets to allocate resources and services in Grid environments is proposed by different researchers like [23] and [24].

Demonstrated by the work of Schnizler [25, p. 31 et seqq.], markets provide incentives to express true values for service requests and offers. This leads to efficient resource allocation. Schnizler differs between static (fixed prices) and dynamic price models. The latter one considers the dynamic availability of resources in a Grid. Our work intends to demonstrate under which conditions a certain form of resource allocation makes sense and what kind of policies have to be defined.

There are several projects with the intention to integrate these research areas. The project GridTrust[1] focuses on a secure technical infrastructure for Grid Systems. The project also addresses the integration of reputation-based concepts to enhance users' confidence. Another related project is CONOISE-G [2]. This project regards the term "virtual organization" as a special form of an open system [26]. In our understanding a virtual organization is a hybrid coordination form (having characteristics of both markets and hierarchies), using a contractual framework between participants. Consequently, our understanding of trust and reputation differs in some aspects.

A truly open Grid market environment, where resources and services can be traded freely, is envisioned in the SORMA project[3]. SORMA intends to establish an open Grid platform where multiple providers and consumers are able to trade Grid resources and services. The eRep project[4] intends to develop a reputation-based mechanism for e-commerce and Grid commerce environments. Both projects are currently running with the authors' participation.

[1] http://www.gridtrust.eu
[2] http://www.conoise.org/
[3] http://www.sorma-project.org
[4] http://megatron.iiia.csic.es/eRep/

3. Framework

This subsection considers the economic motivation of confidence-building activities in Grid economies. The classification to illustrate the problem of uncertainty in economics [17] is based on findings of agency problems in economics. These problems base on the fact that information in economies is usually distributed asymmetrically. However, environmental factors can also lead to uncertainty, which means that only a part of the technological infrastructure used by the participants in a Grid economy is under their influence.

Asymmetric distribution of information appears, if a market participant has more information through its position than another participant. For example, a service provider has more information regarding the provided service than a potential service consumer. Thus, the consumer has to overcome this uncertainty before the agreement is signed. However, the uncertainty regarding the technical infrastructure concerns both, consumer and provider. In the following we focus on asymmetric distributed information between grid participants.

Akerlof [27] describes in his article about a market for "lemons" the problem of uncertainty regarding the quality of second-hand cars. Akerlof's findings can be applied for Grid economies, where the resources represent heterogeneous goods. To reduce the uncertainty, institutional economics provides different concepts to reduce the costs of uncertainty for participants. They focus on the analysis of incomplete and asymmetrically distributed information. This asymmetry leads to imperfect markets as a consequence of uncertainty. As an effect of imperfect markets agents are impeded to act rational.

We differentiate between *hidden characteristics* and *hidden action* to explain the problems occurring in Grid economies. The third causation, which is mentioned in literature, the *hidden intention*, is excluded in further reflections due to its missing relevance in Grid economies. All uncertainty types refer to market failure.

Through hidden characteristics, the fact that not both parties know all relevant attributes, the problem of "adverse selection" [27] arises. There is uncertainty regarding to the effort's quality. The effects of these problems can be limited through some activities. Such an activity is the so called signaling, the active forwarding of information. The market participant, who is better informed, publishes this missing information with e.g. exogenous cost signals or contingent contracts. Another approach to overcome this asymmetric information distribution is screening. The less informed participant undertakes endeavors to retrieve the required information about its partner.

Besides standardization of services and products, the provision of different and differentiated contracts is another possibility to diminish the problem of adverse selection. The service provider can choose one contract with a certain quality level. Based on this choice, the service consumer can draw conclusions about the reliability of the provider.

Hidden action (also an uncertain behavior of agents) follows the so called effect of moral hazard. In contrast to adverse selection, the provider's behavior or quality of the service is not even observable after the transaction occurred. Moral hazard means that the principal and the agent have the same relevant information before and after signing the contract. But after a decision, which is relevant for the output, the agent has more information about its activity and the outcome of this action. In particular the principal can not assess whether the observed results originate in agents efforts or environmental influence. To solve this problem, the agent has to be part in the outcome of its activities. In our Grid-related case it is conceivable that an agent can profit from its rising reputation (e.g. after fulfilling a job).

Confidence-building measures are helpful for reducing risk within transactions between Grid participants. As mentioned above, there is a relationship between confidence-building measures and Grid coordination forms. Presuming an understanding of the structure of transaction costs the amount of those costs determine which coordination form is most efficient. As Williamson has shown, specific contracts define and provide rules for each form of coordination [28] and [29].

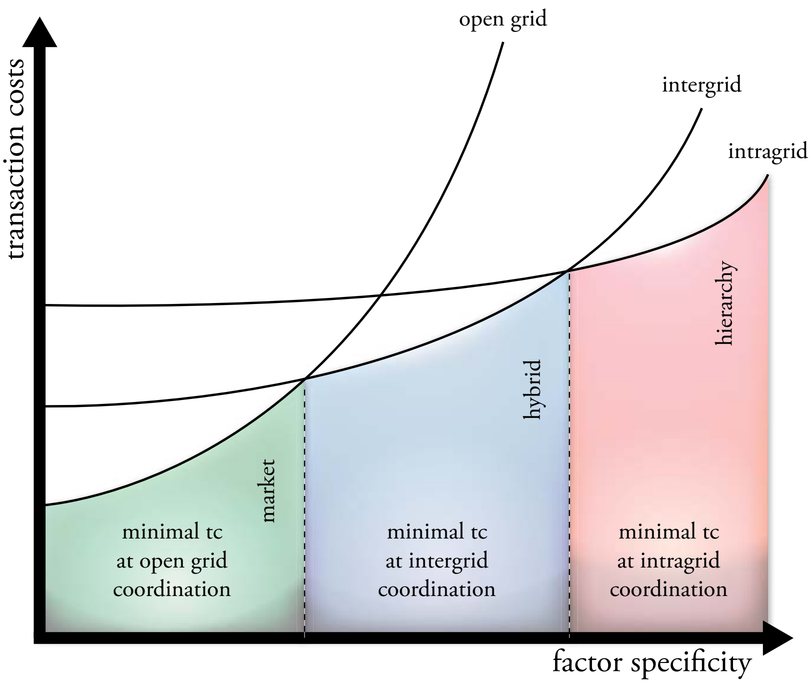

FIGURE 3. Forms of Grid Coordination

Beside the transaction costs the specificity of goods to be traded is of great interest for the selection of the appropriate coordination form. The degree of specificity is measured by comparing the economic value to the value of the next best alternative good. The higher the difference, the more specific is the product or service. The project CATNETS[5], funded by the European Union (EU) and coordinated at our department, provides a Grid-related example for different specific services. There are basic services (corresponding to lowly specific products) and complex services (corresponding to highly specific products) within the catallaxy-based Grid market (see e.g. [30]).

The possible types of coordination range from both extremes, open Grid to Intragrid with the Intergrid in between[6], see also figure 3.

3.1. Intragrid

The term Intragrid describes the connection of several computers or clusters within an organization. Participant is, in this case, only one company that wants to increase its extent of in-house resource utilisation. The distribution is delimited on one place, namely the location of the organisation, or at a more technical view, its local area network.

Hierarchies are marked by asymmetrical and long-term connections between entrepreneur and employees. From an outside view the hierarchy appears as a uniform institution. The hierarchy usually solves the economizing problems by means of rules instead of prices and by controlling through an administrative structure. However, the usage of enterprise internal prices (without reference to the market), mainly for billing and accounting reasons, is not excluded. Current Grid Implementation are structured hierarchical, which we call Intragrid. Intragrids are subject to institution wide regulations. The control intensity within this coordination form is high. The situation of asymmetric information distribution does not appear when strong controlling instances are existing. In the following we abstract from tragedy of the commons problem [31] in hierarchy scenarios. Two concurrent departments of a single company that compete for company bonus payments are institutionally embedded as long as they do not have access to markets.

The incentive intensity within an Intragrid is low due to employment contracts. Existing agreements are fulfilled. However, an outperformance of quality of service attributes is not expected due to the contract structure. Unlike classical employment contracts, we do not consider owner employment relationships. There are only service or resource provider and consumer to be analyzed within an Intragrid. Both are bound to the strict hierarchy frame of rules.

3.2. Intergrid

An Intergrid is a pool consisting of several Intragrids with help of a framework agreement. The most significant attribute in contrast to an Intragrid is the allocation across organizational boundaries.

There are varied options for a creation of coordination forms between hierarchies and markets. The appropriate hybrid form can be chosen individually.

[5]http://www.iw.uni-karlsruhe.de/catnets/

[6]The original terms of coordination forms by Williamson are hierarchy, hybrid and market which are used in the following for explaining the theoretical derivations of our approach

This situation is characterized by a bilateral dependence between contractual partners. The economic term is called neo-classical contract. In the Grid context, the union of several Intragrids leads to a hybrid coordination form, we call Intergrid. Distinct from hierarchies, an Intergrid constitutes a collaboration between legally independent institutions. The inter-institutional agreement includes a higher incentive intensity, but a lower control intensity than the hierarchy type. According to the lower control intensity the Intergrid needs reputation-based mechanisms for compensating the inherent risk. Usually, framework agreements are made where the price and the valid contract period are fixed.

3.3. Open Grid

Market relations appear in a symmetrical and short-term nature. The market operates with decentralized, price-oriented mechanisms, in which the large number of buyers and sellers limit the scope for opportunistic action. The form of contracts used in this form of coordination are called classical contracts. The very low control intensity in comparison with hierarchy and hybrid form requires even better trust and reputation-based mechanisms. Our approach is taking advantage of the high incentive intensity of the market structure to reduce asymmetric distributed information and the associated risk.

The vision of a complete virtualisation of information and communication infrastructure by the provision of resources like cpu cycles, data storage or memory capacity over Grid infrastructures allows the development of an open Grid market. In this case, resources are supplied and consumed both within one company or research institution as well as across organizational borders. In an open Grid the number of participants can not be determined. The distribution is characterised by full transparency with regard to the participants. While the technological infrastructure was given great attention in recent research during the last years, the spheres of business and rules are widely uninvestigated. Open Grid markets offer the greatest opportunity in order to analyze economical logic and rules because they are nearest to a physical world market structure. Open Grid markets are yet not fully implemented. The project SORMA, funded by the EU, takes up this issue. SORMA deals with an technological implementation as well as potential business models and rules. Another EU-funded project, called eRep, focuses on describing and evaluating rules in open Grid markets. Both projects have just been started.

This subsection has shown the connection of transaction costs and organization forms as well as asymmetric distributed information and reputation. Changes in the coordination form of Grid Computing determine, ceteris paribus changes in the policy infrastructure. Also the reputation-based mechanisms to be support this change. This section elaborates the differences within the Grid coordination forms mentioned. The infrastructure spheres connected with our Grid Classification Framework offers good analysis possibilities. Only by the usage of the framework it becomes clear that infrastructure spheres must be considered under completely different views. Thus, the structure of the following section is subdivided by the Classification Framework with its particular infrastructure spheres.

4. Implementation in different Grid Coordination Forms

This section implements the usage of the theoretical framework of the previous section. To keep analogy to that section, the section is subdiveded also into Intragrid, Intergrid and open Grid. Each subsection follows the partition of the infrastructure spheres, i.e. Business, Policies and Technology.

4.1. Intragrid

4.1.1. Business. The deployment of small scale grids, in particular Intragrids as described in section 3 can help enterprises to minimize capital expenses through the aggregation of servers, storage, memory and cpu capacity. In addition, Intragrids can also provide an option for on-demand access to resources' needs as necessitated in the scope of particular demands (e.g. problem solving or seasonal capacity requirements). In the following we illustrate an Intragrid business case related to practice.

Many enterprises' computing centres are organized as cost or profit centers [32]. A cost center is strictly integrated in the firm's form of organization. An information systems cost center within an enterprise has no organizational differences to accounting or human resources departments. Services are provided to support internal processes. In most cases the coordination of information systems is ensured over a predetermined budget (traditional cost center). If necessary there is back charging for internal cost allocation (advanced cost center or profit center model). Pricing and accounting plays an inferior role in this scenario. The customer (in this case, the enterprise) demands a determined quality of service. The provider (the cost center) must meet this demand with the required quality of service level. Otherwise the enterprise will think about a budget adjustment or a personnel replacement within the department. The Intragrid scenario depicts a situation of maximum control and maximum chance enforcing claims due to unsatisfied service customers inside the enterprise. This gain of control and flexibility comes along with drawbacks to in-house expertise, scalability, innovation, coordination costs, etc.

4.1.2. Policies. The principal-agent relationship, determines the existence of different institutions [33]. In this section, only one of the possible institutions, namely the hierarchy unit, is considered. Within the hierarchy unit an agreement about the policies has to be established. This agreement can be an explicit or an implicit one.

In an Intragrid, whose range is limited to a hierarchy unit, the body of rules and regulations can be defined in a certain way (see e.g. [34, p. 182]), so that no principal-agent problem occurs. For the Grid Systems, this leads to fixed prices for resources like cpu or disk space (internal prices). Following, no principal-agent conflict can be found within the Intragrid, if the policies are implemented adequately.

Figure 4 illustrates this simple relationship. The consumer pays a fixed price p_{intra} to receive a service s. For the consumer there is no kind of risk to be observed.

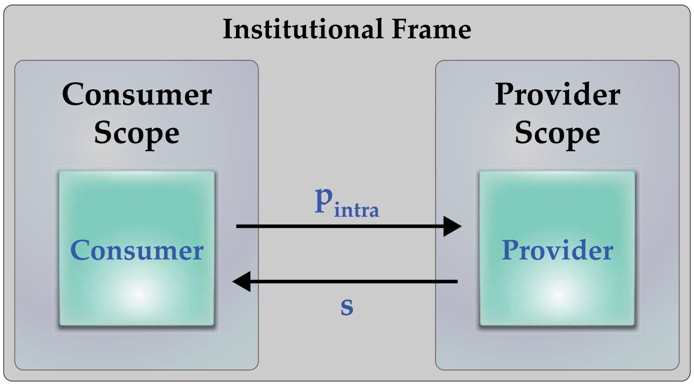

FIGURE 4. Relationship between service provider and consumer in an Intragrid

For the participants there is also no incentive for opportunistic activity, as there are fixed prices and the highest available quality of service level.

4.1.3. Technology. The technology of Intragrids is an unproblematic field. The network is only a local one, so that the availability of services and resources can be ensured. Possible failures of the network and other infrastructural components can be limited. Furthermore the problem of moral hazard, such an agent having problems to detect the origin of a failure, the defective service or the missing environment, can be solved. Moreover, external factors can be neglected, because of the purely internal nature of all transactions.

The implemented Grid system works by aggregating all available computational resources into a virtual resource pool. Resources that might remain idle are matched to the requirements of the job. Thus, large jobs can be spread out over all the systems on the Intragrid for increasing utilization. This rule-based mechanism within the software follows a strict institutional frame.

4.2. Intergrid

4.2.1. Business. The area of commercial Intergrid solutions is sparsely populated. Consider a scenario where, unlike the Intragrid scenario, an internal information system provider is not able or willing to meet the service level agreements. The enterprise is forced to react. In the Intragrid case mentioned above, the management could replace human resources or adjust the annual budget in hope of reaching the desired quality standards. However, it is also possible to get the required services from external suppliers. In this situation of the outsourcing process the enterprise will make a pre-selection of possible suppliers. The main problem in this situation is how to choose the best service provider and what the criteria are that matter. Intermediate results of an explanatory case study we are still carrying out show that there is a lack of applicable mechanisms, which could help in this situation.

The case study results also exhibit that small and medium sizes enterprises managed such situations with common sense. Thereby they use unconsciously trust- or reputation based approaches, for instance with aid of experiences made in the past or survey of customers who know these providers. These pragmatic approaches, which reflect the pragmatic business routines, comprise experiences made in the past. And as distinguished from practice our theoretical thoughts are adaptable to support both macro decisions (for instance the selection of a provider) and micro decisions (for instance the selection of atomistic services invocations within a distributed system). Assuming the enterprise chose a provider which has to deliver all the required services with desired quality in a determined time. In a further step a framework agreement has to be negotiated which defines the service requirements, the amount of services and the quality of service. In addition there are laid down penalties for delivering service quality which does not match with the values in the framework agreement. A typical framework agreement related to this case is a service level agreement in terms of the Information Technology Infrastructure Library (ITIL)[7].

4.2.2. Policies. In contrast to the Intragrids, policies are more interesting and of bigger importance in Intergrids. But the rules and regulations are more difficult to implement and to enforce (see, e.g. [12, p. 49]).

Pratt and Zeckhauser hold, that "whenever one individual depends on the action of another, an agency relationship arises" [33, page 2]. The agent, which is taking action for the principal, has usually an edge on information on the activity it has to fulfill. If the principal is not able to monitor the agent's actions on low costs, the challenge arises. In Grid environments this situation occurs, if markets (in this example Intergrid markets) are used to allocate resources. A service, which wants to meet the requirement, has to buy the needed resources in a market. To ease this situation Pratt and Zeckhauser [33] propose to construct a reciprocal relationship. That means, for each pair of interacting participants a principal-agency relation in the opposite direction has to be constructed. In other words, both participants have to be principal and agent at the same time.

The first relation is easy to construct: the consumer (principal) requests a service and the provider (agent) fulfills this guaranteed service. In figure 5 the price, which has to be paid for the received service s, is denoted by p_{inter}. The prices are determined through the framework contract all participants have signed. This contract defines the time period it is valid, the price for the service, the service's definition and a reputation threshold all service providers have to fulfill. The figure also illustrates the different scopes the Grid agents have.

To meet the second principal-agent relation a reputation mechanism has to be established: the principal of the first case is now the provider of a (potentially good) reputation value and therefore fulfills the role of an agent. The service provider, in the first case the agent, is now acting as principal, which pays with quality of service and receives a reputation value, which is functionally dependent

[7] http://www.itil.org.uk/

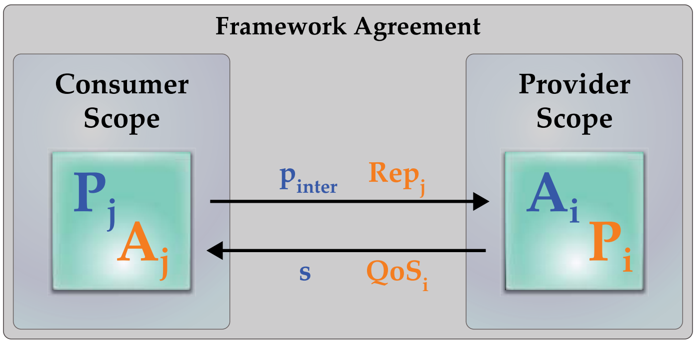

FIGURE 5. Principal-agent relationship between service provider and consumer in an Intergrid

on the quality of service. This reputation should be published for a huge amount of participants to increase its significance.

A deduction for risk is not paid, because the prices are fixed through the framework contract. In an economical view, this is an institution among all participants of the Intergrid. Reputation values are managed through the institution and used to exclude participants with an average reputation value under a certain threshold. This exclusion is technically realized through a central reputation mechanism, which is authorised to exclude participants. Reputation mechanisms are used to monitor the participants' behavior. One possible reputation mechanism is ReGreT, which has been proposed by Sabater and Sierra [35]. The effectiveness of further reputation mechanisms in Grid environments is investigated in Sonnek and Weissman [36].

In Intergrids and their business analogy, i.e. the virtual organisation, the reputation institution is usually implemented through central mechanisms. That conforms with the paraphrase above that a central unit is able to manage partners joining and leaving the system.

4.2.3. Technology. Current implementations of the upcoming Grid standards like the Web Service Resource Framework (WSRF)[8] or the Open Grid Service Architecture (OGSA)[9] from the Global Grid Forum fulfill the requirements of our Intergrid idea. All implementations, like gLite, Unicore or the Globus Toolkit provide functionalities to identify participants, basic security mechanisms etc. The software can be used also between different organisational units, but needs central registration points in the system.

[8]http://www.globus.org/wsrf/
[9]http://www.globus.org/ogsa/

4.3. Open Grid

4.3.1. Business. Besides outsourcing with use of framework agreements a market could also deliver the required services. The vision of an open grid market without a central institution is challanging. An open grid market does not address particular business models or services. It should rather be an independent platform for grid resource or service trade.

In the late 1990's the German telecom "Deutsche Bundespost Telekom" was privatized. New competitors joined the telecommunication market. To participate in the market of telephony provider services a system of dial around service prefixes for every provider was established. For instance a customer was able to choose a particular telephony provider with specific characteristics (price, quality) on demand without concluding a framework agreement. Since most of the providers were unknown to the customers thus the price was the only differentiator. After a certain time differences in the quality of service became obvious. These quality-based characteristics were not reflected by the price. This anomaly in digital service delivery have not been examined in the literature in detail, probably because of the short existence. The dial around service offers have been displaced by framework agreements (e.g. flat rates). Nowadays we are confronted with a very similar situation. Grid Computing resources like memory capacity or cpu cycles are offered as a service. Without having a framework agreement there is no possibility to enforce customers' claims because providers and customers are often unknown to each other. To compensate this lack of certainty the pre-selection of providers gains importance. For this reason we follow a trust- and reputation based approach to make rational pre-selection possible. Another possibility to deal with this uncertainty is an insurance approach, which we do not follow in this paper.

4.3.2. Policies. Being an open system, the problem of different interests of participants in the Grid economy increases. Not every single claim can be assigned to a natural person. Constructing a reciprocal principal-agent relation is very important in open systems. We propose, as in Intergrids, to establish a reputation mechanism in open Grid systems.

The missing framework contract leads to a deduction of risk r_i for each service contract. The consumer has to pay this deduction of risk less, but receives a risk $Risk_i$ in addition to the service (see figure 6). The deduction of risk is determined through market behaviour. It is on behalf of a service provider to have a good reputation in order to decrease this deduction of risk. Since the reputation is functionally dependent on the provided quality of service (QoS), the QoS is finally responsible for the deduction of risk of the following contracts. Hence, the service provider should always fulfill the expected quality standards.

The service consumer, as counterpart, receives the service and the risk of an uncertain execution (e.g. the service is not executed as the provider has promised before). This risk can affect the execution time, the correctness of the outcome, and so on. The consumer is not able to determine the risk before interaction takes

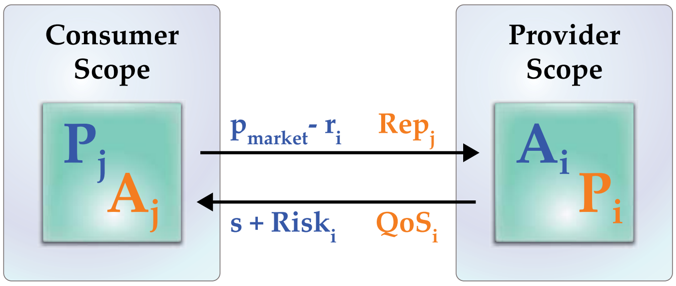

FIGURE 6. Principal-agent relationship between service provider and consumer in an open Grid

place. He can only estimate the risk through own experiences with the provider or experiences, which can be requested from other system members.

As there is no central institution to manage reputation values, we propose to implement a decentral mechanism. With the help of this decentral reputation approach, the service consumer is able to optimize its outcome when choosing a negotiation partner with help of its strategy. The service provider has to optimize its strategy in providing a certain quality of service level as it is the base of the reputation received after the interaction.

In contrast to the reputation mechanisms in Intergrids, the mechanisms in open Grids are used to select services. In Intergrids, for each service provider in a market it is important to have a reputation value above the institutional manager's threshold. Each service provider has to consider its reputation to minimize its deduction of risk r_i. Another difference regards excluding low rated participants. Within an open system, there are no institutions for regulating and enforcing rules. Hence the meaning of reputation in open Grids increases.

In this paper reputation is understood as circulation of an evaluation. The evaluation's source is unimportant, it might also be unknown. Together with an image, which is a believed evaluation of a target, reputation leads to trust [37]. For instance, the Grid agents can lie while propagating reputation. As an effect, agents receive bad reputation and get less profit through a higher deduction of risk. Pinyol et al. [37] propose a cognitive approach to minimize the cheaters' outcome. One possible cognitive approach is Repage [38], which is enhanced in the eRep project. Since this paper is not addressing reputation mechanism design, we refer to the references mentioned above.

4.3.3. Technology. The technology development for example in SORMA has not been finished yet. However, with the de facto standardization of resource descriptions on a service basis (WS-Agreement) the technical prerequisites of trading resources on markets have been made. In addition, the project tries to reconcile the technological and policy sphere in the development of an economical sound and technically feasible open Grid market that is extended by intelligent tools.

Those tools are to be facilitating the bargaining and proving advantages for market participants. Considering this ongoing process we refer to the SORMA web page mentioned above.

5. Conclusion and Future Work

This paper examined the role of reputation in grid environments. Our comprehension of grid environments incorporates the three basic perceptions technology, business and policy. In addition, we depicted the mutual dependence of these spheres. The success of an encoring business model does not only depend on the underlying technology. The realization of a business concept crucially depends on the institutional conditions. For an understanding of these rules, which form institutions, it is necessary to make an excursion in economical theory. Institutional economics provide the instruments for enabling the illustration of reputation-based mechanisms in grid environments as well as an explanation of different expansions of grids. Our approach addresses the difference among the coordination forms of grids. Namely the importance of the policy sphere depends on the coordination form. The coordination form, in turn, determines which reputation mechanism is necessary. In this paper, we introduced three policy concepts corresponding to the different grid expansions. Recommendations can be derived, which form of coordination fits best for each business model.

Finally further work should be done in refining the practical relevance of our framework. Intermediate results of an empirical study we are carrying out, briefly mentioned in section 4, do show the importance of reputation in particular forms of Grid coordinations. Final results will show whether there is a necessity of implementing reputation based mechanisms like our approach to facilitate trade of resources in open Grid markets.[10] Research is also required in refining our formal derivation of risk and reputation. Therefore our model has to be evaluated which is a future task of project eRep.

[10] These results are being published in the context of project SORMA

References

[1] I. Foster, C. Kesselman, J. Nick, and S. Tuecke, "The physiology of the grid: An open grid services architecture for distributed systems integration," 2002.

[2] G. Mller, T. Eymann, and M. Kreutzer, *Telematik- und Kommunikationssysteme fr die vernetzte Unternehmung*. Oldenbourg, 2003.

[3] E. Adar and B. A. Huberman, "Free riding on gnutella," *First Monday*, vol. 5, no. 10, 2000.

[4] T. Eymann, "The infrastructures of autonomic computing," *The Knowledge Engineering Review*, vol. 21, pp. 189–194, 2006.

[5] K. Krauter, R. Buyya, and M. Maheswaran, "A taxonomy and survey of grid resource management systems for distributed computing," *Software – Practice and Experience*, vol. 32, pp. 135–164, 2002.

[6] H. Rotithor, "Taxonomy of dynamic task scheduling schemes in distributed computing systems," in *IEEE Proceedings on Computer and Digital Techniques*, vol. 141, 1994, pp. 1–10.

[7] T. Braun, H. Siegel, N. Beck, L. Boloni, M. Maheswaran, A. Reuther, J. Robertson, M. Theys, and B. Yao, "A taxonomy for describing matching and scheduling heuristics for mixed-machine heterogeneous computing systems," in *Proceedings IEEE Workshop on Advances in Parallel and Distributed Systems*, 1998.

[8] R. Buyya, D. Abramson, J. Giddy, and H. Stockinger, "Economic models for resource management and scheduling in grid computing," *Concurrency and Computation: Practice and Excperience*, vol. 14, pp. 1507–1542, 2002.

[9] R. J. Anthony, "Generic support for policy-based self-adaptive systems," in *DEXA Workshops*, 2006, pp. 108–113.

[10] G. Tonti, J. M. Bradshaw, R. Jeffers, R. Montanari, N. Suri, and A. Uszok, "Semantic web languages for policy representation and reasoning: A comparison of kaos, rei, and ponder," in *The SemanticWeb - ISWC 2003*, 2003.

[11] J. uk In, P. Avery, R. Cavanaugh, and S. Ranka, "Policy based scheduling for simple quality of service in grid computing," in *IPDPS*, 2004. [Online]. Available: http://csdl.computer.org/comp/proceedings/ipdps/2004/2132/01/213210023babs.htm

[12] V. Welch, F. Siebenlist, I. Foster, J. Bresnahan, K. Czajkowski, J. Gawor, C. Kesselman, S. Meder, L. Pearlman, and S. Tuecke, "Security for grid services," in *International Symposium High Performance Distributed Computing (Seattle, WA, June 2003)*, 2003, pp. 48–57. [Online]. Available: citeseer.ist.psu.edu/welch03security.html

[13] R. H. Coase, "The nature of the firm," *Economica*, vol. 4, pp. 386–405, 1937.

[14] O. E. Williamson, *Markets and hierarchies: analysis and antitrust implications: a study in the economics of internal organization.* Free Press, 1975.

[15] P. R. Milgrom and J. Roberts, *Economics, organization and management.* Prentice-Hall Englewood Cliffs, NJ, 1992.

[16] M. Jensen and W. H. Meckling, "Theory of the firm: Managerial behavior, agency costs and ownership structure," *Journal of Financial Economics*, vol. 3, pp. 305–360, 1976.

[17] G. Stigler, "The economics of information," *The Journal of Political Economy*, vol. 69, pp. 213–225, 1961.

[18] A. A. Alchian and H. Demsetz, "Production, information costs, and economic organization," *The American Economic Review*, vol. 62, pp. 777–795, 1972.

[19] Y. Barzel, "Measurement cost and the organization of markets," *Journal of Law and Economics*, vol. 25, pp. 27–48, 1982.

[20] F. Azzedin and M. Maheswaran, "Evolving and managing trust in grid computing systems," 2002.

[21] ——, "Integrating trust into grid resource management systems," in *International Conference on Parallel Processing, 2002. Proceedings*, 2002, pp. 47–54.

[22] B. Alunkal, I. Veljkovic, G. von Laszewski, and K. Amin, "Reputation-based Grid Resource Selection," in *Workshop on Adaptive Grid Middleware*. New Orleans, Louisiana: AGridM 2003, September 2003.

[23] R. Buyya, J. Giddy, and D. Abramson, "A case for economy grid architecture for service-oriented grid computing," in *Proceedings of the 10th IEEE International Heterogeneous Computing Workshop (HCW 2001)*, 2001.

[24] R. Wolski, J. S. Plank, J. Brevik, and T. Bryan, "Analyzing market-based resource allocation strategies for the computational grid," *International Journal of High Performance Computing Applications*, vol. 15, no. 3, pp. 258–281, Fall 2001.

[25] B. Schnizler, "Resource allocation in the grid," Ph.D. dissertation, University of Karlsruhe, 2007.

[26] J. Patel, L. Teacy, N. R. Jennings, M. Luck, S. Chalmers, N. Oren, T. J. Norman, A. Preece, P. Gray, G. Shercliff, P. J. Stockreisser, J. Shao, W. A. Gray, and N. J. Fiddian, "Monitoring, policing and trust for grid-based virtual organisations," in *The UK e-Science Programme All Hands Meeting (AHM 2005)*, 2005.

[27] G. A. Akerlof, "The market for 'lemons': Quality uncertainty and the market mechanism," *The Quarterly Journal of Economics*, vol. 84, pp. 488–500, 1970.

[28] O. E. Williamson, *The economic institutions of capitalism*. Free Press, 1985.

[29] ——, "Comparative economic organization: The analysis of discrete structural alternatives." *Administrative Science Quarterly*, vol. 36, pp. 269–296, 1991.

[30] T. Eymann, O. Ardaiz, M. Catalano, P. Chacin, I. Chao, F. Freitag, M. Gallegati, G. Giulioni, L. Joita, L. Navarro, D. Neumann, O. Rana, M. Reinicke, R. C. Schiaffino, B. Schnizler, W. Streitberger, D. Veit, and F. Zini, "Catallaxy-based grid markets," in *Proceedings of the First International Workshop on Smart Grid Technologies (SGT05)*, 2005.

[31] G. Hardin, "The tragedy of the commons," *Science*, vol. 162, pp. 1243–1248, 1968.

[32] J. Barthlemy and D. Geyer, "An empirical investigation of it outsourcing versus quasi-outsourcing in france and germany," *Information & Management*, vol. 42, pp. 533–542, 2005.

[33] J. W. Pratt and R. J. Zeckhauser, *Principals and Agents*. Havard Business School Press, 1991, ch. 1, pp. 1–35.

[34] K. Czajkowski, S. Fitzgerald, I. Foster, and C. Kesselman, "Grid information services for distributed resource sharing," in *10th IEEE International Symposium on High Performance Distributed Computing*, 2001, pp. 181–194.

[35] J. Sabater and C. Sierra, "Regret: A reputation model for gregarious societies." in *Fourth Workshop on Deception Fraud and Trust in Agent Societies*, Montreal, Canada, 28 May - 19 June 2001, pp. 61–70.

[36] J. D. Sonnek and J. B. Weissman, "A quantitative comparison of reputation systems in the grid," in *GRID '05: Proceedings of the 6th IEEE/ACM International Workshop on Grid Computing*. Washington, DC, USA: IEEE Computer Society, 2005, pp. 242–249.

[37] I. Pinyol, M. Paolucci, J. Sabater-Mir, and R. Conte, "Beyond accuracy. reputation for partner selection with lies and retaliation." in *MABS*, 2007.

[38] J. Sabater, M. Paolucci, and R. Conte, "Repage: Reputation and image among limited autonomous partners," *Journal of Artificial Societies and Social Simulation*, vol. 9, no. 2, 2006.

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This paper examines the role of policies in different grid environments. As Grid technology becomes standardized and stable, various business models are invented and increasingly applied, and economic implications can be observed. Asymmetrically distributed information may allow for opportunistic behaviour of service providers or users who exploit the information gap between providers and consumers on the quality of services. This information gap determines the necessity of policies to keep the Grid system stable. Therefore this paper tackles economic issues by proposing a trust and reputation-based policy framework for enabling future open Grid markets, to recommend the most promising Grid architecture and a corresponding reputation approach in a particular case.

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