Challenges of Capacity Modelling in Complex IT Architectures

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Abstract: As internal cloud, and cloud technologies widespread among companies, the responsibility of providing reliable IT infrastructure and adequate capacities became the top priority for companies. While internal clouds and related technologies creates the flexibility for customer, limited IT resources arise problems for providing capacities, that has impact on IT service quality. The presented research addressing this problem, and seeks creating models describing the relationship between IT service quality and background infrastructure capacity usage with two distinct methodologies, in a complex cloud-like environment of a financial institution. The research was analysed a pilot area of a widely used electronic banking service. As multivariate statistical modelling and hypothesis testing had limited results in phase 1, but in phase 2 further modelling opportunities were explored, a model based neural networks were developed. The research analyses the limitations of pure statistical analysis in cloud-like environments, but concludes to the usability of alternative methods.

1 INTRODUCTION

As the popularity of internal and hybrid clouds is advancing, companies apply cloud technology like solutions in their internal environments. As companies implement virtualization, dynamic resource scaling and load balancing, adequate IT architectures and infrastructures became more and more important. As opposite of external clouds, where capacities are seemingly infinite for users, in case of internal clouds resource capacities are limited, and require careful planning. In this case internal cloud architectures offer flexibility, but also limit of capacity planning, because dependences of infrastructure elements and IT services are difficult to clarify. Exploration of the relation between IT service quality and capacity management is vital in order to understand and improve operational processes and supports identification problems faster and more reliable way.

This paper aims to explore the relationship between front-end quality of IT service in internal cloud environment, and the infrastructure capacity usage, analysing methods to predict required capacities and service levels. The research used the environment of a financial institution (Central-European branch of a multinational bank) that is developing its IT architecture via cloud technologies.

IT service quality prediction allows enterprises to support the need of adaptation and customization of IT infrastructure and thus it helps to prevent the actual occurrence of failures or to mitigate upcoming failures. Such proactive adaptation capabilities are increasingly relevant especially for future service-oriented systems (Metzger et al., 2012) and in internal cloud environments (Rountree and Castrillo, 2013). Investigation of the relation between capacity management and IT service quality support to understand and improve operational processes and enhance problems identification quickly and systematically. It facilitates establishing valid and reliable service performance measures. Measuring customer satisfaction and other performance outcomes can benefit from the solution as well.

2 LITERATURE REVIEW

IT services underpins business operations, IT has business critical role as it has strong impact on business operations. IT service management (ITSM) methodologies and standards, especially ITIL (IT Infrastructure Library) have recently become a very popular approach and a widely used methodology to improve this organizational activity (Taylor, 2007).

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The IT Infrastructure Library, as a comprehensive approach is a set of processes and functions that define best practices for managing, optimizing IT services, ensuring the responsiveness, cost-effectiveness of IT. ITIL helps to make IT a strategic asset for the company. The key ITSM procedures can be grouped into 5 major categories, integrating several processes into a life-cycle ranging from service Strategy to Continual Service Improvement.

Our research topic concentrates on a core process of ITIL: capacity management. This is a business-critical activity that is responsible for the smooth operations of IT supported business operations, that safeguards the quality of services and ensures the efficient processing of large volumes of business transactions. The goal of capacity management is to ensure that the capacities underpinning the business services through IT services meets the agreed requirements cost-effectively and in a timely manner, by understanding and satisfying current and future capacity and performance demand of the business. Capacity management, through the alignment of IT objectives with business priorities on short and long terms reduces the total cost of ownership of IT infrastructure and operations, and has central part of the warranty of the IT services (OGC, 2007). According to Broussard (Broussard, 2008) measuring and management of the performance of IT services is among the top issues for IT managers. Microsoft operations framework (MOF) has capacity management process too (Bagley et.al. 2002).

Capacity management has proactive and reactive tasks to enable the synchronization of IT and business performance. It ensures current operations by optimizing resource utilization and fine-tuning the infrastructure, monitoring the operations and supporting capacity-related incident management. Capacity management has also long term responsibilities that enable organizations to balance long term costs against the IT resources needed, and balancing supply and demand of IT services (development plans, budgeting, procurement, etc.). It has responsibilities and procedures on business, services and component levels (OGC, 2011).

Although the concept has long history and integrates experiences and best practices, designing and establishing comprehensive capacity management activities in a complex IT environment is a demanding task. Capacity management is closely related to application sizing, but it follows a service-oriented and comprehensive approach, covering the whole life cycle of IT services. Another related concept is the performance management. Performance management traditionally monitor and manage IT performance, optimize infrastructure utilization, and support component-level capacity planning and service-level reporting. Capacity management utilizes several methods and techniques (many of them discussed in Kant and Srinivasan, 1992), integrated into a holistic approach of Service Design processes. Implementation issues of capacity management discussed in details by Higday-Kalmanowitz and Simpson (2004).

The main challenge relies on the management of complexity. Recently business services are supported by several multiple interdependent and multilayered IT services. As more automation, virtualization is embedded in the underpinning IT systems, the dynamic nature of the resources requires special attention, careful design and strict control (HP, 2008). The IT organization is responsible for guaranteeing the agreed level of performance and quality to business users. In order to maintain control over the IT environment and to ensure the services meet business requirements, IT must have the explicit knowledge of the dependencies and performance of the entire system, both in real time and in historical terms. A key aspect of capacity management is the detailed understanding of business patterns, user profiles, dependencies of business processes and IT services. This requires extensive and well-targeted, objective monitoring of IT activities and resource utilization. The exploration and documentation of complex interdependencies of IT services and the supporting infrastructure components is also a requirement. Planning and forward looking processes also require sophisticated tools and techniques to enable modelling, analysis and reporting (OGC 2011; EMA 2012).

Capacity management integrates many activities, collects many inputs from several data resources (business, service, component and financial data) and enables several processes that have central role in the management of the IT as a business. It monitors utilization of individual components and response times of services. It collects and transforms business needs and utilization patterns into IT requirements for services. By analysing data it identifies trends, bottlenecks and enables tuning of components, applications or services. On short term the management of thresholds and capacity related incidents is closely integrated to operational activities (scheduling, workload management, virtualization, etc.). On long term, demand management and capacity planning, application sizing etc. requires modelling and trending tools and techniques: trend analysis, analytical modelling and simulations (OGC 2011).

There are similar initiatives in capacity planning and performance optimization. Lee and Asanovic implemented a multiprocessor system simulator (METERG QoS system) to provide a method for the estimation of the lower bound on end-to-end performance for a given configuration of resource reservations (Lee and Asanovic, 2006). A comprehensive high level modeling framework was developed by Heckmann to analyse economical and technical hypothetical questions of service providers throughout a service's life cycle (Heckmann, 2012). HP experts created a closed multi-tier multi-station queueing network model that combines performance modeling with performance profiling (Chen et.al. 2007). Their experiments show that the model is appropriate in a typical 3-tier e-commerce application in a virtualized environment to translate SLAs to lower-level resource requirements for each involved system in providing the service. Kousiouris (Kousiouris, et.al. 2011) used a generic black box approach, based on Artificial Neural Networks, appropriate for SLA negotiations. Our model, based on a similar modelling approach, is focusing on the runtime of a complex group of applications.

3 RESEARCH OVERVIEW

The presented research in this paper is aimed to explore the relationship between front-end quality of the provided IT service, and the background infrastructure capacity usage in an internal cloud environment.

Although the research, as a whole is considered to be an explorative, in order to create a model to describe this relationship, the researchers have strong hypotheses on the related factors. During the development of the relationship model, these hypotheses are codified and tested in a pilot environment with multidimensional statistical methods.

The research was conducted in a Central-European branch of a multinational financial institution (named as "Bank" in the following). The Bank serves both private and business customers with mainly commercial banking products, with the addition of investment possibilities. Products can be reached via several channels, including local offices, telebanking, Internet banking services, and dedicated business terminals for companies.

Information technology is a vital part of this company, as in every financial institution. Information technology is expected to provide cost savings, and improved internal efficiency (Fung, 2008; Ehikhamenor, 2003), but it is also expected to create new opportunities for expanding business, and interacting with customers (Liao and Wong, 2007, Vatanasombut et al 2008; Lee, 2008).

By today, the banking industry heavily depends on the information technology services, therefore it is vital to provide these services at least on a minimum acceptable level. Failing this condition results decreasing quality in business products, lower customer satisfaction, and eventually losing customers.

With the increase of technological complexity, it is more and more difficult to monitor and relate component performances and capacities (Metzler, 2003). The question is what is required to provide quality services, what are the factors that have impact on service quality?

In case of complex IT architectures, with the application of cloud technologies, IT infrastructure resources are often shared (virtualised) among logical elements. In results a complex load on the physical level by logically separate servers and services. Companies usually measure the physical level and neglect end-user quality questions. Moreover even physical level measures are the results of ad-hoc decisions, resulting incomplete datasets for analysis. But the main challenge is the lack of definite relationship between infrastructure performance and end user service quality.

To explore the above mentioned research questions the services of the Internet Banking channel of the institution were selected. The research idea was considered adequate for research purposes, because of the following reasons:

- Service quality is directly perceptible by customers
- The background IT architecture is complex, and covers the relevant banking products and services
- Provides sample data in adequate size for statistical analysis that is representative for the research services.

Although the main conditions are adequate for analysis, the research had to deal with limited and incomplete datasets on the physical and logical level of the IT architecture.

The Internet Banking channel covers 8 main banking products and services, with 4 other administrative services. While the administrative services cover over one third of the overall transaction numbers, these services use only load on the direct web server, while the business services use

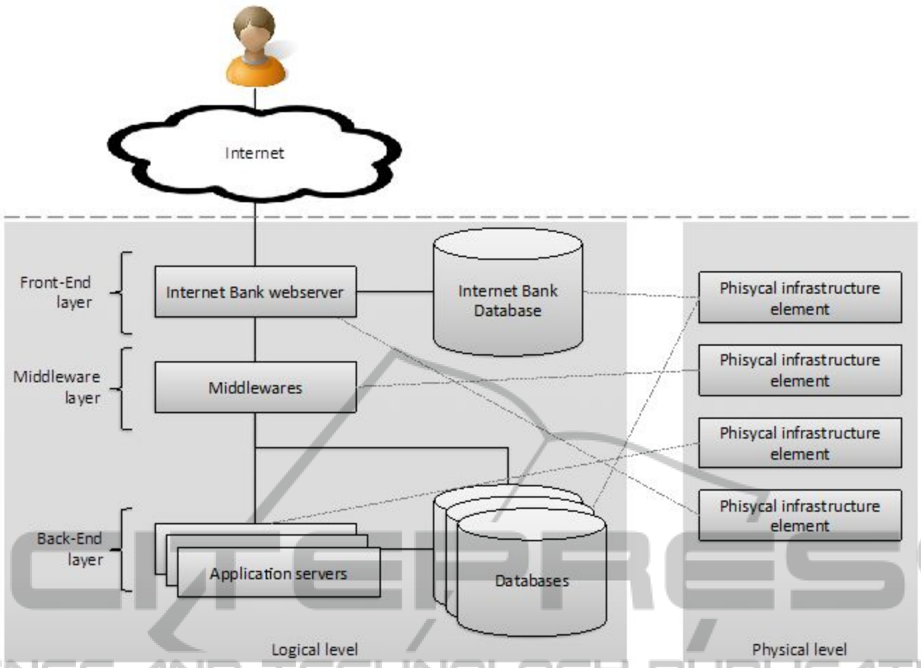

Figure 1: Architecture overview of the researched Internet Bank.

a wide range of the IT architecture. This paper analyses the problems of the most popular transaction type: domestic money transfer, that covers almost two third of business service transactions.

3.1 Architecture Structure of Services

In order to understand the relationship between components, the architecture behind the visible services should be explored. Generally IT architecture of every provided service consists of a front end (client software) and a back-end (servers and resources) layer (Figure 1). The two layers are connected via a middleware layer (Stephens, 2010).

In case of an infrastructure cloud (Sitaram and Manjunath, 2011) the capacity of the same physical resource (a server, a storage, CPU, memory, etc.) is shared between several virtualised elements (application servers, database servers, etc). Moreover, the same virtual server can be used by several other applications and services. Therefore a certain IT service competes for the same resources against other IT services.

Based on the used technology and policy settings virtual infrastructure elements, or applications can have dedicated resources, or a service can use resources in a flexible way, based on its current needs. The presented research concentrates on the latter environment, because in this case the quality of a service does not depend only on the used capacities, but also influenced by other competing resources.

In case of the presented research, the Internet Bank is accessed by the customers of the bank via an online user interface that can be used in any browser. This interface is served directly in the front-end layer with an application server, and its database that contains front-end related data. In case of business services the access of the back-end infrastructure elements (applications, databases, via the middleware layer) is required to record transactions, to check account balances, or to filter fraudulent activities. Each virtual server of database runs on different physical infrastructure elements that are shared among several logical infrastructure elements, even outside of the Internet Banking service group.

In this architecture quality of the money transfer service is measured as response times within the boundaries of the Bank, in the context, where business services are defined as the available functions, or transaction types of the user interface. Because the bank have no influence neither on the quality of the Internet network, nor on the quality of provided internet service for the customer, this part of the response time was not used during analysis.

Measurement on transaction numbers, and transaction time periods were recorded for the researched service (money transfer), and the used

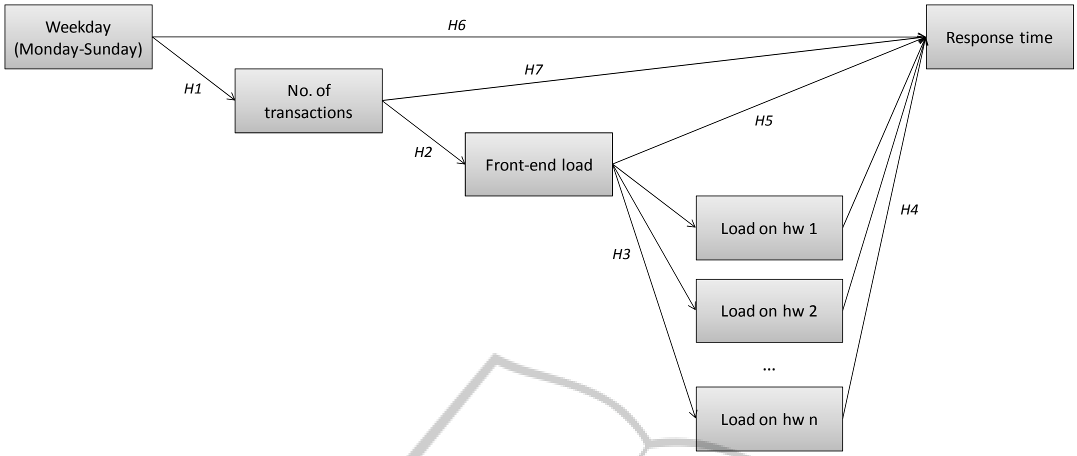

Figure 2: Basic research model and hypotheses.

logical and physical infrastructure elements through the data flow and processing were identified. Because logical infrastructure elements use– even in case of dedicated pools – the capacities of the physical infrastructure, measures were applied on the physical level.

4 ANALYSIS

In Phase 1 the research started to prepare a prediction model based on multivariate statistical analysis. In order to form the model series of hypotheses was formed and tested. In phase 2 the limitations of the research model were addressed and alternative methods were used.

4.1 Phase 1: Research Model and Hypotheses

Figure 2 summarizes the expectations of the model. It is expected, that the service quality of money transfer – in this case the response time – is impacted by four main factors:

- Capacity usage of the used physical infrastructure (H4)
- Capacity usage of the front-end application (H5)
- The day of the week (H6)
- Number of transaction in the measured timeframe (H7)

As background hypothesis, the research analyzed the relationship, how the capacity usage is impacted by the behaviour of the users during a week that revealed in the number of transactions. For this relationship we analyzed the relationship between the day of the week and the number of transactions (H1), the number of transaction and the capacity usage of the front-end application (H2), and the front-end load and capacity usage of back-end applications (H3). For every relationship (H1-H3 and H4-H7) the research expected positive impact that makes available prediction model for service quality.

4.2 Data Preparation

In many researches data are analysed for identifying extraordinary values. In this research extraordinary values (in every parameter) are the most vital parts of the research problems. If there are particular high values in response time that does not fit into the patterns of the data, researching the reasons is the most valuable for companies, because these response time causes them the problems in operations.

These cases are not uncommon for the research service in this shared and virtualized environment, and these kinds of cases can have serious impact on customer satisfaction and company reputation (Johnson and Peppas, 2003, Johnston 2004). Response time above accepted in the Service Level Agreement represent a 24,31% share of the total transactions.

Because of these reasons, and despite only 3,7% of the data are considered as extraordinary, no data were excluded at this phase of the research, nor were the sample split into normal and extraordinary cases.

4.3 Hypotheses Testing

To test the hypothesis 1 (H1), that specific days has influence on the number of transactions the analysis of variance were executed. To test the homogeneity of variances Levene Statistics was applied and was significant (0,000), while F test also justifies the difference of transaction number means of different weekdays.

Moreover there are also differences in the patterns of capacity usage in the Front End layer (H2) and Processing layer components. Capacity usage averages tend to follow transaction numbers (strong correlations >0,9 on significance level < 0,01), but response times (H7) follow a different pattern (no significant correlation). Moreover the research could not find significant correlation between service quality and the front-end load or the processing layers (H4 and H5).

The filter the cross-impact of each component, partial correlation analysis supported hypotheses testing. Even with this refines analysis, the research cannot confirm the relationship between the capacity usage of the physical infrastructure and service quality (H4 and H5).

The research can only confirm, that there is a relationship between the special days and response times, but this relationship alone is not complete to build a predictive model for service quality.

4.4 Phase 2: Neural Network Analysis of Capacity Data

To overcome the unsatisfying results of statistical models in capacity analyses, we applied another promising modelling approach, artificial neural networks (ANN). Neural networks are inspired by the working mechanism of human brain and they are known as promising solutions in forecasting and business classification applications, because of their beneficial characteristics (Turban, 2011):

- They are able to deal with highly nonlinear relationships,
- Not prone to restricting normality and/or independence assumptions
- Can handle variety of problem types
- Usually provides better results (prediction and/or clustering) compared to its statistical counterparts
- Handles both numerical and categorical variables.

Neural networks are able to "learn", they are often called universal approximators (Sifaoui, 2008). Learning algorithms specify the process by which neural network learns the underlying relationship between input and outputs or between inputs. Learning algorithms can be supervised or unsupervised (Mohri et al., 2012), (Barlow, 1989). Supervised learning is often applied in prediction area, while unsupervised learning is frequently used in clustering problems. Pattern recognition, forecasting, prediction, and classification are the typical tasks for ANN. Application areas are various, like finance, marketing, manufacturing, operations, information systems, and so on.

In our case neural networks were utilized for those services where the statistical investigation had no satisfying result. According our task type, which is a prediction, one of the most promising ANN model, multilayer perceptron network was selected. Multilayer perceptron is a feedforward, supervised learning model (Rumelhart, 1986).

Several software tools are available for modelling neural networks, amongst other commercial and open source data mining software suits, like SAS Enterprise Miner, Statistica Data Miner, PASW, Rapidminer, R and standalone solutions, like NeuroSolutions, BrainMaker, NeuralWare and NeuroShell. Rapidminer was selected as a modelling environment, because nowadays it is a leading open source data mining solution with rich functionality (Rexer, 2009). It has more than 600 operators and user friendly graphical user interface.

ANN network topology for HUF transfer service consisted of one input layer, one output layer and one hidden layer. Input variables included date, like weekday, hour and minute and infrastructure measurements, like CPU. Output variable was PI runtime. Training data set of HUF transfer model included 11807 records of HUF transfer service data of a monthly period. This data set was applied to build ANN model. Model testing was done on the 13622 records of HUF transfer service data from next month. Results included predicted response time, actual response time are shown on the figure 3.

In model evaluation the following error functions were applied: correlation, root_mean_squared_error, absolute_error, squared_error, prediction_average, spearman_rho, kendall_tau. Correlation was 0.208 for the whole data set, which was not satisfactory result. This bad value is caused by the outliers (8% of the whole data set). In a modified data set which doesn't contain outliers; correlation was 0.89, which is an appropriate outcome. The ANN modelling environment was applied afterwards for capacity investigation in the bank by consultants. The ANN model was regularly updated and maintained according the changing capacity environment.

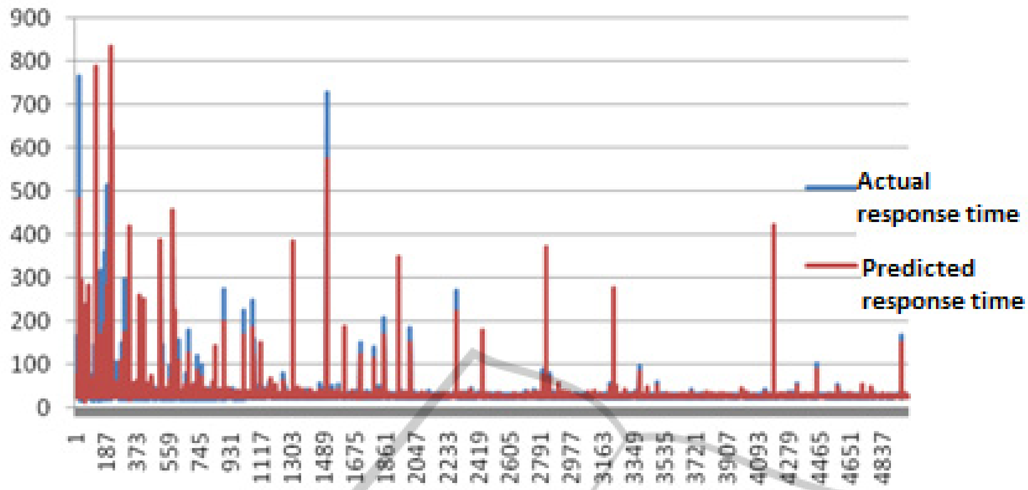

Figure 3: Predicted and actual response time for HUF transfer service.

5 CONCLUSION

Our results shows that traditional multivariate statistic-based models and techniques have only limited explanation power in today's complex virtualized, cloud-like IT infrastructure, as popularly labelled as internal clouds. Seemingly trivial hypotheses were failed, suggesting that there are hidden interdependencies and unrecognized relationships between IT infrastructure elements and the business services. Although realizing the necessity and usefulness of traditional statistical analysis, to develop a comprehensive and easy-to-use model more sophisticated tools should be used, underpinned with the knowledge crystallized in the corporate architecture models.

This paper analyzed the relation between capacity management and IT service quality. We set up a research model and hypothesis, which was tested in a Bank. We could accept four hypotheses, but two were declined. These two services required another research approach, beyond the traditional statistical models. Therefore an artificial neural network for capacity modelling was selected, as alternate modelling method. ANN has several promising characteristics; the most important ones are its non-linear feature and learning ability. One of the main limitations of our result is that neural networks are not so popular amongst business decision makers, because they are deemed to be black-box solutions; we have no explanation about the results. In spite of the sometimes negative attitude of decision makers towards ANN, this model was applied after the research in the Bank for capacity modelling in IT operations.

Capacity and service level management can be supported with ANN based prediction models. Predicted changing numbers of transactions (based on a marketing campaign or policy issues) is a good input parameter for running the model. Based on the ANN approach changed capacity usage and internal response time can be predicted, and unacceptable response time periods can be identified. Based on the predicted response times, capacity and service level managers can decide on a) investing into new infrastructure elements to provide the required capacity for peak times, b) change server capacities to restructure resources for more demanding applications or c) influence customer behaviour to smooth overused capacities into underused time periods. Capacity planning allows organisations to prepare their future quality of service for predicted user behaviours.

Further developments include fine-tuning of the ANN modelling environment and testing other ANN topologies, and additional architectural environments.

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