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Grid Architecture for Risk Management: A Case Study in a Financial Institution

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GRID ARCHITECTURE FOR RISK MANAGEMENT: A CASE STUDY IN A FINANCIAL INSTITUTION

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Abstract

Modern financial market places are the most competitive and most dynamic ones in all of the history wherefore especially market risk management is a vital task in the financial services industry. Since market risk management is a compute and resource-intensive process, Grid applications seem to be a promising solution to meet the tremendous calculation demand in the financial services industry while preventing investment and maintenance costs for additional compute resources. In our case study we researched a newly implemented Grid solution in a large German bank installed to evaluate market price and portfolio risks in a fast and accurate way. The new Grid-based solution allowed the bank to reduce risk calculation update cycles from twice a day to every 7 minutes while time-to-market for new products could be reduced to one fourth of the original time. In this paper, based on a real example we investigate how banks can successfully implement Grid solutions in a fast and effective way and explore the based on economic impacts.

Keywords: Case Study, Market Risk Evaluation, Grid Computing, Financial Services Industry.

1 INTRODUCTION

Today, modern financial market places are the most competitive and most dynamic ones in all of the history (Pollock and Hodgson 2004). Through the permanent development of Web technologies, the across-enterprise integration (B2B) of applications increased significantly in the last decades (Chung and Zhang 2002). In line with most businesses' strategies, enterprises adopt supply-chain improving technologies in order to stay competitive in a fast changing environment. One way to meet this challenge is a collaborative IT-system which enables businesses to change processes and procedures "on the fly". In the course of this demand, Grid (Foster and Kesselman 1999) systems help to improve competitiveness by providing a collaborative, service-oriented, and cost-efficient infrastructure (Guentzel and Leymann 2003). Grid concepts are becoming increasingly relevant to the commercial information technology, especially with the rise of IT-sourcing strategies (Foster et al. 2002). Increasingly, large-scale enterprise applications are no longer running exclusively within central computing facilities. Instead, they operate on heterogeneous resource clusters that may span multiple administrative units within a single company, as well as various external networks. Today's trend away from static pre-planning of IT-resources with a fixed allocation towards a dynamic assignment of resources will increase. According to a report of the Insight Research Corporation (2006), the worldwide Grid spending is expected to grow from 3.9 billion USD in 2007 to approximately 24.5 billion USD in 2011.

One of the most promising application domains of Grid systems is the financial services industry with its information-driven business processes and its high computational demands (Hackenbroch and Henneberger 2007, Schwind et al. 2007, Lan et al. 2005). The increasing competition in the banking sector leads to a high pressure for restructuring and further automation of IT-related business processes. Additionally, fast changing customer needs force financial services providers to provide highly customized financial products on demand. For these products, the risk/return ratio has to be evaluated by complex and compute-intensive calculations that have to be adjusted with regard to the entire risk/return structure of the financial services provider. Once the ratio is evaluated, adjusted and approved by the senior management, the product is market-ready. Therefore, a fast, accurate, and comprehensive risk valuation to meet the new capital requirements by laws and regulations like Basel II (2004) is becoming a key driver for reducing time-to-market.

This paper presents the results of a case study that has been conducted in a large German bank that developed a Grid-based platform for evaluating market and portfolio risks as well as to reduce time-to-market. Based on a real example, we investigate how banks can successfully implement Grid solutions in a fast and effective way to shorten the time for valuating and reporting portfolio and market risks and to increase the utilization of compute resources. The contribution is intended to be of interest to both: researchers who explore the role of Grid technology in the financial services industry as well as financial services providers that challenge the same situations depicted in this case study.

The remainder of this paper is organized as follows. First, we provide a brief overview of the role of risk management in the financial services industry that motivates the requirements of a fast and accurate market risk evaluation. Furthermore, the results of a comprehensive literature research of existing Grid approaches in the financial services industry and their predicted benefits are presented. Based on these results, we will present our research design and the methodology of the conducted case study in order to explore the role of the Grid-based platform of the bank. The situation and motivation of the large German bank to develop a Grid solution is analyzed in detail before the according Grid architecture and its benefits are presented. The paper concludes with an outline of the economic impact of Grid computing on the financial institution and an outlook to further research questions.

2 MARKET RISK MANAGEMENT IN THE FINANCIAL SERVICES INDUSTRY

Risk management in common is an essential and vital task in the financial services industry mainly driven by the following factors: (i) the pressure from regulators for a better control of financial risks, (ii) the globalization of financial markets, which has led to exposure to more sources of risk, and (iii) technological advances, which have made enterprise-wide risk management a no-so-distant reality (Jorion 2006, p. ix). The Federal Reserve System stated in the Trading and Capital-Markets Activities Manual (1998) that if risk management and its integrated processes are not well implemented or not sufficiently embedded in a strong global (firm-wide) risk management system and senior management and the directors are not actively involved in overseeing the risk management, disastrous losses and even bankrupts are the consequences. Famous cases from the mid 1990s like Orange County, Metallgesellschaft, Barings, and Daiwa are referenced by Rawnsley (1995), Jorion (1995), and Leeson (1996) and impressively demonstrate the impacts of controlling risks not sufficiently. However today, too, the US subprime crisis of 2007 with its billions of dollar losses and bankruptcy of several mortgage lenders and hedge funds shows the importance of an effective and efficient total risk management. Globalized and interweaved capital markets led to high depreciations on risky investments for global acting financial services providers.

It is necessary to control the total risk of an institution via appropriate risk tracking and risk controlling processes and thus to achieve a substantial contribution for the overall management of the financial institution. The total risk of an institution mainly consists of market risk, credit (or default) risk, liquidity risk and operation risks (Basel II 2004). Market risk enfolds the risk of financial losses due to changes in market prices, e.g., stock prices, interest rates, and exchange rates. The most important method for measuring the market risk is the Value at Risk (VaR) method (see, e.g., Jorion 2006). VaR indicates, in percentage terms, the maximum probable loss on a given portfolio, referring to a specific confidence interval and time horizon. First notable introduced by JPMorgan's RiskMetrics System in 1994 (Pafka and Kondor 2001), the VaR methodology is now leading to the holy grail of firm-wide risk management[1] (Jorion 2006, p. vii).

Initially confined to measuring market risk, VaR is now being used to control and manage nearly all kinds of financial risk actively, including credit and operational risk. Often used approaches of calculating VaR are the variance/covariance approach, Monte-Carlo (MC) simulations and historical simulations. All methods are highly compute and time-intensive whereas the MC simulation takes an exceptional position. MC analysis is by far the most powerful method with all its model capabilities[2] to compute VaR and probably the most comprehensive approach to measuring market risk if the modeling is done correctly (Jorion 2006, p.265-268). One of the big drawbacks is its computational time due to the computing complexity of $O(n^2)$. For instance, to measure the VaR for a portfolio of 1,000 assets with 1,000 sample paths, the total number of valuation amounts is 1 million. By valuating derivatives, simulations of simulations even amplify the computation. In exchange, the achieved accuracy of VaR with MC is unique. Jorion (2006, p. 269) compared accuracy and speed of VaR methods for a 99% VaR for options portfolios with the result that full MC comes arbitrary close to the true VaR while computation time is approximately 830 times higher, compared to the Delta method of 5.34% mean absolute error in VaR.

According to Basel II the bank's total capital (see equation 2.1) must exceed the total-risk-charge (TRC), which is the sum of credit-risk-charge (CRC), market-risk-charge (MRC) and operational-risk-charge (ORC).

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[1] Appropriate use of VaR, however, may have avoided some of the spectacular debacles of recent years. (Jorion 2006, p. 572).

[2] Even includes fat tails. A good discussion and the impact of that topic can be found at Bali (2003).

$$\text{Capital} > \text{TRC} = \text{CRC} + \text{MRC} + \text{ORC} \quad (2.1)$$

Since all three risk categories are measured by the VaR method, the bank is offered an incentive to calculate risks as accurately as possible to reduce the reported risks. In Jorion (2006, p. 58-64 and 148) the required calculation of MRC according to the internal-models-approach is given, showing the importance of accuracy by multiplier k with a range from 3 to 4 depending on the number of exceptions between reported risk-charge and actual profit and losses (P&L). That means that in worst case, a bank has to charge 33% more capital that cannot be used for investments.

The faster and the more accurate a financial institution can estimate the VaR of an asset, the more detailed necessary financial reserves can be calculated for covering risk-based investments in order to meet the capital requirement by regulations. This can have tremendous competitive impact on the time to market of today's complex financial products and thus to reaction time on customers.

Currently, the financial services industry is running many projects to meet the regulations and directives of the Basel Committee on Banking Supervision and the European Community. Therefore, appropriate IT-supported risk management processes that are implementable into present IT system landscapes of financial services providers are vital to succeed in a fast-paced, aggressive marketplace.

Grids, defined by Foster and Kesselmann (2004), based on service oriented architectures (see, e.g., Alonso et al. 2004, Huhns and Singh 2005) seems to be such advancements and have a high potential for supporting the implementation of an effective financial risk management in the financial services industry (Schwind et al. 2007, Moreno-Vozmediano et al. 2007, Heckenbroch and Henneberger 2007).

3 GRID COMPUTING IN THE FINANCIAL SERVICES INDUSTRY

During the last few years, Grid computing (Berman et al. 2003) has evolved into a well-understood architecture that provides users and applications immediate access to a large pool of IT-resources (storage, databases, application servers, and applications). Foster (2002) defines a Grid as a system that coordinates IT resources that are not subject to centralized control, uses standard, open protocols and interfaces, and delivers nontrivial qualities of service. Regardless of their operating characteristics, Grid computing enables heterogeneous and geographically dispersed IT-resources to be virtually shared and accessed across an enterprise, industry, or workgroup. By unleashing latent power of connected resources, Grid systems can be used to significantly accelerate compute-intensive business processes.

Beyond the acceleration of large-scale computing tasks, Grid computing allows for the dynamic assignment of jobs to resources in an efficient way. Furthermore, due to parallelization, several jobs can be subdivided into a large number of tasks which run simultaneously. This dynamic allocation leads to a higher utilization of resources, resulting in costs savings. Furthermore, Grid computing enables the dynamic reallocation of resources to meet spikes in demand (Endrei et al. 2004) or changing business requirements.

The financial service industry is one among other industries that requests increasingly the use of Grid solutions for their intensive computing demand. The overall goal of Grid implementations in the financial services industry is to realize virtualization and provisioning as two core principles that distinguish Grid computing from other forms of computing. Virtualization means that individual resources (servers, storage, etc.) are pooled by type and then made available as services within a bank across department, country, and even continent boundaries. The association of compute requirements to physical resources is flexible, allowing workloads such as the described market price risk valuation or portfolio risk valuation to change their profile over their usage lifecycle. Provisioning implies that when virtualized services are requested, the appropriate resources can be identified and made available automatically. Equally, when the resource is no longer needed, the physical server can be reprovisioned for a different purpose, allowing vastly better usage of the asset over its whole useful lifecycle.

However, little research has been conducted to analyze suitable application areas for Grid technologies in the finance industry and its benefits for the financial institutions adopting Grid solutions.

Lan et al. (2005) draft a Grid-based stock option brokerage platform whereas Macleod et al. (2006) outline a Grid-based architecture for implied volatility calculations. Another Grid-enabled application for financial risk analysis based on Monte Carlo simulations is presented by Defrance et al. (2006). However, all of these papers are conceptual in nature and do not evaluate or apply real-world data for their Grid applications. Therefore, an indication of the benefits resulting from the adoption of these Grid solutions in a financial institution cannot be provided.

Moreno-Vozmediano et al. (2007) present a Grid-enabled application for portfolio optimization based on VaR estimation by means of Monte Carlo simulations. For the evaluation of the benefits resulting from Grid technology, empirical data is used from investment companies providing 76 asset values in a static file. The results of the simulation show that by running a portfolio optimization application on a Grid, the time of execution can be reduced significantly. Furthermore, the Grid-enabled application can evaluate more scenarios and thus provides a significantly improved estimation of VaR in a shorter period of time.

As mentioned before, research papers analyzing the adoption, usage, or even impact of Grid solutions within the financial services industry are still rare. The empirical case presented in the following section addresses this research gap by analyzing how Grid solutions can be implemented and used successfully.

4 RESEARCH DESIGN AND METHODOLOGY

In order to investigate suitable application areas for Grid solutions in the financial services industry, we conducted a qualitative in-depth case study in a large German bank that has developed and adopted a Grid-based architecture for market risk management. In general, a case study approach was chosen allowing for a comprehensive description and analysis (Aaker et al. 1998).

Since there are only few studies about the advantages of Grid technologies adoption in the financial services sector (Moreno-Vozmediano et al. 2007), we decided to conduct an exploratory research approach. This allows us to investigate and outline the full picture of the bank's motivation to develop a Grid solution, as well as unfolding effects and economic impacts.

Since we analyzed the Grid solution from a technical and economic perspective, we used the embedded, single-case design according to Yin (2003). By conducting structured in-depth interviews with the leaders of the IT department responsible for the Grid application development and implementation in October 2007 we were able to apply our exploratory research in a grounded theory-like approach. The interviews were recorded, fully transcribed, and finally validated by the interviewees to ensure the accuracy of their responses and to eliminate erroneous inferences. Besides the analysis of the interview transcripts, we analyzed project documentations and Grid usage figures in order to enable accurate data analysis.

In the following section we will describe the motivation of the analyzed financial institution to adopt a Grid-based solution for risk management.

5 MOTIVATION FOR CHANGING THE PLATFORM

As described above, risk controlling and risk management are central, compute intensive processes for a bank. For our case study, we worked together with the IT business unit that developed a Grid-based platform for two different financial applications of the bank. These Grid-enabled applications are used to (i) valuate market price risks for controlling purposes and to (ii) valuate portfolio risks for the stock trading group of the investment banking division. This exemplarily demonstrates the potentials of Grid solutions in the financial services industry:

Within our case study, we mainly focused on the motivation, the implementation, and the economic impacts of Grid applications rather than how different algorithms and calculations are processed and used. In this section, we describe the situation before the Grid infrastructure was implemented and identify the motivation for the change.

The case bank (in the following called BANK) is one of Germany's biggest private-sector financial services organisations measured by consolidated assets. Two departments of BANK are in focus of our case study: the functional integration department of the business unit IT/Organization and the market price risks controlling department of the controlling business unit

As already outlined, market price risk is defined as the potential loss resulting from changes in market prices. The market price risks controlling department employs a VaR method for measuring its market price risks on a daily basis, using a one-day holding period and a confidence level of 99 percent. This means, that under normal market conditions, the chance for a loss greater than the calculated VaR is 1 percent. The method calculates potential losses arising from market price risks taking into account historic market fluctuations (volatility) and market correlations. The underlying parameters correspond to an observation period of 1 year. The reliability of the market risk measuring procedures is reviewed regularly with a special focus on assessing the quality of the individual risk calculation procedures. The Backtesting (see Jorion 2006, p. 139-156) involves comparing the risk forecast with the actual results (profit or loss). The complexity of calculating threats based on hard to estimate market prices mainly consists of three dimensions: first, the underlying (numerical) model, second, the overall number of scenarios/simulations that can be calculated and third, the number of transactions/ positions one has to take into account for each simulation. By increasing the number of simulation runs, the grade of accuracy can be improved (Moreno-Vozmediano et al. 2007) which in turn depends on the availability of sufficient compute resources. The case bank, especially the stock trading division of the investment banking department depends on most exact calculation within a short period of time.

In order to ensure a large-enough supply of IT resources, the internal IT service department has to provide the IT infrastructure, platforms, and applications for the risk controlling department, including support level services. In addition, the IT department has to carry out projects together with the risk controlling department to continuously optimize their IT landscape, including planning, designing and implementing new IT solutions and applications. The demand for a new platform to valuate market price risks at the bank arose for various reasons: risk management is vital for financial institutions and the requirements for risk management due to new products, especially derivates, and regulations increased rapidly since the end of the 1980s (e.g. Jorion 2006, p. 11-12). In this context, time-to-market is essential, i.e., if financial institutions can evaluate potential threats faster than the market, they have a competitive advantage due to an improve information base for their decision making. Furthermore, the complexity and the amount of financial products considerably increased over the last 15 years. The complexity of the valuation of these products, as well as the models and methods required by regulations for estimating the risk related to those new products increased tremendously the demand for compute-resources. Summing up, increasing competition and regulation together with decreasing time-to-market cycles is forcing the IT departments of financial institutions to find new ways in order to meet those ever-rising demands. This includes the integration of new products in the existing (system) infrastructure to be able to valuate risk and return of complex products nearly in real time. Most of the today existing IT systems at the bank for valuating market price risks, e.g., price risks for stocks, interest rates, or exchange rates, are historically grown systems which cannot meet anymore modern demands and requirements. The case bank had to replace its heterogeneous system with a lot of different servers and applications in order to achieve the following performances:

- Reliability: partially, desktop solutions such as Microsoft Excel® were used to calculate the portfolio profit or loss (P&L). Complex, error-prone and instable VBA-code scheduled to be executed over night to calculate risks was not seldom disabling the machine in the morning hours or broke down during the night. Resource-intensive just-in-time hot fixes were the consequences to deliver risk measures. The bank needed a stable and reliable platform.

- Accuracy: The more detailed and faster market price risks can be evaluated, the more detailed capital reserves can be calculated that are needed to back up risk-based investments required by new regulations. With the capital that is not needed to back up risk-based investments, the bank can invest this capital again in order to raise its profit.

- Speed: The faster market price risks can be valuated the faster can the bank react to current situations and customer needs.

- Orchestration: Some departments in risk controlling for market prices had their own dedicated server-systems, as well as the IT department with its integrated server-farms that had to harmonize the use for achieving an effective utilization and to guarantee a proper quality of service in time. Furthermore, interfaces between applications to distribute data and partial results were costly to maintain and for implementing changes, e.g., due to new products, a lot of dependencies have to be taken into consideration.

All together, the functional integration department and the market price risk controlling department agreed that this architecture was not able to support the upcoming requirements that Basel II and the German MaRisk (German short form for Minimum Requirements for Risk Management) regulations evoke. Driven by the increasing complexity of the financial products and the bank's internal model to quantify market price risks, the IT could not contribute to decrease the time to market of new financial products with the current platform. To fulfill these requirements, the bank had to redesign its application and infrastructure landscape fundamentally to accelerate and stabilize the very compute-intensive risk calculations.

In 2005, the bank decided for the PoET project which started in January 2006 and was finished with the first release in December 2006. In the first half of 2007, the PoET platform was enhanced by the functionality for the stock trading department for valuating portfolio risks. The next section describes the bank's implementation approach and the results of the PoET platform.

6 GRIDIFICATION OF RISK CALCULATIONS

In order to reduce time-to-market of new financial products, the market price risk controlling department commissioned the functional integration department in the beginning of 2006 to build a stable and reliable platform to accelerate the very compute-intensive risk calculations.

Since the calculation of market price risks can be computed in parallel, the development team aimed at building a distributed and scalable architecture that enables an easy integration of new functionalities (by means of services) without the need to change the interfaces. As already mentioned Grid architectures are highly scalable and facilitate distributed and parallel computing wherefore the team decided to establish a Grid infrastructure by consolidating the already existing hardware resources (storage, databases, servers, etc.).

6.1 Grid-based Risk Controlling

Since January 2007, the resulting Grid-based application is being used successfully to calculate market price risks during nighttime. Figure 1 shows the architecture layout of the PoET platform. It becomes obvious that the platform can easily be connected with different financial software products like

MUREX or MaRS. MUREX is a front-office risk management and trading application whereas MaRS is a middle-office application for market price risk controlling. The integration of these front and middle-office applications into the PoET platform is realized by using the transformation engine WebSphere DataStage TX that maps any sort of data (structured, semi-structured and mixed data) from multiple places to multiple places through a completely codeless environment.

For the risk calculation, high-availability databases are used in order to facilitate parallel calculations on different Grid compute resources that are triggered by the PoET controller. The PoET controller inserts the according data required for the risk calculations into an event queue and the controllers of the different Grid calculation servers poll the queue in order to retrieve the jobs. Finally, the calculated values are stored in according databases.

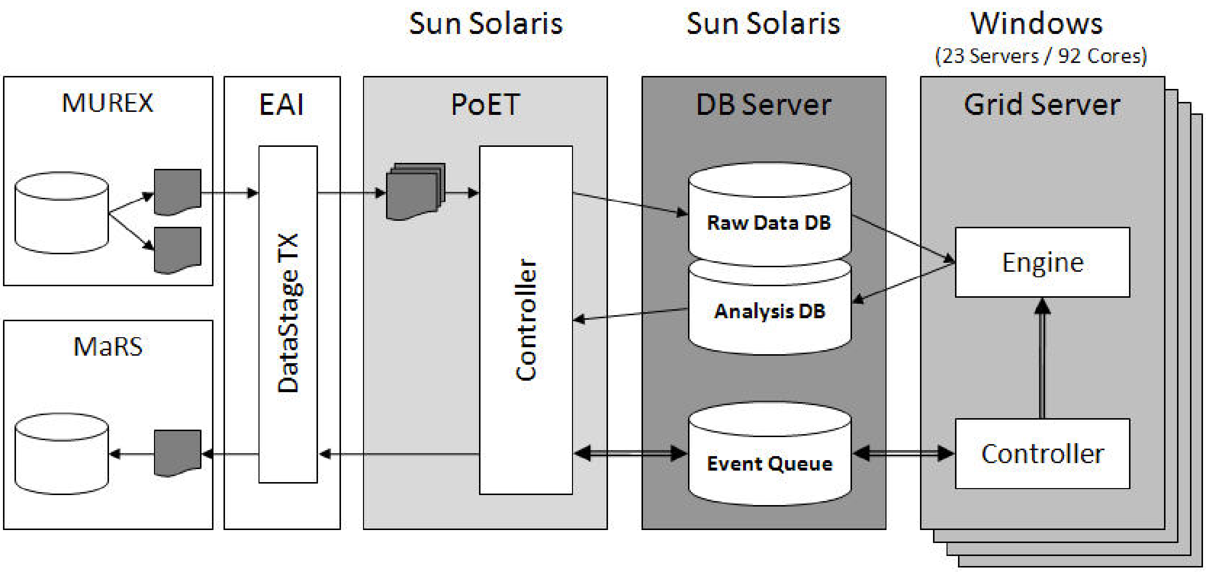

Figure 1. Architecture of the Grid-based platform PoET.

6.2 Grid-based Risk Valuation for Portfolios

A few months after the successful adoption of the PoET platform the stock trading department had the request to use the Grid infrastructure during the day in order to speed up the risk calculations for their portfolios. Therefore, the development team integrated the trading application into the Grid platform PoET and thereby obtained a significant reduction in computing time without purchasing additional hardware resources.

Since then, the calculation of risk measures for portfolios is performed during the day and done by determining the presumed “fair values” of the derivatives. These “fair values” are determined, as far as possible, on the basis of quoted market prices. If quoted market prices are not available, the fair values are determined using the discounted cash flow method, on the basis of a comparison with similar market transactions or other valuation models (e.g., option pricing). The discounted cash flow method is based on the estimated future cash flows and applicable discount rates. The valuation models are mostly numerical and take into account parameters such as yield curves, spread curves, and volatility. Therefore, the calculations are very complex and compute-intensive. Finally, the determined values are stored in according databases and used for the valuation of portfolios. Since the “fair values” are stored in high-availability databases, the calculation of risk measures can be performed in parallel which leads to a further significant decrease of computing time.

Besides VaR calculations, forward-looking analyses which assume extreme market situations are also performed. Therefore, statistical simulations and extreme scenarios are employed which expose the market positions to extraordinary market price fluctuations, crisis situations, and worst-case scenarios. The simulated results are then analyzed with a view to identify any risk potential which could jeopardize BANK. Since the simulations and scenarios are mostly based on historical data, the calculations are very complex and can therefore benefit from the connected resources of a Grid infrastructure.

6.3 Impacts and Benefits

Figure 2 presents the daily utilization of the Grid platform PoET that consists of 23 Quad-Core-CPUs. It becomes obvious that the risk controlling (App A) is performed twice a day. In the late night between 3:45 a.m. and 5:30 a.m. the PoET platform is used to forecast the market price risks whereas the Backtesting is performed in the evening between 5:00 p.m. and 6:45 p.m. in order to compare the risk forecast with the actual results (profit or loss). During the day (between 9:15 a.m. and 6:30 p.m.), the Grid resources are utilized by the trading department in order to calculate the risk measures for portfolios (App B). Finally, in the late evening between 9:00 p.m. and 10:00 p.m., the daily reports on market price risks and the daily reports on portfolio risks are produced. As depicted in figure 2, the synergy between these two different applications can be exploited in order to increase the overall utilization of the Grid resources and to accelerate the computing time.

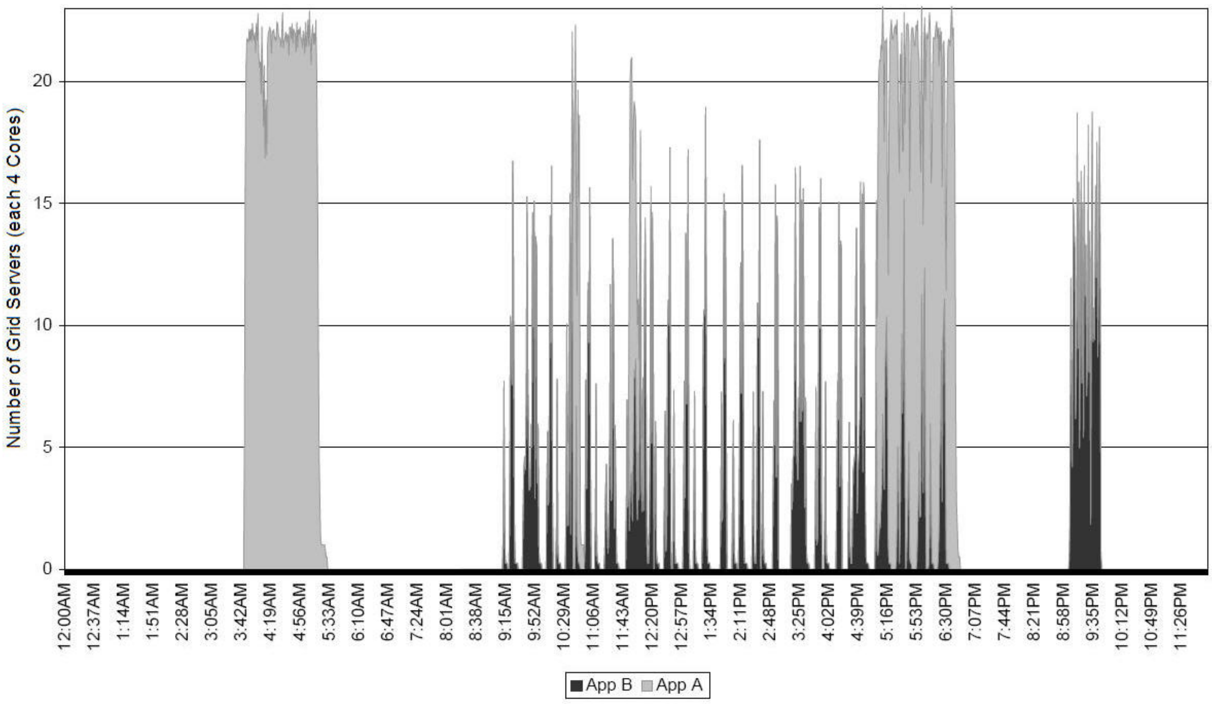

Figure 2. Utilization of the Grid-based platform PoET of one day.

The consolidation of the existing hardware resources by establishing a Grid-based platform has led to a fully scalable and reliable architecture that can easily be enhanced by additional applications or hardware resources. Especially the reliability and stability that the Grid solution provides is one of the major benefits for the calculation of market price risks. The time-to-market could thereby significantly be reduced to one fourth of the original time. In general, a reduction of the time-to-market of financial products leads to a competitive advantage and a fast reaction time on customers' needs (Davamanirajan et al. 2002).

By integrating the stock trading application into the Grid platform, intra-day calculations of risk figures for portfolios have been made possible. By using the Grid-based resources, the VaR calculations could be accelerated from about 3.5 hours to 7 minutes providing another huge potential for the investment bankers of BANK to react faster based on a tremendously improve base of information.

6.4 Outlook

In near future, BANK will raise the number of CPUs to about 400 cores in order to integrate additional applications into the Grid-based platform PoET. Besides risk calculations for equity trading, the range of application areas covering risk calculations will be enhanced by the possibility to calculate risk measures for credit trading. Furthermore, it will be possible to calculate additional risk type measures like liquidity risk and event risk on the existing Grid resources.

Currently, the different compute jobs are pushed into an event queue and the Grid servers retrieve the jobs by polling the queue when they are idle. In order to optimize the job scheduling, a Grid middleware solution (like Condor, Platform LSF, Sun N1 Grid engine, or Globus toolkit) will be integrated into the PoET platform in near future. Furthermore, a virtualization technology (like Xen or VMware) will be applied to pool and share hardware resources in order to further optimize the resource utilization.

The greater vision of BANK is to establish an enterprise Grid that includes all kind of enterprise applications that can be isolated and encapsulated by means of services.

7 CONCLUSION

In this paper, we provided the results of our qualitative in-depth case study conducted in a large German bank and presented the Grid-based platform on which two different financial applications for evaluating market and portfolio risks are running. By presenting the architecture of the Grid solution and its utilization of one day, we demonstrated how banks can successfully implement Grid solutions in a fast and effective way to shorten the time for valuating and reporting portfolio and market risks and to increase the utilization of compute resources. The contribution is intended to be of interest to both: researchers who explore the role of Grid technology in the financial services industry as well as financial services providers that challenge the same situations depicted in this case study.

Referring to the case bank, the costs for setting up two different platforms would have been significantly higher than the Grid solution presented in this paper. Furthermore, this example showed that reliability and stability of the architecture could be raised and that the Grid solution provides more flexibility to integrate further financial applications. In a next step, we will conduct further, extensive case and field studies in the financial services sector in order to expose more application areas for Grid-based solutions.

Beside the research question of the potentials of sharing resources within a financial institution, even more considerably questions could be asked: what are the potentials of Grid technology if it is used across company boundaries? Does sourcing approaches make sense to share Grid-based services for the whole financial services industry?

We believe that the principles of service oriented architectures (SOA) and especially Grid technology will be the next innovation step of IS in the financial services sector to enable new forms of financial transactions and business models in a high efficient way.

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