SORMA - Business Cases for an Open Grid Market: Concept and Implementation

Jens Nimis[1], Arun Anandasivam[2], Nikolay Borissov[2], Garry Smith[3], Dirk Neumann[4], Niklas Wirström[5], Erel Rosenberg[6], and Matteo Villa[7]

[1] FZI Forschungszentrum Informatik Karlsruhe, Germany,
nimis@fzi.de
[2] Institute of Information Systems and Management (IISM)
University of Karlsruhe, Germany
{anandasivam,borissov}@iism.uni-karlsruhe.de
[3] School of Systems Engineering, University of Reading, UK
garry.smith@computer.org
[4] Department of Information Systems, University of Freiburg, Germany
dirk.neumann@vwl.uni-freiburg.de
[5] Swedish Institute of Computer Science, Sweden
niwi@sics.se
[6] Correlation Systems Ltd., Isreal
erel@cs.co.il
[7] TXT e-Solutions, Italy
matteo.villa@txt.it

Abstract. Economic mechanisms enhance technological solutions by setting the right incentives to reveal information about demand and supply accurately. Market or pricing mechanisms are ones that foster information exchange and can therefore attain efficient allocation. By assigning a value (also called utility) to their service requests, users can reveal their relative urgency or costs to the service. The implementation of theoretical sound models induce further complex challenges. The EU-funded project SORMA analyzes these challenges and provides a prototype as a proof-of-concept. In this paper the approach within the SORMA-project is described on both conceptual and technical level.

1 Introduction

Until now, the exchange of computing resources has been mainly driven by voluntary sharing in non-profit settings via small-scale Grid networks. The free sharing concept is, however, not applicable in large-scale scientific and commercial networks. Participants tend to free-ride aiming to reduce costs [1]. In particular, they will consume without offering own resources. Technical scheduling algorithms for fair sharing are often centralized, and have problems, when organizational boundaries are crossed, and information about demand and supply can be manipulated. More precisely, if demand exceeds supply, the scheduling algorithms fail to allocate the resources efficiently.

Economic mechanisms enhance technological solutions by setting the right incentives to reveal information about demand and supply accurately. Market or pricing mechanisms are ones that foster information exchange and can therefore attain efficient allocation [14]. By assigning a value (also called utility) to their service requests, users can reveal their relative urgency or costs to the service [9, 13]. The mediated resource allocation and delivery over the market will allow better utilization of available resources, which automatically directs those resources provided to the clients, who value them most.

The EU-funded project SORMA[8] is designing and implementing an Open Grid Market and will test it in real world use cases. To establish an Open Grid Market in practice, there are several obstacles that have to be overcome. The bidding process cannot be managed manually as it is too complex and time-consuming, so there is a need for intelligent tools, which simplify access to Grid-based systems in a way that businesses are empowered to make use of them. In essence, these intelligent tools must support the automation of the bidding process, which is dependent on the resource supply situation and business policies. Additionally, the Open Grid Market has to be equipped with intelligent monitoring tools that gather resource information frequently in order to correct unexpected events such as demand fluctuations or failure to share resources. Other aspects like the structured design of market mechanisms, contract management and a market information service are part of the Open Grid Market as well.
In this paper, we focus on the implementation and the first running prototype in SORMA. Our scenario is based on the business cases from our partners TXT e-Solution and Correlation Systems. In their applications the Grid is applied to process amounts of forecast data and to analyze video streams in real-time as described in Section 2. Section 3 gives an overview of the architecture and describes the prototypical implementation of the selected entities. Section 4 concludes with a summary and an outlook.

2 Pilot Applications

SORMA comprises an application infrastructure integrating theoretic economic models to construct a general Open Grid Market platform. The assessment of the SORMA platform as well as the developed theoretic models is realized via two pilot Grid applications that will be run on the final SORMA system. The pilots are a Supply Chain Management software and a geospatial data analysis software provided by SORMA partners TXT e-Solutions[9] and Correlation System Ltd.[10], respectively.

[8] http://www.sorma-project.eu
[9] http://www.txtgroup.com/
[10] http://www.correlation-systems.com/

2.1 Supply Chain Management with TXTDemand

TXTDemand is a demand forecasting tool and part of TXT's Supply Chain Management suite. It combines complex forecasting algorithms as well as algorithms for the analysis of historic data and current sales data with interactive revision tools. Business analysts from the customers of TXT have access to TXTDemand to get support in their daily tasks of defining demand and replenishment strategies. Time-critical jobs process previous days' sales data over night and create initial forecast plans, which are analyzed by the business experts during the following day. This application has recently adopted a grid-based architecture in order to solve performance problems when used in business scenarios involving very large amounts of data. The Grid support is required in the following two situations:

- The night BATCH phase, where data is processed off-line, implies "slowly" changing request of grid resources, since the number of records to process is more or less stable over time. Daily or weekly, there can be small variations that require negotiation of new resources on the Grid market. Execution duration is a critical factor here, since it should start and also finish at a quite precise time.
- In the INTERACTIVE phase end-users need to access the application online. In this case, the request for Grid resources depends on everyday human activities, so there can be unpredictable peaks of requests within a short period of time. In contrast to the BATCH phase, start and finish times cannot be planned, while again execution duration needs to be kept as low as possible.

In the scenario TXT assumes to have customers, who do not have the technical infrastructure (or are not economically interested into having it) for running the application, thus they rely on third party's resources (resource providers). The role of TXT is to act as an application broker by offering ASP service to its customers. The application portions jobs to be run on the Grid. Therefore, a market is required to achieve the best price for each job-part and to prioritize time-critical jobs by adjusting the price. The market has to support third party framework agreements (i.e. concerning Service Level Agreement (SLA) issues, security, etc.) in order to provide a substantial level of quality of service (QoS). The prices for the jobs can be defined dynamically in an agreement depending on submission time, execution time and duration. A bid generator facilitates the strategic price adaptation. As outlined in Figure 1, the customer is not aware of the Grid market. Instead TXT buys the required Grid resources on the market on demand. The goal is to ensure a better QoS to customers to reduce cost and to enhance the resource utilization.

In some business situations, customers may want to host the application. Yet, they may need to outsource the computational power required for the most CPU- and data-intensive computations. Then, TXT can no longer act as a broker, but TXTDemand application at customer's site will need to negotiate directly on the SORMA market to find a suitable resource provider. This scenario poses

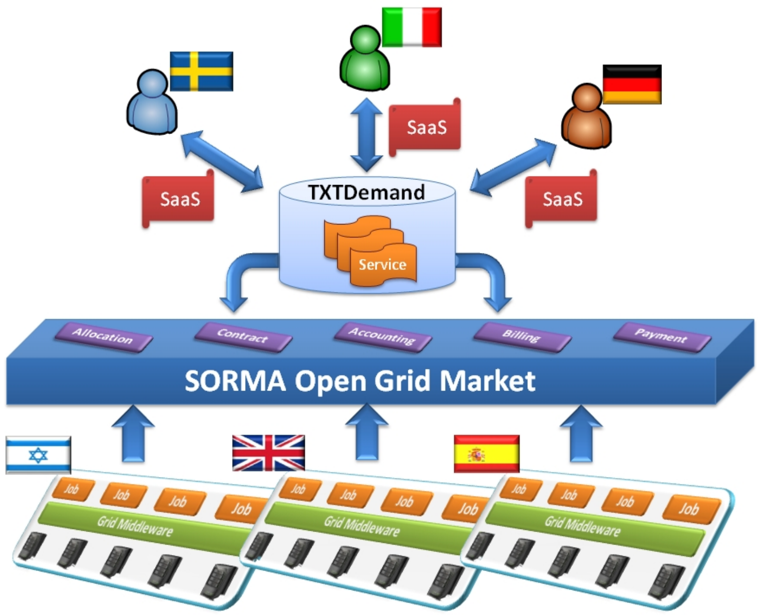

Fig. 1. Integration of TXTDemand with the Open Grid Market

more technically challenging requirements, as the market access and negotiation process need to be fully automated. Moreover, the business benefits for both TXT and its customers is harder to demonstrate. The access to the SORMA market via the TXTDemand application enables the customer to lower their investments in hardware infrastructure.

2.2 Real-time Geographical Data Analysis

Correlation Systems Ltd. is a provider of geospatial data analysis tools and applications. The core software platform of Correlation Systems provides an execution environment for geospatial data analysis, geographic data mining and a self-learning behavioral analysis system. The software is able to receive geospatial information from multiple types of data sources including GPS receivers, cellular networks, analytical video surveillance systems etc. The data from the different sensors are aggregated to a video stream with additional information. The transformation from incoming sensor data to a video stream consumes vast amounts of computing power. Since data can be split into smaller chunks and thus the jobs can be parallelized, a Grid network can significantly improve the response time of the application. Customers can view the results using a graphical interface (Figure 2). Furthermore, customers can define alert rules to receive pictures, if a predefined event occurs in the stream. In this case, the picture is further analyzed and results in a picture with more detailed information, which requires more computing power.

Both processes are characterized by a large number of atomic operations where the processing results may influence on the next processing steps. For example, while processing a video stream the system receives N frames per second, where the pre-processing is responsible for the following tasks:

- Detection of motion
- Detection of object (i.e. body, face)
- Localization of the objects.

Pre-processing is performed in sequence, where a following processing step is only performed, if the previous one has completed successfully and has delivered a result that gives reason for further processing steps. Data reduction may be performed in case of a lack of resources, by reducing the data rate of the video stream. Due to the characteristics of the process, it is important to minimize the overhead related to each specific transaction and if necessary to conflate smaller processing steps into larger ones in order to minimize transaction costs. The system is required to be fully automatic, i.e. users may define their strategy or rules regarding the resource allocation, however all decisions on the actual resource allocation are required to be performed in real-time.

3 Architectural Design of the Open Grid Market

The holistic approach of SORMA comprises several aspects like resource monitoring, market mechanisms, automated bidding, SLA or payment. Special business cases as defined in Section 2 require a generic market platform, where the exchange of resources and service are executed in a standard manner among different computer systems. Standard communication protocols and the virtualization from the underlying resource managers outline the openness of the market to offer access to the platform for other Grid systems like Amazon's Elastic Compute Cloud or Sun Microsystems' network.com [18]. A distinct definition of each component with specified tasks in the Market platform is inevitable for building a modular and flexible Open Grid Market. The logical architecture of the Open Grid Market represents entities and their dependency on other entities (Figure 3). The flow of information or control are depicted by arrows. An arrow from an entity A to an entity B means that A sends information to B or passes control to B.

3.1 Layered Architecture

Layer 4 represents the human interaction with the Grid application. At the provider side a provider IT specialist makes use of the intelligent tools in layer 3 to model the provider's business strategies and the offered Grid resources as well as to elicit the preferences of the user by the software agent. *Grid resource* in this context means a physical resource, a raw service or a complex service

Fig. 2. Demo Client of Correlation Systems' Motion Detection Application

[6]. SORMA will initially focus on the trading of "physical resources", but from a logical architecture standpoint, it is correct to consider that any type of resource or service could be offered at this layer. On the consumer side it has to be distinguished between the Grid application's end user(s) and the consumer's IT support staff who will use the intelligent tools to model an application's resource requirements and the consumer's preferences

On Layer 3 SORMA provides Intelligent Tools for consumers and providers in order to easily access the SORMA market. Four modeling entities allow consumers and providers to define their bidding strategies. Providers can choose between pricing policies to increase revenue, whereas consumers specify important technical requirements for their jobs. The bid and offer generator are applying machine learning strategies to adjust the bidding price. The aim is to achieve a better price on the market.

Layer 2 is the place, where the offered resources or services are assigned to the Grid applications of the consumers, following certain market organizations. A major role on Layer 2 is assigned to the *trading management*. It is the access

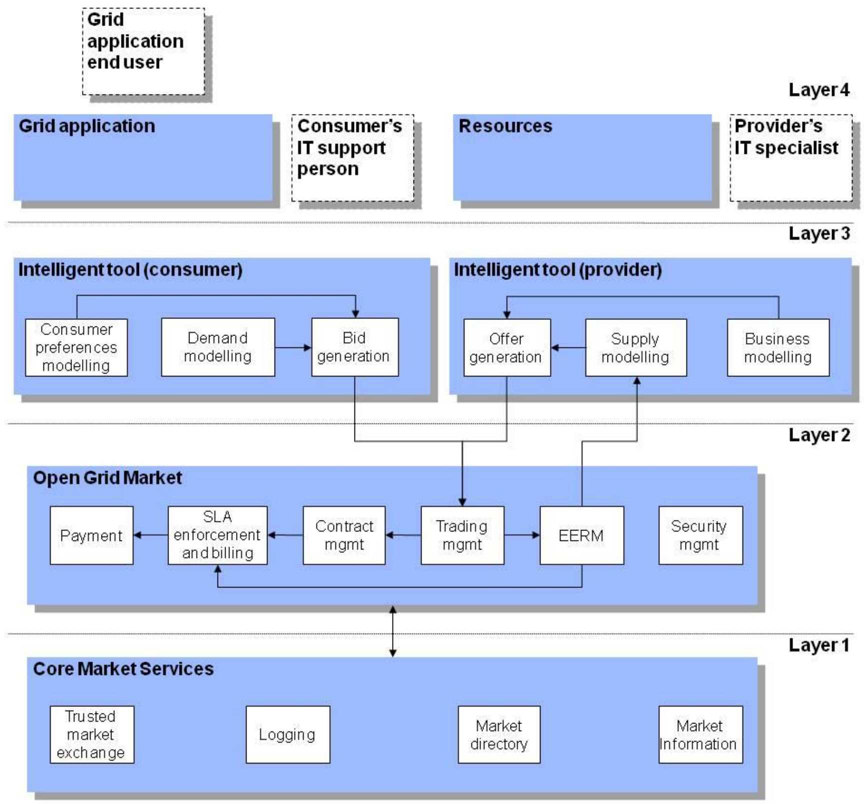

Fig. 3. Architecture of the Open Grid Market

point for the consumers to the Open Grid Market, where they can find the offered services and place their according bids. Therefore as a first step, the trading management matches the technical descriptions of the request (received from the consumers' bid generation) to the suitable technical descriptions of the offered resources (collected from the associated Grid market directories). In the second phase the trading management orchestrates the bidding process from the (possibly competing) consumers according to a given market mechanisms (e.g. English auction). If the bidding process finishes successfully the corresponding bid and offer are submitted to the contract management and the participants are informed.

The trading management is supported by the *contract management*, *SLA enforcement & billing* and the *payment component*. The interface between the resources and the market platform is provided by the *Economically Enhanced Resource Management (EERM)*. This component provides a standardized interface to typical Grid middleware (e.g. Unicore, Globus Toolkit or Sun Grid

Engine) and shields clients from resource platform specific issues by virtualization. Another essential task of EERM is to monitor the resource usage and check the compliance with the SLA. Information about resource usage deviating from the agreement have to be cleared or even punished according to the SLA. Since standard Grid middleware does not provide all the infrastructure services necessary for an open marketplace, on Layer 1 the available information of standard Grid middleware is augmented by additional infrastructure services including real-time logging, market information (historical information about former transactions) and market directory (current information about resources, prices etc.) For more details on the implemented SLAs we refer the reader to [5, 8, 17]. The security management component on Layer 3 is intended as the entry point for a single sign-on mechanism and is responsible for a tamper-proof identity management for the consumers, the suppliers and the constituent components of the SORMA system. Thus, all components that are developed as part of the SORMA system will have to provide security connectors to build the technological bridges from the respective layers to the security management.

3.2 Prototypical Implementation

One goal within the SORMA project besides theoretical models is to develop a running prototype as a proof-of-concept. Thus, we emphasis in this section the current implementation. The Demand and Supply Modelling Components support the users of the Intelligent Tools (Layer 3) to specify the technical aspects of their resource requests and offers respectively. This support comprises three main parts:

1. a user interface based on Gridsphere [19] to allow the input of the technical resource specifications on consumer and supplier side with a standard webbrowser (see Figure 4),
2. a matchmaking library that technically matches resource requests to offers to fulfil the request
3. and at its heart a specification language that is able to express the resource specifications for the resources traded on the SORMA marketplace on different layers (from raw resources to complex services) [6].

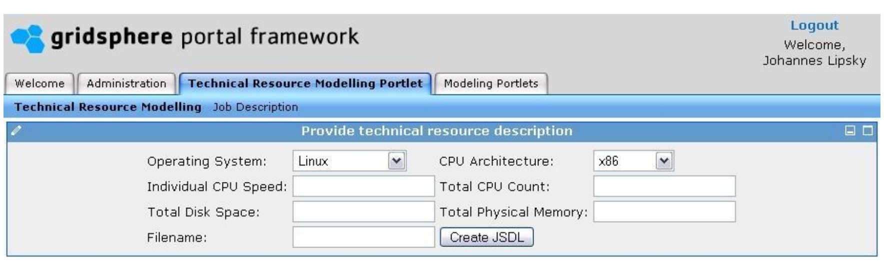

Fig. 4. Gridsphere User Interface for Technical Resource Specification

As discussed in the last section, the Open Grid Market implemented by SORMA supports a wide variety of goods, namely physical resources, raw services and complex application specific services. Thus, one approach towards SORMA resource modeling could be to develop a single comprehensive new language from the scratch that is especially tailored towards the SORMA requirements. In general, such languages tend to be complex and are often not easy to reuse in other environments [6]. The approach followed in SORMA is to use established standards and technologies and to adapt them according to the SORMA requirements in order to have a modular compact and yet expressive set of languages. Prominent representatives for the distinct goods are the Job Submission and Description Language (JSDL) [2] for raw resources, parts of the Common Information Model (CIM) standards [11] or the Web Service Resource Frameworks (WSRF) [3] for generic service description, and the Web Ontology Language for Services (OWL-S) [27] as well as the Web Service Modeling Language (WSML) [10] for application specific complex services. As all these languages are mutually independent it is necessary to define a connector language between them that allows relating the description on the different layers with another. Therefore, a connector language called Resource Dependency Language (RDL) has been developed to define the consecutive and parallel processing steps within one layer and indicate the dependencies between different layers.

The matchmaking library matches technical request descriptions with technical offer descriptions on the marketplace in order to find possible offer candidates that technically could satisfy the request. It has to be considered that the matchmaking only covers the technical aspects of the resource and not the economic parameters. The Trading Management performs economic matchmaking and is described later in this document. There are two possibilities for matchmaking: Boolean matchmaking that only returns if a certain offer fulfils a request or not (return values $\in \{0, 1\}$) or fuzzy matchmaking that states how good an offer fulfils a request (return values $\in [0, 1]$). While the evaluation logic of Boolean matchmaking is easy to derive from the evaluation results of the three layer languages and from the structure of the connector trees, fuzzy matchmaking needs the definition of fuzzy evaluation rules for all four languages. Some of the language layers already have basic support for fuzzy matchmaking. For example JSDL allows exact matching for CPUs with a specified clock speed, as well as matching for all CPUs that have a clock speed greater than a specified threshold.

Bidding for heterogeneous and dispersed services can be a complex and time-consuming process based on the applied bidding strategies and market mechanisms. Agents should be able to make autonomous decisions, choose the appropriate market for their bids and send out bids automatically according to a predefined strategy. Market-based allocation of computational resources is widely explored in the literature. Thus, the allocation process is controlled by market mechanisms e.g. Vickrey, English, Dutch, and double auctions [12] as well as combinatorial mechanisms [4, 24, 25]. Prominent examples of market mechanisms for scheduling of computational resources like CPU and Memory are based on proportional share mechanisms [15], where the users receive a share of the computer resource proportional to their valuations fraction of the overall valuation across all users. A related and implemented mechanism is the so-called pay-as-bid mechanism proposed in [23, 26], where the user pays the price he has bid.

We assume that agents are self-interested. Hence, they aim to implement a strategic behavior in order to maximize their utilities. In this context the mechanism design and auction literature investigated various bidding strategies for market-based scheduling [16, 20, 22]. Such strategic behavior is ranging from the selection of the right auction to the published/requested resource configuration or the definition of the willingness-to-pay/reserve price. Consumers and providers are faced with multi-attribute decisions. Personalized bidding agents will be configured with a set of strategies and learning algorithms in order to automatically execute the providers' or consumers' preferences. In his thesis [20], Phelps classified bidding strategies into non-adaptive e.g. Truth Telling, Equilibrium-Price and Zero Intelligence strategy and adaptive strategies e.g. Zero-Intelligence Plus, Kaplans Sniping Strategy, Gjerstad-Dickhaut and Reinforcement-learning.
Three bidding strategies were implemented in SORMA: Truth-Telling as a non adaptive strategy, Zero-Intelligence Plus and Q-Strategy with adaptive bidding strategies. Each consumer and provider is using SORMA intelligent tools to specify her demand or supply regarding technical requirements for computational resources, their QoS and the price. The bid and offer generator component as a part of the intelligent tools is implemented within SORMA's Bidding Agent Framework [7]. Furthermore, the preferred bidding strategy can be configured by policies, which are defined by a rule description language and executed within a rule engine. Policies represent utility and pricing functions. Through the utility function, the participant specifies the overall objectives as a mathematical function that is to be maximized by its bidding agent. The pricing policy enables a static specification of a valuation or price calculation function for calculating the bid and reporting the bid to the Open Grid Market. The bid message contains the technical and economic preferences for both the provider and consumer.

The trading management is responsible for executing and providing evidence of economic matchmaking in SORMA. C-Space (Conversation Space) constitutes the Trading Management in SORMA. It is a framework for creating and executing conversations. A conversation follows a certain protocol that determines who can say what, and when. The protocols are defined by users in terms of Java classes that are submitted to C-Space and run in the C-Space trusted infrastructure. These protocols support different kinds of auctions or other trading mechanisms, for instance direct bargaining. We use the abstraction of conversations to emphasize the generality of the framework. All network communication between users and the trusted infrastructure consists of encrypted and signed SOAP messages according to the WS-Security specification. The user's trustworthy certificate issued by Certificate Authorities is monitored and validated by the Security Management component.

4 Conclusion

Exchanging computing power, storage space or memory over a large-scale network enables to run complex applications and services in an acceptable period of time. The process of exchanging resources can be facilitated by a platform offering a market for these resources. The design of this platform is, however, quite challenging. Providers and consumers need intelligent tools to participate in the market for automatic management. The user should initially configure his preferred strategy and the intelligent tool will autonomously update the price and other parameters. Depending on the applied market mechanism, participants have to dynamically adapt their strategies according to their outcome. The underlying platform infrastructure has to be flexible in the sense of extendability. New market mechanisms or SLA requirements should not trigger a complete redesign of the infrastructure. A flexible infrastructure with modular components and standardized message protocols allows a fast adaption and a new design of markets on demand. In this paper, we presented the first prototype implementing the concept of the Open Grid Market. The architecture gives an overview about the interplay of the components. We use a layered structure to identify resource-centric, user-centric components and market-centric components. Currently, we have implemented on the user side the components comprising bid and offer generator as well as demand and supply modeling. On the market-centric side the trading management component and the EERM are running successfully. For more information on the EERM component, we refer to [21].
As a next step the SLA enforcement and the contract management component need to be scrutinized to finalize the preliminary version. A visualization of the SLA component based on AJAX technology is already available. On Layer 1 the trusted market exchange and market information component, which are currently under development, are necessary to provide essential information to the intelligent tools.

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