ProfNet PlagiatService

-Prüfbericht-

für
Dr. Reinhard Brandl

Münster, den 19.02.2019

ProfNet PlagiatService - Zusammenfassung

Autor	Dr. Reinhard Brandl
Titel	Cost Accounting for Shared IT ...
Typ	Dissertation
Abgabetermin	06.06.2007
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Seiten	256	Abkürzungsverzeichnis	[ ]
Absätze	1.223	Anhang	[ ]
Sätze	4.102	Eidesstattliche Erklärung	[ ]
Wörter	60.005	Inhaltsverzeichnis	[X]
Zeichen	366.696	Literaturverzeichnis	[X]
Abbildungen	0	Quellenverzeichnis	[ ]
Tabellen	5	Stichwortverzeichnis	[ ]
Fußnoten	26	Sperrvermerk	[ ]
Literatur	0	Symbolverzeichnis	[ ]
Wörter (netto)	55.014	Tabellenverzeichnis	[X]
		Vorwort	[ ]

Analysetyp	Indizien
Bauernopfer-Absatz	3
Bauernopfer-Satz	7
Bauernopfer-Wort	4
Bauernopfer-Zitat	6
Eigenplagiat	376
Zitat-Veränderung	7

Anteil Fremdtexte (netto): 6 % (3.279 von 55.014 Wörtern)

Phrase-allgemein	109
Phrase-fachspezifisch	88
Phrase-Redewendung	2
Zitat-Fremdtext-ohne Quelle	89
Zitat-Fremdtext-vollständig	1
Zitat-im Text-ohne Quelle	146

Anteil Fremdtexte (brutto): 12 % (7.264 von 60.005 Wörtern)

59% Gesamtplagiatswahrscheinlichkeit

Alle Ergebnisse dieses Reports werden von der Software automatisch berechnet, so dass alle Angaben jeweils den Stand der Software-Entwicklung wiedergeben.

ProfNet Institut für Internet-Marketing

ProfNet PlagiatService - Ergebnis Textanalyse (alle Analysen)

Kriterium	Dimension	Prüfdokument	Erstprüfer	Fachbereich	Hochschule	Fachrichtung	Hausarbeiten	Seminararbeiten	Bachelor Thesen	Diplomarbeiten	Master Thesen	Dissertationen	Habilitationen	alle
Dokumente	Anzahl	1	8	0	0	913	790	740	4974	4548	1238	29591	748	818009
Abbildungen	Anzahl (Durchschnitt)	0	19	0	0	6	2	2	10	8	7	6	2	2
Absätze	Anzahl (Durchschnitt)	1223	1466	0	0	412	104	118	214	344	291	557	464	276
Fußnoten	Anzahl (Durchschnitt)	26	744	0	0	36	29	39	64	58	54	112	91	28
Literatur	Anzahl (Durchschnitt)	0	1	0	0	1	1	4	1	1	1	4	2	2
Sätze	Anzahl (Durchschnitt)	4102	6370	0	0	1738	450	497	932	1416	1306	2442	1951	899
Seiten	Anzahl (Durchschnitt)	256	390	0	0	111	30	31	69	100	89	164	110	55
Tabellen	Anzahl (Durchschnitt)	5	9	0	0	2	1	1	3	3	4	4	2	1
Wörter	Anzahl (Durchschnitt)	60005	104640	0	0	27085	7318	7642	14520	22007	20944	39314	31099	15053
Zeichen	Anzahl (Durchschnitt)	366696	743415	0	0	174729	48339	50888	97274	147586	138247	262639	211218	98408
Zitate	Anzahl (Durchschnitt)	764	580	0	0	143	66	60	97	150	140	229	200	92

Die statistischen Ergebnisse der Textanalyse des Prüfdokumentes werden mit den Ergebnissen aller analysieren Texte verglichen.

ProfNet PlagiatService - Ergebnis Textvergleich (alle Vergleiche)

Kriterium	Dimension	Prüfdokument	Erstprüfer	Fachbereich	Hochschule	Fachrichtung	Hausarbeiten	Seminararbeiten	Bachelor Thesen	Diplomarbeiten	Master Thesen	Dissertationen	Habilitationen	alle
Dokumente	Anzahl	1	8	0	0	800	112	53	750	4111	464	25938	362	55634
Mischpl.-eine	Anzahl (Durchschnitt)	0	25	0	0	1	1	4	1	1	1	1	1	2
Teilplagiat	Anzahl (Durchschnitt)	0	267	0	0	9	4	6	5	7	9	13	11	13
Mischpl.-mehrere	Anzahl (Durchschnitt)	0	59	0	0	2	1	1	1	2	2	3	3	4
Zitierungsfehler	Anzahl (Durchschnitt)	0	583	0	0	2	1	6	3	3	3	6	11	4
Bauernopfer	Anzahl (Durchschnitt)	3	110	0	0	2	1	0	2	3	3	5	3	4

● **59%** Gesamtplagiatswahrscheinlichkeit

Die Textvergleichsergebnisse des Prüfdokumentes werden mit allen analysierten Texten verglichen. Die Plagiatswahrscheinlichkeit wird grob vom Programm automatisch berechnet.

Textstelle (Prüfdokument) S. 7

Cost Accounting for Shared IT Infrastructures Reinhard Brandl Dipl.-Wi.-Ing., Ingénieur INP Grenoble Abstract The provision of central IT infrastructure components, such as servers, storage and networking equipment, accounts for a considerable proportion of the IT budgets of larger organizations. Typically, such components

● **2%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

components [6] CPU [6] 1 [6] CPU [6] 2 [6] CPU [6] 1 [6] CPU [6] 2 [6] CPU [6] 1 [6] CPU [2] 2 [2] Web Server [2] M/M/2 [2] S = 0,024s [2] Application Server [2] M/M/2 [2] S = 0,414s [2] Database Server [2] M/M/2 [2] S = 0,05s [2] Think time [2] M/G/ [2] Figure 6 QN-Model of the infrastructure used in the experiments [2] Cost Accounting for Shared IT Infrastructures 91 [94] 94 Reinhard Brandl,

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [

Textstelle (Prüfdokument) S. 9

Ing., Ingénieur INP Grenoble Abstract The provision of central IT infrastructure components, such as servers, storage and networking equipment, accounts for a considerable proportion of the IT budgets of larger organizations. Typically, such components are shared among multiple applications and internal customers. Objective measurements of their respective resource consumption are technically difficult and incur high costs. In practice, infrastructure cost allocation is regularly based on simplified allocation keys, which cause multiple free-rider problems and discontent

2% Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

resource consumption (e.g., CPU time or number of I/O operations) is not a relevant cost driver and can be ignored. However, more and more IT infrastructure is nowadays shared among multiple applications and business units. Typical examples include database servers, application servers or virtualized servers (e.g., using VMware [Vmwa] or Xen [UCCL]). In these cases the resource consumption of

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 1

Textstelle (Prüfdokument) S. 9

difficult and incur high costs. In practice, infrastructure cost allocation is regularly based on simplified allocation keys, which cause multiple free-rider problems and discontent among the stakeholders. This thesis proposes a method to estimate the expected resource consumption of customer-oriented services across the components involved. The estimates are determined in a load test prior to the roll-out of an application system and then combined to so-called resource profiles. By means of these resource profiles, costs can be allocated to services or service invocations. During regular operations, consumption measurements at the different components can

● **3%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

technically difficult. We propose a method to derive adequate estimators for the resource consumption of a service invocation, which can then provide a basis for cost allocation keys. & The expected resource consumption of services can be estimated with high accuracy in load tests. Measurements during regular operations can be omitted. & We use Queuing Networks to validate the estimated

see previous section) . In the experiments we installed the applications under consideration in an isolated test environment, as is usual for operational approval tests [OoOC02] prior to the roll-out of a new software release. Bymeans of the load generator, we then simulated consecutive service invocations, while the performance monitors recorded the system s utilization in log files.

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 1
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

Textstelle (Prüfdokument) S. 9

and in heterogeneous environments. Furthermore, they should support IT Capacity Planning and bridge the gap between business forecasts and IT resource planning. The concept was implemented in a software toolkit and evaluated in a set of experiments with multi-tier database applications in a data center of the BMW Group. Queuing Network Models were used to validate the resource profiles under different system workloads. In the experiments, a surprisingly high accuracy of consumption estimates as well as of Queuing Network Model predictions could be determined. Besides the

● **4%** Einzelplagiatswahrscheinlichkeit

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high accuracy in load tests. Measurements during regular operations can be omitted. & We use Queuing Networks to validate the estimated resource profiles under different workloads. & Experiments with multi-tier database applications in a heterogeneous environment yield surprisingly high accuracy of the estimated resource profiles. The estimates also provide the necessary input for analytical capacity planning, which often suffers from a lack of data to parameterize

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 1

Textstelle (Prüfdokument) S. 19

● **2%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

we added ten more users until we reached the predicted bottleneck of 220 concurrent users. The QN Verifier then analyzed the data and computed for the intervals with constant numbers of users the average utilization of the involved servers. As the sudden and simultaneous start of 10 new users may lead to a non-steady transient behavior in the

• **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

Textstelle (Prüfdokument) S. 23

among multiple applications and service customers. Regarding today's IT budgets, the largest portion (28%)* is spent on salaries of full-time IT staff (see figure 1.1). The second largest cost pool is computer hardware (21 %), which accounts together with Networking and Communications hardware (14%) for more than one-third of an average IT budget. In times of 1Between September and December 2005, Forrester Research surveyed 270 IT executives at European enterprises (> 1,000 employees, different industries) on their IT budgets and spending for 2006 (see Bartels, 2006). 24 Networking and communications hardware Figure 1.1: Composition of an average IT Budget (Source: Bartels, 2006) rising budget pressure, IT managers are typically required to provide not

5% Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

together with Networking and Communications hardware (14%) account for more than one third of current IT budgets. Typically, these infrastructure costs (e.g., servers and networking infrastructure) are allocated to business units based on simplified cost allocation keys [Sysk02; GaMa05, p. 136].

not only for usage-based approaches [RoVB99]. Notes 1 Exact figures: Full-time IT staff 28%, Computer hardware 21%, Software 18%, IT Services 19%, and Networking and communications hardware 14% (Base: 270 IT executives at European enterprises were asked for their budget composition in 2006, September-December 2005). WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 Table 3 Comparison of load test measurements with QN predictions Web Server Application Server Database Server users u [%] uqn [%] u uqn u [%] uqn [%] u uqn u [%] uqn [%] u uqn 10 0,65% 0,32% 0,003 7,55% 5,38% 0, 022 2,59% 0,65% 0,019 20 1,01% 0,63% 0,004 10,36% 10,76% 0,004 1,72% 1,30% 0,004 30 1,31% 0,95% 0,004 20,14% 16,14% 0,040 2,17% 1,95% 0,002 40 1,71% 1,27% 0,004 18,37% 21,51% 0,031 2,45% 2,60% 0,002 50 2,06% 1, 59% 0,005 33,40% 26,88% 0,065 3,45% 3,25% 0,002 60 2,41% 1,90% 0,005 29,78% 32,24% 0,025 3,75% 3,90% 0,002 70 2,70% 2,22% 0,005 39,68% 37, 60% 0,021 4,42% 4,55% 0,001 80 3,06% 2,53% 0,005 46,22% 42,94% 0,033 4,76% 5,20% 0,004 90 3,40% 2,85% 0,005 47,39% 48,27% 0,009 5,07% 5,84% 0,008 100 3,76% 3,16% 0,006 64,22% 53,58% 0,106 5,58% 6,48% 0,009 110 4,10% 3,47% 0,006 58,96% 58,86% 0,001 6,52% 7,12% 0,006 120 4,38% 3, 78% 0,006 75,58% 64,11% 0,115 6,74% 7,76% 0,010 130 4,73% 4,09% 0,006 74,01% 69,31% 0,047 6,99% 8,39% 0,014 140 5,05% 4,39% 0,007 83,23% 74, 43% 0,088 7,78% 9,01% 0,012 150 5,29% 4,69% 0,006 88,62% 79,43% 0,092 8,10% 9,61% 0,015 160 5,56% 4,97% 0,006 92,66% 84,24% 0,084 8,30% 10, 20% 0,019 170 5,71% 5,24% 0,005 96,35% 88,76% 0,076 8,85% 10,74% 0,019 180 5,79% 5,47% 0,003 97,12% 92,80% 0,043 8,79% 11,23% 0,024 190 5,83% 5,67% 0,002 97,39% 96,07% 0,013 8,93% 11,63% 0,027 200 5,63% 5,80% 0, 002 94,95% 98,32% 0,034 8,51% 11,90% 0,034 210 5,94% 5,87% 0,001 97,44% 99,48% 0,020 9,00% 12,04% 0,030 220 5,55% 5,89% 0,003 94,25% 99,89% 0,056 8,32% 12,09% 0,038 92

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 1
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Textstelle (Prüfdokument) S. 24

see Bartels, 2006). 24 Networking and communications hardware Figure 1.1: Composition of an average IT Budget (Source: Bartels, 2006) rising budget pressure, IT managers are typically required to provide not only such a cost type classification, but to allocate the costs to the business processes or the business units2 that caused them. The technological changes described above have also affected cost structures of data centers and approaches to determine appropriate cost allocation keys. Mainframes traditionally provide accounting mechanisms that are

● **2%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

organizational/ [2] accounting issue. It focuses on making IT [2] costs visible and assigning them to accounting objects, such as the provided IT [2] services. Cost allocation distributes the [2] costs to the business units, enables the assessment of their financial performance and [2] improves forecasting and decision making. [2] It deals mostly with technical aspects, such [2] as measuring usage and

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Textstelle (Prüfdokument) S. 24

instance Fujitsu Siemens, n.d.; IBM, n.d.b). By means of the consumption shares, infrastructure costs (e.g., amortization, maintenance, licenses) can be subdivided among the customers. In distributed client/server environments, as depicted in figure 1.2, the determination of such usage-based allocation keys is by far more challenging (Bertleff, 2001, p. 63). If 2In the following referred to as the customers of IT services. Client 1 Customers Web Server Web Server Web Server Web Server App. Server App. Server App. Server App. Server DB DB DB DB Ann \ Mpp. DB Server \ DB Middle ware DB App. Server Data center Figure 1.2: Example: Shared and dedicated Data Center Resources the hardware is dedicated to specific customers, the incurred costs can be treated as direct costs (see example of client 1 in figure 1.2). The actual resource consumption (e.g., CPU time or number of I/O operations) is not a relevant cost driver and can be ignored. However, more and more IT infrastructure is nowadays shared among multiple applications and business units. In such environments, the resource consumption of applications is a major driver for new investment decisions. An average application server in an industrial data center (e.g., 4 processors, 16 GB memory) can easily host dozens of light-weight applications, whereas in other workload scenarios, the same server may be fully utilized by one or two applications. If the costs for such a server are treated as indirect costs and are apportioned via flat rates or fixed percentages, the IT management, as well as the concerned business units, has only a few possibilities for cost controlling and planning. The

41% Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

has recently become a major topic for CIOs. Nowadays enterprise software architectures are mostly designed as multi-tier clientserver applications. In such environments the determination of usage-based allocation keys is very challenging [Bert01]. If the hardware is dedicated to specific customers, for instance business units, those costs can be treated as direct costs. The actual

gibt den Anteil der CPU-Zeit an, der für das Warten auf das I/O-System zur Verarbeitung der Aufträge benötigt wurde. 7.3.2000, 10:30-11:30 %usr %sys %wio %idle DB-Server 21,98 13,71 14,64 49,61 App-Server1 7,34 1,76 0,09 90,76 App-Server2 20,95 4,42 0,00 74,42 App-Server3 32,75 6,63 0,00 60,42 App-Server4 30,82 8,05 0,02 61,12 Tabelle 02-6: Prozessorauslastung im Stundenmittel (in Prozent) Die Überwachung von Solaris-Maschinen kann mit Hilfe des frei erhältlichen Werkzeugs "SE Performance Toolkit" von Richard Pettit und

software architectures are mostly designed as multi-tier clientserver applications. In such environments the determination of usage-based allocation keys is very challenging [Bert01]. If the hardware is dedicated to specific customers, for instance business units, those costs can be treated as direct costs. The actual resource consumption (e.g., CPU time or number of I/O operations) is not a relevant cost driver and can be ignored. However, more and more IT infrastructure is nowadays shared among multiple applications and business units. Typical examples include database servers, application servers or virtualized servers (e.g., using VMware [Vmwa] or Xen [UCCL]). In these cases the resource consumption of the installed

Vmwa] or Xen [UCCL]). In these cases the resource consumption of the installed applications and the workload generated by the customers is a significant cost driver. An average application server in an industrial data center (e.g., 4 CPU / 16 GB memory) can easily host dozens of light-weight applications, whereas in other workload scenarios, the same server may be fully utilized by one or two applications. If the costs for such a server are treated as indirect costs and are apportioned via flat rates or fixed percentages, the IT Management, as well as the concerned business units, has only few

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 1
- 2 Gesamter Buchblock - Mapkit-HomePage, 2001, S. 32
- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 1

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creation of cost transparency is further complicated as servers are usually not offered as a standalone product, but as part of larger IT systems. A request in a three tier database application, for example, comprises a 26 web server, an application server, and a database server, which are all typically used by different applications (see figure 1.2). Tracking resource consumption is one of the toughest but most critical parts of a successful cost transparency program (Appel et al., 2005, p. 13). Besides the improvement in cost transparency, the allocation of IT costs is also an

● **9%** Einzelplagiatswahrscheinlichkeit

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possibilities for cost controlling and planning. Furthermore, the server is usually not offered as standalone product, but as part of a larger IT system. A request in a 3-tier database application, for example, comprises a web WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 The Authors Reinhard Brandl Martin Bichler Michael Ströbel Dipl.-Wi.-Ing. Reinhard Brandl Prof. Dr. Martin Bichler Technische Universität München Fakultät für Informatik Lehrstuhl für Internetbasierte Geschäftssysteme Boltzmannstr. 3 85748 Garching (brandlr|bichler)@in.tum.de Dr. Michael Ströbel BMW Group 80788

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 1

Textstelle (Prüfdokument) S. 26

costs is also an IT Governance instrument, which can encourage desired behavior on the supply and demand side. However, a simplified cost allocation mechanism, based for instance on the number of employees in a business unit, may lead to multiple free-rider problems and political tensions. Business owners of application systems might not consider the resource requirements when selecting off-the-shelf software. Also, the owners of "light-weight" applications might have to bear a very high share of the costs for a particular application or database server, which in turn makes it more difficult to finance these applications. Obviously, a consumption-based model, where IT infrastructure costs can easily be allocated to application owners or even to users directly, increases cost transparency and would have a number of advantages. A technical possibility would be to determine cost allocation keys through detailed monitoring and metering of each service request. This would require assigning a unique identifier for each user to each database request and each thread running on an application server in order to determine exactly how much of the resources a service customer has consumed. It would force the adaptation of the entire IT infrastructure, cause a huge monitoring and metering overhead, and is typically not viable. Furthermore, business customers probably would not accept technical accounting metrics such as the processor times of different servers. As they cannot directly correlate such metrics with their business activities, they can hardly plan or control cost allocation. In mainframe environments, with one single resource, this might have been possible, but the concept cannot be transferred to client/server infrastructures. The use of customer-oriented cost allocation keys (e.g., number of executed business transactions) shifts the problem to the IT units, which must then translate their resource-oriented cost sheets (e.g., per server, per stored gigabyte) into metrics

44% Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

WI Aufsatz server, an application server, and a databaseserver, which are all typically used by different applications. A cost accounting approach, which ignores the resource consumption, may lead to multiple free-rider problems. For example, application owners do not consider the resource requirements when selecting off-the-shelf software. Also, the owners of "light-weight" applications might have to bare a very high share of the cost for a particular application or database server, which in turn makes it more difficult to finance these applications. Obviously, a usage-based model, where IT infrastructure costs can easily be allocated to application owners or even to users directly increases cost transparency and would have a number of advantages. A technical possibility would be to determine consumption-based cost allocation keys by detailed monitoring and metering of each service request. This would require assigning a unique ID for each user to each database request and each thread running on an application server in order to determine exactly how much of the resources a service customer has consumed. It would force the adaptation of the entire IT infrastructure, cause a huge monitoring and metering overhead, and is typically not viable (irrespective of the fact that a business user probably would not accept technical accounting metrics as the CPU times of different servers). In this paper, we propose a method to determine usage-based cost allocation keys for customer-oriented services based

of multiple servers. As he cannot directly correlate the charges with his (business) activities, it is difficult for him to plan or manage resource consumption. In mainframe environments, with one single resource, this might have been possible, but the approach cannot be transferred to client/server infrastructures. Second, due to performance and security reasons the original business context of a transaction (e.g., user, service) is mostly not available in the backend. User names are

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

Textstelle (Prüfdokument) S. 27

of their customers and, for instance, are not required to determine fair cost shares. Regarding the technical complexity and the potential overhead, it is not surprising that IT Cost Accounting and Chargeback is often based on simplified cost allocation keys (Gadatsch et al, 2005; Syskoplan, 2002). Practitioners, however, regularly report discontent, conflicts, investment setbacks and distorted use of IT services due to internal cost allocation. IT analysts at Gartner even estimate that through 2008, 50% of chargeback initiatives implemented by

● **2%** Einzelplagiatswahrscheinlichkeit

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Communications hardware (14%) account for more than one third of current IT budgets. Typically, these infrastructure costs (e.g., servers and networking infrastructure) are allocated to business units based on simplified cost allocation keys [Sysk02; GaMa05, p. 136]. Comprehensive IT Asset Management and chargeback solutions have found limited use as of yet [GaJK05] . Usage-based accounting and pricing should lead to

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 1

Textstelle (Prüfdokument) S. 27

initiatives implemented by IT organizations will be seen as failures on the part of the business, the IT organization or both (Gomolski, 2005, p. 2). Summing up, in shared and distributed IT infrastructures the determination of accurate usage-based cost allocation keys is often fraught with technical problems and unreasonable overheads. Simplifications, however, may lead to organizational problems such as free-rider behavior, political tensions or biased management decisions. 1.2 Research Approach Most research on the design of IT

● **2%** Einzelplagiatswahrscheinlichkeit

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that a business user probably would not accept technical accounting metrics as the CPU times of different servers). In this paper, we propose a method to determine usage-based cost allocation keys for customer-oriented services based on their estimated resource consumption. Deriving such an estimator, however, is a nontrivial task. & First of all, the estimator should be

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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determination of cost allocation keys is particularly difficult. From the existing literature on IT Cost Accounting and Chargeback we derive that, from a customer perspective, services such as the execution of a business transaction or the access to an information system would be an appropriate basis for cost allocation. However, instead of measuring the resource consumption during regular operations, we propose to determine, during standard load tests prior to the roll-out of an application system, estimates for the expected resource consumption of such services. The consumption estimates at the different resources are combined to a resource profile per service. The resource profile then could constitute the basis for the allocation of costs per service or per service invocation. Deriving such profiles, however, is not a trivial task. We consider four basic requirements: 1. Accuracy The resource profiles should be unbiased, in the sense that on average they should not over- or underestimate the true resource consumption. 2. Consistency The estimation of resource profiles should be in the same manner applicable to various kinds of hardware and software resources. 3. Capacity Planning The resource profiles should enable a translation of the customers' forecasted service usage into

● **10%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

fine granular services (e.g., "view catalogue page", "add item to cart"). However, for this paper, we decided to consider the whole Pet Store as single service (Access to an Information system , see section 3). Our intention was, first, to compare the resource consumption of different user profiles and, second, to verify that Queuing Network Theory is also

see previous section) . In the experiments we installed the applications under consideration in an isolated test environment, as is usual for operational approval tests [OoOC02] prior to the roll-out of a new software release. Bymeans of the load generator, we then simulated consecutive service invocations, while the performance monitors recorded the system s utilization in log files.

and so forth) and then applied a linear regression. We consider the slope of the regression line as average consumption per additional user and as estimate for the expected resource consumption. The Pearson correlation coefficient (r 2 [1; 1]) and the resource profile p for the Pet Store example is shown in table 2. For comparison we included the resource profile of

similar resource consumption in the infrastructure. If estimates for the expected consumption at the different resources and the number of service invocations were known, this could constitute the basis for cost allocation keys. The elaborate process of measuring and consolidating log data from different components could be bypassed. Furthermore, these estimates would be valuable inputs

allocation keys for customer-oriented services based on their estimated resource consumption. Deriving such an estimator, however, is a nontrivial task. & First of all, the estimator should be unbiased, in the sense that on average it should not over- or underestimate the true resource consumption. & Second, the estimation should be applicable to various IT infrastructures (i.e., different hardware, operating systems and applications), without a need to change the respective systems. & Third, the

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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various kinds of hardware and software resources. 3. Capacity Planning The resource profiles should enable a translation of the customers' forecasted service usage into IT resource requirements and thus support the IT Capacity Planning. 4. Operating Efficiency The estimation should cause little extra work and integrate well with existing IT Service Management processes. The concept is based on the hypothesis that the resource consumption increases linearly with the number of service invocations. To validate this hypothesis and to evaluate the concept regarding the above requirements we create the following artifacts: First, a process to derive resource profiles from load test measurements (method) and, second, a software toolkit implementing

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consumption. & Second, the estimation should be applicable to various IT infrastructures (i.e., different hardware, operating systems and applications), without a need to change the respective systems. & Third, the estimation should cause little extra work and integrate well with existing IT service management processes. While the first requirement is essential for the cost allocation key to achieve incentive compatibility, the second and third requirements target the viability of the

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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planning, their accuracy is also sufficient for cost allocation (Requirements 1 and 3). 3. Proof of concept: BMW Group The experiments take place in a data center of our industrial partner, the BMW Group. Thus, we can evaluate the practicability of the approach and analyze how it could be integrated into professional IT Service Management processes (Requirements 2 and 4). The research presented in this thesis aims to contribute a viable alternative to existing cost allocation methodologies and should constitute a basis for further studies on the organizational and technical design of IT Cost Accounting and Chargeback systems. 1.3 Overview of the Thesis The thesis

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within an organization. Third, the process can be performed at low cost during standard approval tests. We identified two major organizational success factors, which influence the practicability of the approach. On the one hand, the cost for integration into existing accounting and software testing processes should be minimal. On the other hand, business units and

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 7

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in section 3.3. We then derive four major requirements on resource profiles and the profiling process that we consider as critical to the practical success of the approach (section 3.4). In section 3.5 we present the process for the determination of resource profiles and the software toolkit developed to validate the concept. Section 3.6 gives an overview of the validation presented in the subsequent chapters. Section 3.7 compares the concept to related approaches. Chapter 4 We present the results of several experiments conducted with the software toolkit introduced in section 3.5. In sections 4.1 and 4.2 we provide an overview of the test infrastructure, the example application systems and the test series. In section 4.3 we then detail the experimental results. For the experiments we have set the following three objectives: First, we try to verify if the model

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

sizes. To compare the CPU times with measurements on other infrastructures, they must be normalized, e.g., by using standard performance benchmarks [SPECa]. These resource profiles provide an overview of the expected resource consumption for different types of user behavior. If historical usage data is available, an average resource profile can be derived. Otherwise, the determined

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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results. For the experiments we have set the following three objectives: First, we try to verify if the model describing the total resource consumption holds in the example environment. Second, we test the precision of the measurement and analysis tools. Third, we analyze the effects of parameter changes during the profiling process and compare the experimental results with the model predictions. The results are summarized in section 4.4. Chapter 5 The motivation for the model-based validation approach presented in this chapter is twofold. First, it should enable a validation of the accuracy of the consumption estimates

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The resource consumption of a service request may depend to a certain degree on the workload. A linear extrapolation of a single service request might therefore be biased. & (2) Inaccuracies of the measurement and analysis instruments may introduce a systematic error, or also lead to high sample variance. In order to cause as little extra overhead as possible (e.g., no reimplementation of

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in section 5.6. As standard of comparison we introduce in section 5.7 published 32 results of a related experiment. The findings are summarized in section 5.8. Chapter 6 In this chapter, we describe the results of a proof-of-concept conducted in cooperation with our industrial partner, the BMW Group. We first detail our motivation (section 6.1) and discuss whether the general considerations on requirements, objectives and practiced approaches are in accord with the situation at the BMW Group (section 6.2). We then focus on Java/J2EEbased application

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and average consumption vectors. As the problem of allocating infrastructure costs is of a quite general nature, we further followed this idea and analysed its potential in cooperation with our industrial partner, the BMW Group. 4 Results and experiences from the pilot test 4.1 Organisational context At the BMW Group, management and operation of the considered OLTP systems is organised on two

- **3** Einflussfaktoren f r den Einsatz vo..., 2007, S. 932

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whether the general considerations on requirements, objectives and practiced approaches are in accord with the situation at the BMW Group (section 6.2). We then focus on Java/J2EEbased application systems, report experiences of the tests in a data center of the BMW Group and propose an integration of resource profile determination into the existing IT Service Management Processes (section 6.3). Section 6.4 summarizes the results of the proof-of-concept. Chapter 7 The thesis concludes with a summary of results (section 7.1) and a brief outlook onto future areas of research (section 7.2). Chapter 2 IT Infrastructure Cost Allocation 2.1 IT Cost Accounting

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measured in load tests with respective workloads. We conducted several experiments with J[2] EE applications in a distributed client/ server infrastructure consisting of Unix, Linux, and Windows servers in a data center of the BMW Group and achieved very promising results even in a very heterogeneous environment with multiple software modules, operating systems, and hardware infrastructures. The estimation procedure could be integrated with

different hardware, operating systems and applications), without a need to change the respective systems. & Third, the estimation should cause little extra work and integrate well with existing IT service management processes. While the first requirement is essential for the cost allocation key to achieve incentive compatibility, the second and third requirements target the viability of the

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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employee). Arbitrary allocation bases may lead to distorted product costs and biased management decisions. The optimal design of Management Accounting and Cost Accounting systems is the subject of a broad range of literature. In particular, we refer the interested reader to Kaplan and Atkinson (1998) and Horngren et al. (2005) (United States perspective), Reichmann (2006) and Horv th (2006) (German perspective), and Spitta (2000) (focus on IT costs). Management Accounting and Cost Accounting focus on the provision of decision support information for

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exact Mean Value Analysis (MVA) [ReLa80] or, for networks with a large numbers of users and multiple job classes, the Self Correcting Approximation Technique (SCAT) [NeCh81]. We refer the interested reader to [MeAD04] and [BoRi97; BoGM06] for a more detailed description of these algorithms. 5.2 The QN Verifier For the validation of the Queuing Network computations, we first developed

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of decision support information for managers. As mentioned above, the allocation of costs and the collection of internal charges for the usage of Information Systems intentionally changes users' behavior. Planning and controlling those effects falls under the realm of Information Management. According to Krcmar (2004), Information Management includes overall managerial functions as well as the Management of Information, Management of Information Systems and the Management of Information and Communication Technologies (see figure 2.1). The objective of Information Management is to ensure, with regard to business objectives, the best possible use of the resource information. Information Management is a management as well as a technology discipline, and is an integral part of corporate management (Krcmar, 2004, p. 49). Above mentioned tasks of

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In: Journal of Information Technology 11 (1996) 2, pp. 101 117. [Vmwa] VMware, Inc.: Virtualization software. httpwwwvmwarecom, Last accessed: 2006- 08-29. WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 [2] 2 Survey of Literature [2] and Current Practice [2] Cost accounting for IT infrastructures falls [2] under the realm of IT (Infrastructure) Controlling (see for instance [Karg99; KrBR00; [2] GaMa05]) or, from the ITIL perspective [2] [OoOC01], IT Financial Management. [2] Several concepts exist (e.g., cost-center accounting, process

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [

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to business objectives, the best possible use of the resource information. Information Management is a management as well as a technology discipline, and is an integral part of corporate management (Krcmar, 2004, p. 49). Above mentioned tasks of planning 36 Managerial Functions of Information Management IT Governance Strategy IT Processes IT Personnel IT Controlling Management of Information Supply Demand Usage Management of Information Systems Data Processes Application Life Cycle Management of Information and Communication Technology Storage Processing Communication Technology Bundles Figure 2.1: Model of Information Management (adapted from Krcmar, 2004, p. 47) and controlling users' or departments' behavior are fulfilled by the overall managerial functions. IT Governance specifies "the decision rights and accountability framework to encourage desirable behavior in the use of IT" (Weill and Woodham, 2002 cited by Krcmar, 2004, p. 288). IT Controlling coordinates the use of the resource information, the lifecycle of the Information Systems (Portfolio, Project and Product Controlling) and the IT infrastructures (Infrastructure Controlling) (Krcmar, 2004, p. 421). The allocation of

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following model of IM by Krcmar [Krc04]. s of an ente Management ofInformation Supply Demand Usage Management of Information Systems Data Processes Application life cycle Managerial Functions of Information Management IT-Governance Strategy IT-Processes IT-Personnel IT-Controlling Processing Storage Communication Management of Information and Communication Technology Technology Bundles Picture 3. Model of information management by Krcmar [Krc04] From one point of view IM is one management task, distributed to 3 levels; it refers to information itself at the highest

is accountable for them. That is, they have thoughtfully designed their IT governance, rather than focusing only on how IT is managed. 2 IT governance specifies the decision rights and accountability framework to encourage desirable behavior in the use of IT. It is not about IT management and the detail of particular IT decisions and their implementation, rather about the arrangements for who makes critical decisions

- **4** Dubrovskaya, Snezhana: Information ..., 2005, S.
- **5** CIO Futures. Lead With Effective Go..., 2002, S. 36

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tensions, investment setbacks and distorted use of IT services (Blosch et al., 2003b, p. 6). In the following sections we focus on identifying appropriate cost allocation approaches to avoid those conflicts. Concerning further reading on Information Management, we refer the interested reader to Biethahn et al. (2004) ; Heinrich (2002) and Krcmar (2004). Teubner and Klein (2002) provide a comparative book review. Furthermore, IT Cost Accounting and Chargeback is typically addressed in literature on IT Controlling (see for instance Gadatsch and Mayer, 2006; Heilmann, 2001; Kargl, 1999; Krcmar

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exact Mean Value Analysis (MVA) [ReLa80] or, for networks with a large numbers of users and multiple job classes, the Self Correcting Approximation Technique (SCAT) [NeCh81]. We refer the interested reader to [MeAD04] and [BoRi97; BoGM06] for a more detailed description of these algorithms. 5.2 The QN Verifier For the validation of the Queuing Network computations, we first developed

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or internal users rOOODDOOOOa Business units Application Management and Operations i IT unit 2 J Infrastructure Management and Operations i IT unit 1 i Scenario II Figure 2.2: Example: Organization of IT Service Provision 2.1.3 Overview of Processes IT Cost Accounting and Chargeback can be divided into three major processes (Blosch et al., 2003b): Cost Identification, Cost Allocation and Cost Recovery (see figure 2.3)1. Whether and how these processes are implemented depends primarily on the funding of the IT units. Three basic funding models can be distinguished (

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appropriate approach is mainly dependent on management requirements and the [2] organizational structure of the IT unit (e.g., [2] service center, cost center, profit center). [2] Overall, cost accounting can be divided [2] into three major steps (figure 1) [Gart03]. [2] Cost identification is an organizational/ [2] accounting issue. It focuses on making IT [2] costs visible and assigning them to accounting objects, such as

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [

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Commerce, 2001, ch. 5.3.2). The three IT Cost Accounting and Chargeback processes then can be described as follows. Cost Identification focuses on achieving cost transparency inside the IT units. The objective is to identify actual costs for the different IT services and thus control the efficiency of their provision. This process is mandatory, whether or not the costs are further allocated to the business units (Blosch et al., 2003b, p. 8). The underlying costing approach (e.g., full-costing, variable-costing) typically

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of their financial performance and [2] improves forecasting and decision making. [2] It deals mostly with technical aspects, such [2] as measuring usage and identifying cost allocation keys for the different IT services. [2] Finally, cost recovery describes the process [2] WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 [2] Cost [2] identification [2] Cost [2] allocation [2] Cost [2] recovery [2] Cost accounting [2] Figure 1 The cost accounting process (adapted from [Gart03]) [2] 84 Reinhard Brandl,

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [

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is mandatory, whether or not the costs are further allocated to the business units (Blosch et al., 2003b, p. 8). The underlying costing approach (e.g., full-costing, variable-costing) typically depends on overall accounting guidelines. Cost Allocation then distributes the costs to the business units. The objective is to enable business and IT managers to control what the money is spent on (e. g., cost share per business unit, cost share per process). In a typical company more than half of the IT costs are spent on shared services (e.g., data center operations, network management, telecommunications) (Blosch et al., 2003a, p. 14). For these services the chosen cost allocation keys2 are decisive. Arbitrary cost allocations may distort the determined cost shares and bias management decisions. 2An overview

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an organizational/ [2] accounting issue. It focuses on making IT [2] costs visible and assigning them to accounting objects, such as the provided IT [2] services. Cost allocation distributes the [2] costs to the business units, enables the assessment of their financial performance and [2] improves forecasting and decision making. [2] It deals mostly with technical aspects, such [2] as measuring usage and identifying

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [

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plunge Creates financial discipline in IT unit The wrong behaviors are encouraged Table 2.1: Benefits and Problems of IT Cost Accounting and Chargeback (adapted from Blosch et al., 2003b, p. 7) Cost Recovery actually charges the accounts of the business units for their usage of IT services. The focus lies on changing customer behavior. To a certain degree and according to management objectives, market mechanisms can be used to regulate supply and demand of IT services. Charges may be dependent on costs or on market prices, for instance. However, Cost Recovery can also lead to political tensions and to suboptimal use of IT services. Thus, credible cost identification and

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Store from Sun Microsystems [SuMi]. Section 6 compares the approach with related work. The paper concludes with a short summary in section 7. of setting prices and charging the businessunits for their usage of IT services. One objective is to set incentives, e.g., for costconscious behavior, and to regulate supply and demand of IT services. Hence, it has a strategic orientation. The latter

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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desktop computer with office applications and network access, see Bertleff, 2001, p. 62 for an example) and incurred costs clearly allocated to the business units (e.g., per desktop computer, per telephone line). By far more complex is apportioning costs for the provision of central business application systems, represented by the dark-gray boxes in figure 2.4. This is because, firstly - in contrast to standardized desktop-related services each application system has its own infrastructure, application and support requirements and, secondly,

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cost accounting (full and variable costing) as well as for process- or activity-based costing approaches. Generally, we propose a three-stage process (see figure [2]). Budgeted costs for the provision of shared IT resources are apportioned among the services according to services expected resource consumption and forecasts of the resources total usage. Thus, for every service a

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labor costs might require a time recording system (see Spitta and Becker, 2000 for a discussion of possible problems) and, finally, determining usage shares of shared IT infrastructure resources could become technically complex. Major functions required for the provision of an application system, their relative cost shares4 and possibilities to allocate these costs to customers are depicted in figure 2.5. Under the assumption that an appropriate time-recording system exists, costs for external and internal implementation services can be

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the CIMS System Description Manual [CIMS]) (Tiered) flat rate per application (App ! BU) The application-oriented approach can be further simplified if one considers only the provision of an application in a data center as "IT product" and allocate costs by a flat rate to a single business owner. The actual resource consumption is not considered. The BMW

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IT Controlling predominantly recommends the use of technical consumption metrics, such as processor time, number of Input/Output (I/O) operations and stored Gigabytes (see for instance Gadatsch and Mayer, 2006, p. 180, Spitta, 2000, p. 282 or Kargl, 1999, p. 122). In a mainframe environment the allocation of resource consumption is supported by comprehensive accounting mechanisms such as the System Management Facility (SMF) of IBM (see IBM, n.d.b) or the "Rechenzentrum-Abrechnungsverfahren" (RAV) of Fujitsu-Siemens 5For a fundamental discussion of "reasonable" cost allocation principles we refer the interested reader to Riebel (1994, p. 67-79). 44 (see Fujitsu Siemens, n.d.). In the context of today's distributed and heterogeneous client/server infrastructures such an approach has flaws (Bertleff, 2001, p. 63). On the IT side, metering and consolidating consumption data from distributed and heterogeneous components is

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SQL statement, for instance, does not contain any information about the actual user of the application who submitted the query. Modern database management systems support the allocation of resource consumption (CPU time, query runtimes, etc.) to the connection pools of the application servers, but they cannot reconstruct the original user. Measured usage (HW! App! BU)

exact Mean Value Analysis (MVA) [ReLa80] or, for networks with a large numbers of users and multiple job classes, the Self Correcting Approximation Technique (SCAT) [NeCh81]. We refer the interested reader to [MeAD04] and [BoRi97; BoGM06] for a more detailed description of these algorithms. 5.2 The QN Verifier For the validation of the Queuing Network computations, we first developed

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Bertleff, 2001, p. 63). On the IT side, metering and consolidating consumption data from distributed and heterogeneous components is elaborate and cost-intensive. On the customer side, diverse technical metrics, such as processor times from different servers, are difficult to comprehend and to control. Overall, the diversity of IT functions requires differentiated Cost Accounting and Chargeback methods. Particularly in shared client/server environments usagebased cost allocation seems to be difficult. The necessary efforts for the determination of accurate cost allocation keys could potentially outweigh their benefits. These problems have motivated a closer analysis of appropriate cost allocation approaches for today's

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and database server). Measuring and allocating resource consumption directly to business units is associated with two fundamental problems. First, from a user perspective, diverse technical metrics are difficult to comprehend and to control. Let s consider a business manager, receiving an account statement, based on the CPU times of multiple servers. As he cannot directly correlate the charges with his (

effective usage and cost control. In the following, we focus on cost allocation and in particular on the determination of usage-based cost allocation keys in shared client/server environments where the resource consumption of the provided IT services is a significant cost driver. Despite the vast amount of literature in the domain, technical aspects of

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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infrastructure entities and applications might not be clear-cut. Software infrastructure is applicationindependent, such as operating systems, server software, database management systems and application integration software. However, applications suites, which bundle multiple applications, e.g., for Enterprise Resource Planning (ERP) or Customer Relationship Management (CRM) often also contain software infrastructure entities. For instance, SAP platform software such as SAP Net Weaver (see SAP, n.d.a) belongs to software infrastructure (level 1), whereas the ERP solution built upon is part of the applications (level 3). 46 2.2 Survey

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been a long-standing dream for some vendors and CIOs. The concept is simple and attractive: rather than buying a software license for an application such as enterprise resource planning (ERP) or customer relationship management (CRM) and installing this software on individual machines, a business signs up to use the application hosted by the company that develops and sells the software, giving

- **6** Delivering software as a service, 2007, S. 1

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on scientific work in the domain, three major research branches have emerged: First, the adoption of Activity-based costing approaches to data centers to overcome the limitation of traditional cost accounting systems (section 2.2.1.1); second, IT Controlling in distributed environments (section 2.2.1.2); and third, the optimal design of chargeback systems and practices to achieve organization-level objectives (section 2.2.1.3). 2.2.1.1 Process and Activity-based Costing Traditional cost center/cost unit costing is primarily designed to determine costs for end-

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of different streams in the literature: & Controlling and Cost Accounting [Rieb94; Horv06] & Information Management [Krcm04] and IT Controlling [Karg99; KrBR00; GaMa05] & Chargeback systems [Drur97] and IT Controlling in distributed environments [Aure97; HWWB99; Sche05] & Organizational design of chargeback systems [McKa87; VeTB96; RoVB99] & Costing approaches: Traditional costing [MaiJ96; Spit00], Process costing [Fuer94; Funk99], Activity-based costing [GNMA02] &

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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selects out of them for each activity center one cost driver (Fiirer, 1994, p. 153): Processing: number of I/O operations Storage: size of reserved space Output: number of printed pages 6For an overview of traditional IT Cost Accounting, we refer the interested reader to Mai (1996), who discusses the applicability and the optimal design of three traditional Cost Accounting approaches (Full Costing based on actual/budgeted costs and Variable Costing based on budgeted costs) for IT infrastructures with shared resources. 48 The

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exact Mean Value Analysis (MVA) [ReLa80] or, for networks with a large numbers of users and multiple job classes, the Self Correcting Approximation Technique (SCAT) [NeCh81]. We refer the interested reader to [MeAD04] and [BoRi97; BoGM06] for a more detailed description of these algorithms. 5.2 The QN Verifier For the validation of the Queuing Network computations, we first developed

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historical data, the average number of consumption units of the cost-driving resource. Thus, he derives cost portions per transaction and, by forecasted or measured quantities, the costs for business processes (Fiirer, 1994, p. 137 et seqq.). The concept is illustrated by examples of mainframe infrastructures at major banks in Switzerland. Besides the costing approach, a major contribution is the in-depth evaluation of stakeholders and objectives of IT Cost Accounting (see Fiirer, 1994, p. 38-55). Funke (1999) goes in his work even a

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profiles. Sections 4 and 5 present methods for estimating resource profiles for IT services and describe how we use Queuing Network Models for validation and capacity planning. The concept is illustrated by experiments with the example application Java Pet Store from Sun Microsystems [SuMi]. Section 6 compares the approach with related work. The paper concludes with a short summary

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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decentralization of IT systems affects IT Controlling. For his considerations, he structures IT Controlling according to Krcmar and Buresch (1994) in Portfolio Controlling, Project Controlling, Product Controlling and Infrastructure Controlling. IT Cost Accounting is part of IT Infrastructure Controlling (see section 2.1.1). However, from his 1997 perspective, the determination of usage-based cost allocation keys is less problematic, as on the one hand, hardware and software in distributed environments is mostly dedicated to business units (Aurenz, 1997, p. 355) and on the other hand, future accounting software will provide user-oriented accounting metrics (Aurenz, 1997, p. 357). Current literature on IT Controlling mostly proposes technical metrics to allocate costs of shared client/server infrastructures (see for instance Gadatsch and Mayer, 2006, p. 180) and does not

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Technology 11 (1996) 2, pp. 101 117. [Vmwa] VMware, Inc.: Virtualization software. httpwwwvmwarecom, Last accessed: 2006- 08-29. WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 [2] 2 Survey of Literature [2] and Current Practice [2] Cost accounting for IT infrastructures falls [2] under the realm of IT (Infrastructure) Controlling (see for instance [Karg99; KrBR00; [2] GaMa05]) or, from the ITIL perspective [2] [OoOC01], IT Financial Management. [2] Several concepts exist (e.g., cost-center accounting, process costing). The choice of [2]

On the business side, it should enable an effective usage and cost control. In the following, we focus on cost allocation and in particular on the determination of usage-based cost allocation keys in shared client/server environments where the resource consumption of the provided IT services is a significant cost driver. Despite the vast amount of literature in

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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business (e.g., through regular negotiations about rates and services, communication of total costs and charges). This supported a mutual understanding of costs and requirements and resulted in an enhanced business-IT partnership. According to the authors, "this is the (largely) untapped potential of IT chargeback" . 52 2.2.2 Empirical Surveys We present three empirical surveys, each with a different focus. Hübner et al. (1999) analyze IT Cost Management in centralized and decentralized environments. Gadatsch et al. (2005) focus on the overall state-of-the-practice of IT

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Multichain Queuing Networks. In: Journal of the ACM 27 (1980) 2, pp. 313 322. [Rieb[94]] Riebel, Paul: Einzelkosten- und Deckungsbeitragsrechnung. Gabler, Wiesbaden 1994. [RoVB99] Ross, Jeanne W.; Vitale, Michael R.; Beath, Cynthia Mathis: The untapped potential of IT chargeback. In: MIS Quarterly 23 (1999) 2, pp. 215 237. [Sche05] Scheeg, Jochen Michael: Integrierte IT- Kostentabellen als Instrument für eine effiziente IT-Leistungserbringung im Informationsmanagement: Konzeption und praktische Umsetzung. Difo-Druck,

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [

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as guidelines for the analysis and improvement of the IT Service Management (ITSM) processes8. In the following, we briefly present the advice on IT Cost Accounting and Chargeback of two wide-spread models, namely the Information Technology Infrastructure Library (ITIL) and the Control Objectives for Information and related Technology (CobiT). Information Technology Infrastructure Library ITIL is a structured collection of best-practices for the realization of a cost-efficient IT organization and for the provision of high-quality services (Häusler et al., 2005, p. 16 et seqq.). In the first half of this decade it has emerged as a de-facto standard and has gained an enormous popularity (Häusler et al, 2005, p. 6 et seqq.). ITIL can be divided into

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of Oregon Gene Kim Tripwire Abstract Information technology managers are confronted with a myriad of best-practice frameworks for information technology service management. These frameworks include the Information Technology Infrastructure Library (ITIL) and the Control Objectives for Information and related Technology (COBIT). Advocates of these frameworks promote the value of these guidelines in achieving cost reductions and improving business

- 7 The value, effectiveness, efficienc..., 2004, S.

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planning, standard unit costs for each IT resource (e.g., per processor 56 time, per stored GB). The expenditures per cost center are then monitored and determined on a monthly basis (ch. 5.3.14). If the business units are charged for their usage of IT services, the chargeable items should be as close as possible to the organization's business deliverables. "Only a lack of information should force Charging to be directly based on resource usage; this lack of information must be overcome and it is important that in the analysis phase, steps are taken to ensure the future vailability of information" (ch. 5.4.4). On the other hand, business deliverables are often not suited for chargeback, mainly because the allocation of resource consumption would require unacceptable high measurement efforts (ch. 5.4.4). ITIL does not provide a complete answer to this dilemma. The benefits must be weighed against the cost of implementation and operation of the charging and monitoring system from case to case. Control Objectives for Information and related Technology CobiT is a framework for IT governance and control practices. It does not explicitly describe how ITSM

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Microsystems [SuMi]. Section 6 compares the approach with related work. The paper concludes with a short summary in section 7. of setting prices and charging the businessunits for their usage of IT services. One objective is to set incentives, e.g., for costconscious behavior, and to regulate supply and demand of IT services. Hence, it has a strategic orientation. The latter

SQL statement, for instance, does not contain any information about the actual user of the application who submitted the query. Modern database management systems support the allocation of resource consumption (CPU time, query runtimes, etc.) to the connection pools of the application servers, but they cannot reconstruct the original user. Measured usage (HW! App! BU)

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consistent objectives conflicting objectives Figure 2.12: Consistent and conflicting Objectives (adapted from F rer, 1994, p. 50) processor second, per transferred byte) and customer-oriented (e.g., per business activity, per business transaction) cost allocation arises. If business units are charged for their usage of IT services, a customer-oriented approach seems to have considerable advantages. At the business units cost allocation for instance per business transaction enables a better controlling of IT usage (including predictability, comprehensibility, reproducibility and ability to control costs) and an

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Microsystems [SuMi]. Section 6 compares the approach with related work. The paper concludes with a short summary in section 7. of setting prices and charging the businessunits for their usage of IT services. One objective is to set incentives, e.g., for costconscious behavior, and to regulate supply and demand of IT services. Hence, it has a strategic orientation. The latter

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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accounting determines costs per resource (e.g., for a particular server) or at least per resource pool (e.g., for all Unix servers). These costs can be either directly attributed to a single business owner or apportioned by some form of usage-based cost allocation key (see next section). Business transactions typically involve multiple resources. Measuring and consolidating their total resource consumption is mostly not possible or associated with unreasonable efforts. On the other hand, allocating costs by various technical consumption metrics neglects most of the positive controlling potential of IT charges. Against this background, the purpose of chargeback for shared client/server and network infrastructures is seriously questioned (see for

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incentive compatibility, the second and third requirements target the viability of the approach. Clearly, direct apportioning of IT infrastructure costs could easily outweigh the benefits of a usage-based cost allocation key. Based on a series of load tests, we derive for every service a so-called resource profile as estimator for its true resource consumption. We consider CPU

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transactions Business transactions T i i i i IT Infrastructure Costs Figure 2.13: Classification of practiced Approaches 2.4 Practiced Approaches The second objective of the literature study was to get an overview of practiced approaches to IT Infrastructure Cost Allocation. Besides approaches that are based on non-IT allocation keys (e.g., cost allocation per employee or per revenue share), we identified five basic concepts for apportioning infrastructure costs. These concepts are briefly introduced in the following (see figure 2.13 for an overview). Direct cost allocation Where a hardware resource is dedicated to a specific application or a business function, the costs of the assets can be directly attributed. This procedure is transparent and easy to implement. It is not ITspecific. However, the underlying assumption - that there is a single business owner of a resource - is mainly limited to application server and storage infrastructure. Other resources, like network components or middleware for application integration, are usually shared. (Tiered) flat rate per application If the application, rather than the infrastructure, is dedicated to a single business owner, costs can be allocated by a flat rate. The actual resource consumption is not considered. The BMW Group uses such flat rates for applications on its J2EE infrastructure (see chapter 6). Gartner recommends tiering the flat rates according to functionality, expected usage (e.g., number of registered users) and service levels (see Blosch et al., 2003a; Heine, 2006). This approach is particularly easy to implement, as no explicit differentiation of resource costs and no metering is required. The accompanying lack of transparency may be accepted if the applications are of a similar nature (complexity, workload, etc.) and are predominantly used by a single business unit. Measured hardware usage of end-users A widespread approach to allocating costs of a shared infrastructure is a proportional breakdown to the business units according to their resource consumption. Measured usage is commonplace for disk storage and telephony services. However, when it comes to client/server computing, a single request usually involves multiple heterogeneous components (e.g., web server, application server and database server). Measuring and allocating resource consumption directly to business units is associated with two fundamental problems. 1. From a user perspective, diverse technical metrics are difficult to comprehend and to control. Let us

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see below) We classified the identified concepts in the following according to the mapping of hardware (HW), applications (App) and business units (BU). We excluded approaches that are based on non-IT allocation keys (e.g., cost allocation per employee or per revenue share, etc.). Direct cost allocation (HW! BU) Where a hardware resource is dedicated to a specific application or a business function, the costs of the assets can be directly allocated. This procedure is transparent and easy to implement. It is not IT-specific. However, the underlying assumption that there is a single business owner of a resource is mainly limited to computing and storage infrastructure. Other resources, like network or EAI components, are usually shared. Measured usage (HW! BU) A widespread approach to allocating costs of a shared infrastructure is a proportional breakdown to the business units

cost of payroll to the departments and business units based on the number of paychecks they received". (Excerpt from the CIMS System Description Manual [CIMS]) (Tiered) flat rate per application (App ! BU) The application-oriented approach can be further simplified if one considers only the provision of an application in a data center as "IT product" and allocate costs by a flat rate to a single business owner. The actual resource consumption is not considered. The BMW Group uses such flat rates for applications on its J2EE infrastructure. Furthermore, Gartner recommends tiered flat rates [Gart03], based for instance on the required service levels. This approach is particularly easy to implement, as no explicit differentiation of resource costs and no metering is required. The accompanying lack of transparency may be accepted if the applications are of a similar nature (complexity, workload, etc.) and are predominantly used by a single business unit. In our opinion, none of the approaches fulfills the above described requirements, such as customer-orientation (e.g., through non-technical accounting metrics) and the integration of

owner of a resource is mainly limited to computing and storage infrastructure. Other resources, like network or EAI components, are usually shared. Measured usage (HW! BU) A widespread approach to allocating costs of a shared infrastructure is a proportional breakdown to the business units according to their resource consumption. Measured usage is commonplace for disk storage

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consider a business manager, receiving an account statement, based on the processor times of multiple servers. As he cannot directly correlate the charges with his (business) activities, it is difficult for him to plan or control resource consumption. In mainframe environments, with one single resource, this might have been possible, but the approach cannot be transferred to client/server infrastructures. 2. Due to performance and security reasons, the original business context of a transaction (e.g., user, business activity) is mostly not available in the backend. User names are not further transmitted after a successful authorization 66 and connection pools are used for database access. A SQL statement, for instance, does not contain any information about the actual user of the application who submitted the query. Modern DBMS support the allocation of resource consumption (processor time, query runtime, etc.) to the connection pools of the application servers, but they cannot reconstruct the original user. For centrally controlled, scheduled and monitored batch jobs these problems can be partially overcome. However, for interactive workload a clear assignment of resource consumption - and thus of costs - to users is often not possible. Measured hardware usage

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and telephony services. However, when it comes to client/server computing, a single request usually involves multiple heterogeneous components (e.g., web server, application server and database server). Measuring and allocating resource consumption directly to business units is associated with two fundamental problems. First, from a user perspective, diverse technical metrics are difficult to comprehend and to control. Let s consider a business manager, receiving an account statement, based on the CPU times of multiple servers. As he cannot directly correlate the charges with his (business) activities, it is difficult for him to plan or manage resource consumption. In mainframe environments, with one single resource, this might have been possible, but the approach cannot be transferred to client/server infrastructures. Second, due to performance and security reasons the original business context of a transaction (e.g., user, service) is mostly not available in the backend. User names are not further transmitted after a successful authorization and connection pools are used for database access. A SQL statement, for instance, does not contain any information about the actual user of the application who submitted the query. Modern database management systems support the allocation of resource consumption (CPU time, query runtimes, etc.) to the connection pools of the application servers, but they cannot reconstruct the original user. Measured usage (HW! App! BU) For accounting and billing of shared IT services, a broad range of commercial tools is available (see for instance IBM [IBCo],

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allocating resource consumption to applications or databases is supported by most operating systems and server software. It is also the domain of professional accounting and billing tools (see for instance Econet, n.d.; IBM, n. d.a; Nicetec, n.d.; USU, n.d.)12. Their strengths are the collection of accounting data by custom agents or by log files analysis, the consolidation of this information and the generation of reports for chargeback and management information. However, in client/server environments they are also facing the problems described in the previous paragraph. Thus, they mostly provide only a per-application and not a per-user or a per-department view on resource consumption. Accordingly, they assume either a single business owner per application or use external data from the application or the organization to derive cost portions for the business units: "Once you know the cost of an application as a whole, you can determine the cost of functional metrics produced by the application. For example, if you knew that "Payroll" cost $10, 000 and that it produced 1,000 paychecks then the average cost of a paycheck is $10.00. Then, you could allocate the cost of payroll to the departments and business units based on the number of paychecks they received." (Excerpt from the CIMS System Description Manual: CIMS Lab, n.d.) 12An overview of commercial accounting and billing tools is provided by Siebertz (2004, p. 49). Business transactions There may be two very different motivations behind using business transactions for the allocation of IT costs. On the one hand, it could be considered as a form of simple overhead cost allocation, similar to costs per employee or cost per revenue share. On the other hand, it could be intentionally used for enabling an effective controlling of IT usage

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and billing of shared IT services, a broad range of commercial tools is available (see for instance IBM [IBCo], USU [USU] Nicetec [Nice] and Econet [Econ]). Their strengths are the collection of accounting data by custom agents or by log files analysis, the consolidation of this information and the generation of reports for chargeback and management information. However, in client/server environments they are also facing the problems described in the previous section. Thus, they mostly provide a per-application view on resource consumption and use external data from the application or the organization to derive cost portions for the business units: "Once you know the cost of an application as a whole, you can determine the cost of functional metrics produced by the application. For example, if you knew that "Payroll" cost $ 10, 000 and that it produced 1,000 paychecks then the average cost of a paycheck is $ 10.00. Then, you could allocate the cost of payroll to the departments and business units based on the number of paychecks they received". (Excerpt from the CIMS System Description Manual [CIMS]) (Tiered) flat rate per application (App ! BU) The application-oriented approach can be further simplified if one considers only the provision of an application in a

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providers (see for instance Brenner, 2004). The Society for Information Management surveyed in 2003, 2004 and 2005 the management concerns of IT executives. The top-ranked issue in all three reports was IT and business alignment, defined as "applying IT in an appropriate and timely way, in harmony and collaboration with business needs, goals, and strategies" (Luftman et al., [2006]). As top enablers of IT and business alignment, the respondents of the 2005 survey indicated: IT understands the firm's business environment (Luftman et al., 2. Traditional cost allocation methods, which are based on static mappings

2006). Business managers drive IT to focus on cost-effective support of business

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and end users often have competing and even incompatible needs, but balance can be achieved with this method. In business-IT alignment, IT is applied in an appropriate and timely way, in harmony and collaboration with business needs, goals, and strategies. Terms such as "harmony," "linkage," "fusion," "fit," " match," and "integration" are often used synonymously with the term " alignment." For the past 15 years, academics, consultants, and

- **8** Measure your business-IT alignment, 2003, S. 26

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typically used by a small number of people with a management or a reporting function. Furthermore, the resource consumption per individual user in OLTP systems is far smaller than in OLAP systems. This causes higher efforts for measuring and allocating resource consumption, in particular if the users are distributed across business units. The infrastructure of application systems can be realized with different technology bundles such as mainframe or client/ server architectures (see section 2.1.5). We set the scope for

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and telephony services. However, when it comes to client/server computing, a single request usually involves multiple heterogeneous components (e.g., web server, application server and database server). Measuring and allocating resource consumption directly to business units is associated with two fundamental problems. First, from a user perspective, diverse technical metrics are difficult to comprehend and to control. Let s

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server architectures (see section 2.1.5). We set the scope for the following considerations to client/server architectures, firstly, because they are predominant in today's data centers and, secondly, because their distributed and heterogeneous nature complicates the determination of usage-based cost shares (see section 2.4). 3.2 Concept 3.2.1 IT Services from a Customer Perspective In section 2.1.5 a model of Information and Communication Technology was introduced (see figure 2.6). This model is technology-oriented and does not necessarily reflect a customer's perspective. For end users,

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On the business side, it should enable an effective usage and cost control. In the following, we focus on cost allocation and in particular on the determination of usage-based cost allocation keys in shared client/server environments where the resource consumption of the provided IT services is a significant cost driver. Despite the vast amount of

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is technology-oriented and does not necessarily reflect a customer's perspective. For end users, the complexity of application systems, technology bundles and software and hardware infrastructure entities is typically not transparent. They perceive an application system largely as black-box, accessible through (graphical) user interfaces and providing a number of business-related services. In the context of the considered operational, interactive OLTP systems, possible kinds of services can be: Execution of a business transaction (e.g., " process order", "update stock", and "add customer") 74 Users grouped into business units (customers) Services accesible through user interfaces Applications and application systems Software and hardware infrastructure resources Figure 3.2: Customer Perspective on Information and Communication Technology Access to an Information System (e.g., "retrieve order details", "browse catalog", and "check plant status") The customer perspective and the notion of services lead to an adapted and simplified model of Information and Communication Technology (see figure 3.2). The users, grouped into business units, access the services of application systems through (graphical)

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the customers (e.g., end-users, business units) perspective. For them the complexity of the underlying software and hardware is mostly not transparent . Instead, they perceive the system largely as black-box, accessible through (graphical) user interfaces and providing a number of business-related services. Categories of such services could be Execution of a business transaction (e.g., process order , update stock , and add customer) or Access to an Information System (e.g., retrieve order details , browse catalog , and check plant status). An application may implement one or more of those services, but a service can also comprise multiple applica- WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 Cost Accounting for Shared IT Infrastructures 85 tions.

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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of one or more application systems. Furthermore, an application can access other infrastructure components (e.g., computing, storage, printing resources) over the communication networks. The basic question, raised in the previous chapter (see section 2.1.4), is how costs for the provision of infrastructure resources can be allocated to the business customers. Common approaches based on measured usage or direct costs have flaws Application Human Resource Resource -supports Non Processlinked Service Preliminary Service -consists CH Service Customer Business Proc.

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cost accounting (full and variable costing) as well as for process- or activity-based costing approaches. Generally, we propose a three-stage process (see figure [2]). Budgeted costs for the provision of shared IT resources are apportioned among the services according to services expected resource consumption and forecasts of the resources total usage. Thus, for every service a

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causerbased cost allocation or cost proportionality (see figure 2.11). This might lead to various acceptance problems: "Cost transparency is not achieved" (management) "Cost portions are arbitrary" (customers) "Usage forecasts are worthless for planning IT resources " (IT unit) To overcome this difficulty, we focus below on the development of a methodology which bridges the gap between customer-oriented services and IT infrastructure resource consumption. 3.2.2 Determining Resource Profiles for Services In shared infrastructures, the resource consumption of users, services or applications is a cost driver. It would be obvious to use metered consumption values as an objective basis for apportioning infrastructure costs. Unfortunately, in heterogeneous client/server environments metering and allocating resource consumption to users and applications is difficult, if not impossible (see section 2.4). For services, as defined in the last section, it is even worse as they have a business, but not necessarily a technical meaning. Hence, measuring at runtime is not a feasible solution. Against this background, we propose an alternative approach that is based on the assumption that the invocation of a service always results in the same resource consumption in the infrastructure. In other words: The cumulated resource consumption of a service increases linearly with the number of concurrent or subsequent service invocations. If estimates for the expected consumption of the different resources and the number of service invocations were known, this could constitute the basis of cost allocation keys. The elaborate process of measuring and consolidating log data from different components could be bypassed. Furthermore, these estimates would be valuable inputs for the alignment of business forecasting and IT Capacity Planning. In the following, we propose a methodology

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true resource consumption of a user given varying workloads. [3] .2 Requirements It is unclear whether such estimates can be made with high enough accuracy in heterogeneous IT infrastructures: & ([1]) The resource consumption of a service request may depend to a certain degree on the workload. A linear extrapolation of a single service request might therefore be biased. & (2) Inaccuracies of the measurement and

can also comprise multiple applica- WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 Cost Accounting for Shared IT Infrastructures 85 tions. We assume that the invocation ofsuch a service always results in similar resource consumption in the infrastructure. If estimates for the expected consumption at the different resources and the number of service invocations were known, this could constitute the basis for cost

consumption is most evident for the network resource. In contrast, the transferred bytes of the Pet Store to the SAN seem not to be related with the number of concurrent users. The application is programmed to avoid " expensive" disk accesses as far as possible. Instead most data is kept in the memory of the servers.

WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 Cost Accounting for Shared IT Infrastructures 85 tions. We assume that the invocation ofsuch a service always results in similar resource consumption in the infrastructure. If estimates for the expected consumption at the different resources and the number of service invocations were known, this could constitute the basis for cost allocation keys. The elaborate process of measuring and consolidating log data from different components could be bypassed. Furthermore, these estimates would be valuable inputs for the alignment of business forecasting and IT capacity planning. The concept is not dependent on a specific costing methodology. It is applicable for traditional cost accounting (full and variable costing) as well as for process-

every service a cost portion is determined, which is allocated to the customers

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to estimate for a service i a so-called resource profile, p, which is defined as a vector of n consumption values p - with j = l...n denoting the different resources1. The profile then multiplied by the number of service invocations of a certain customer should result in an estimator for the resource consumption of this customer. The number of service invocations per customer can be traced by the analysis of business records ("Execution of a business transaction") or by the authorization/authentication infrastructure ("Access to an Information System"). 1A list of symbols is provided in the appendix (see section A.l). 3.2.3 Resources in a Client/Server Environment We propose categorizing resources according to the base functionalities of Information and Communication Technology: Communication, Computing and Storage (see figure 2.6). The

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accounts according to their number of service invocations. In the following, we describe a methodology to estimate for a service i a so-called resource profile, p, which is defined as a vector of n resource consumption values pij, with j [1] . . . n (CPU time Web Server, CPU time Application Server, CPU time Database Server, transferred bytes, etc.). The expected values pij are

CPU time, storage I/O, and network traffic, which typically are the scarce resources, and consequently the cost drivers and parameters for new investment decisions. This profile multiplied by the number of service invocations in an accounting period can then be the basis for a usage-based cost-allocation. The actual charges for business units might of course also be

mean of measurements during a load test. The resource profile multiplied by the number of service requests of a certain service customer (which can easily be traced) should result in an estimator for the resource consumption of this customer. The question is, whether the sample average of values in p is a good estimator for the true resource consumption of a user given varying workloads. [3] .2 Requirements It is

fine granular services (e.g., "view catalogue page", "add item to cart"). However, for this paper, we decided to consider the whole Pet Store as single service (Access to an Information system , see section 3). Our intention was, first, to compare the resource consumption of different user profiles and, second, to verify that Queuing Network Theory is also

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Computing: Processing time [seconds] For computing resources we propose including estimates of processing times at the different servers in the resource profiles. As measurements of processor times on different hardware are not directly comparable, they must be normalized, e.g., by using standard performance benchmarks (see SPEC, n.d.a). Memory is often also considered as a scarce resource. However, the maximum amount of physical memory a server can allocate on a machine is typically dedicated at startup (e.g., by setting a range for virtual memory) and it is possible to take this value as the basis for cost allocation. Storage: Amount of transferred data [blocks] We exclude disk space from our considerations, as it is usually allocated a priori to a specific application or a database. Besides space constraints, the storage I/O of database servers is a typical bottleneck in OLTP systems. We propose using the amount of transferred data for the resource profiles, as the number of I/O operations may be dependent 78 IT Infrastructure

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by SUN. However, in real-world scenarios it is important to use realistic database sizes. To compare the CPU times with measurements on other infrastructures, they must be normalized, e.g., by using standard performance benchmarks [SPECa]. These resource profiles provide an overview of the expected resource consumption for different types of user behavior. If historical usage data is available, an

of our resource profile. We excluded disk space, as it is usually a priori allocated to a specific application or a database and elaborate accounting tools are available. Memory is often also considered as a scarce resource. However, the maximum amount of physical memory a server can allocate on a machine is typically determined at startup (e.g., by setting a range for virtual memory) and it is possible to take this value as the basis for cost allocation. The experimental infrastructure was set up in a data center of the BMW Group (see table 1). We combined different operating systems (Linux, Windows and Unix) and

experiments we used CPU time, network and storage I/O as variables pij of our resource profile. We excluded disk space, as it is usually a priori allocated to a specific application or a database and elaborate accounting tools are available. Memory is often also considered as a scarce resource. However, the maximum amount of physical memory a server can allocate on a

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systems. We propose using the amount of transferred data for the resource profiles, as the number of I/O operations may be dependent 78 IT Infrastructure costs IT cost centers / units r Resource Services profiles Service 2 Service 3 Service 4 Customers / users cost centers / units business processs Customer 1 Service 1 Customer 2 Customer 3 Customer 4 Customer 5 (1) Cost identification (2) Cost allocation to services (3) Cost allocation to customers ->-?-? Figure 3.4: Cost Allocation by Services and Resource Profiles on the actual workload and factors like the disk fragmentation. The proposed categories, resources, usage variables and consumption metrics are typical examples and can be adapted to the

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Communication [1] WAN [1] LAN [1] " [1] Computing [1] Unix [1] Linux [1] " [1] Storage [1] SAN [1] NAS [1] " [1] p41 [1] p42 [1] p43 [1] p44 [1] ... [1] Service [1] 4 [1] p31 [1] p32 [1] p33 [1] p34 [1] ... [1] Service [1] 3 [1] p21 [1] p22 [1] p23 [1] p24 [1] ... [1] Service [1] 2 [1] p11 [1] p12 [1] p13 [1] p14 [1] ... [1] Service [1] 1 [1] Resource [1] profiles [1] (1) Cost identification (2) Cost allocation to services (3) Cost allocation to [1] customers, ... [1] Customers / users [1] Cost centers / units [1] Business processs [1] Services [1] Customer [2] 2 [2] Customer [3] 3 [3] Customer [3] 4 [3] Customer [5] 5 [5] IT cost centres / units [5] Figure 2 Cost allocation using resources profiles [5] 86 Reinhard Brandl, Martin Bichler, Michael Ströbel [2] 2 * 36,4 GB [2] (RAID 1) [2] 13 GB LUN

process (adapted from [Gart03]) [2] 84 Reinhard Brandl, Martin Bichler, Michael Ströbel [1] 1 [1] Communication [1] WAN [1] LAN [1] " [1] Computing [1] Unix [1] Linux [1] " [1] Storage [1] SAN [1] NAS [1] " [1] p41 [1] p42 [1] p43 [1] p44 [1] ... [1] Service [1] 4 [1] p31 [1] p32 [1] p33 [1] p34 [1] ... [1] Service [1] 3 [1] p21 [1] p22 [1] p23 [1] p24 [1] ... [1] Service [1] 2 [1] p11 [1] p12 [1] p13 [1] p14 [1] ... [1] Service [1] 1 [1] Resource [1] profiles [1] (1) Cost identification (2) Cost allocation to services (3) Cost allocation to [1] customers, ... [1] Customers / users [1] Cost centers / units [1] Business processs [1] Services [1] Customer [2] 2 [2] Customer [3] 3 [3] Customer [3] 4 [3] Customer [5] 5 [5] IT cost centres / units [5] Figure 2 Cost allocation using resources profiles [5] 86 Reinhard Brandl, Martin

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consider "Communication". 3.2.4 Cost Allocation by Services and Resource Profiles Although the categorization of resources is related to the activity centers of process costing approaches, the concept of allocating costs by resource profiles and services is not dependent on a specific costing system. It is applicable for traditional cost accounting (full and variable costing) as well as for process- or activity-based costing approaches. Based on the overall process structure of IT Cost Accounting and Chargeback (see section 2.1.3), we propose a three-stage approach for apportioning infrastructure costs: 1. Cost identification. Direct and indirect infrastructure costs are allocated to the accounts of

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from different components could be bypassed. Furthermore, these estimates would be valuable inputs for the alignment of business forecasting and IT capacity planning. The concept is not dependent on a specific costing methodology. It is applicable for traditional cost accounting (full and variable costing) as well as for process- or activity-based costing approaches. Generally, we propose a three-stage process (see figure [2]). Budgeted costs for the provision of shared IT resources are apportioned among the services according to services

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metric (e.g., processor time). Based either on forecasted or on past consumption levels, the costs per consumption unit (e.g, processor second) are calculated. 2. Cost allocation to services. For each service, a resource profile which contains the estimated consumption at the different resources (e.g., processor time Unix, processor time Linux, number of SAN I/Os) is determined. By multiplication with the cost per consumption unit, the cost shares per service are calculated. 3. Cost allocation to customers. Depending on the costing approach,

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IT Infrastructures 85 tions. We assume that the invocation ofsuch a service always results in similar resource consumption in the infrastructure. If estimates for the expected consumption at the different resources and the number of service invocations were known, this could constitute the basis for cost allocation keys. The elaborate process of measuring and consolidating log

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finally allocated to cost centers (e.g., business units), to cost units (e.g., products) or to business processes. Therefore, the measured, forecasted or estimated number of service invocations is multiplied by the cost shares of the services. The concept is illustrated by figure 3.4. In the following we focus on the second stage ("Cost allocation to services") and, in particular, on the development of a methodology for the determination of the resource profiles. 3.3 Model Hypotheses In section 3.2.2 we first introduced the concept of resource profiles: A resource profile p for a service i consists of n values p -, which are estimates of the expected resource consumption of service i at resource j. Our considerations were based on the following hypothesis: 80 1. The cumulated resource consumption of a service increases linearly with the number of concurrent or subsequent service invocations. This hypothesis focuses on the increase of the resource consumption. To derive a model which describes the total observed resource consumption, we extend the first hypothesis as follows: 2. The total resource consumption is composed of the resource composition of background activities and of the resource consumption caused

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profiles. Sections 4 and 5 present methods for estimating resource profiles for IT services and describe how we use Queuing Network Models for validation and capacity planning. The concept is illustrated by experiments with the example application Java Pet Store from Sun Microsystems [SuMi]. Section 6 compares the approach with related work. The paper concludes with a short summary

compare the CPU times with measurements on other infrastructures, they must be normalized, e.g., by using standard performance benchmarks [SPECa]. These resource profiles provide an overview of the expected resource consumption for different types of user behavior. If historical usage data is available, an average resource profile can be derived. Otherwise, the determined bandwidth of the

consumption is most evident for the network resource. In contrast, the transferred bytes of the Pet Store to the SAN seem not to be related with the number of concurrent users. The application is programmed to avoid " expensive" disk accesses as far as possible. Instead most data is kept in the memory of the servers.

CPU time [sec] 0,0389 0,5530 0,1293 0,8183 0,0838 0,7577 0,2071 0,8251 0, 830 [1] ,000 DB Server CPU time [sec] 0,0008 0,1474 0,0200 0,9550 0,0089 0, 9449 0,0251 0,8749 3,715 1,000 SAN I/O [blocks] 0 n/a 7,1230 0,7518 0 n/a 0 n/a 159,14 0,970 Network I/O [bytes] 174.521 1,0000 434.651 1,0000 250.183 1,0000 562.443 1,0000 398.283 1,000 2 3 4 based application used for project statustracking at the BMW Group. The linear increase of the resource consumption is most evident for the network resource. In contrast, the transferred bytes of the Pet Store to the SAN seem not to be related with

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monitors, cause a certain amount of resource consumption, even when there is no service workload on the resources. Consequently, this resource consumption should not be included in the resource profiles. The resource consumption per service may depend to a certain degree on the actual load at the resources. Those effects are described for Communication, Computing and Storage resources. In the following, we illustrate such behavior with an example from each category. In Ethernet networks, the collision rate depends on the utilization of the network segment. If a packet collision occurs, the sender retries the transmission and thus raises the

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workloads. [3] .2 Requirements It is unclear whether such estimates can be made with high enough accuracy in heterogeneous IT infrastructures: & ([1]) The resource consumption of a service request may depend to a certain degree on the workload. A linear extrapolation of a single service request might therefore be biased. & (2) Inaccuracies of the measurement and analysis instruments may introduce a systematic error, or also lead

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is. We summarize the three hypotheses in the following model. The parameter yij describes the total consumption of resource j during the execution time t of x concurrent or subsequent invocations of service i. The parameter dj indicates the resource consumption of the background activities, the load-independent and Uij the load-dependent resource consumption caused by the service invocations. However, for the resource profile we require one estimate p - of the expected resource consumption, independent of the actual utilization of the resource j. We therefore define p as sum of the baseline consumption bij and of uij as constant approximation of the load-dependent resource consumption Uif Assuming that the utilization of

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among multiple applications and business units. Typical examples include database servers, application servers or virtualized servers (e.g., using VMware [Vmwa] or Xen [UCCL]). In these cases the resource consumption of the installed applications and the workload generated by the customers is a significant cost driver. An average application server in an industrial data center (e.g., 4 CPU / 16 GB memory)

compare the CPU times with measurements on other infrastructures, they must be normalized, e.g., by using standard performance benchmarks [SPECa]. These resource profiles provide an overview of the expected resource consumption for different types of user behavior. If historical usage data is available, an average resource profile can be derived. Otherwise, the determined bandwidth of the

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that the utilization of the resources varies, the first and the third hypotheses are contradicting. We argue that the approximation and thus the determination of estimates for the resource consumption is justified if " or ~ 0, i.e. the resource consumption of a service invocation is not or is barely dependent on the actual workload. The total consumption can then be described as follows: The requirements from this model on a software tool supporting the estimation of resource profiles are twofold. First

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Summary Cost allocation of shared IT infrastructure such as server capacity or network equipment is technically difficult. We propose a method to derive adequate estimators for the resource consumption of a service invocation, which can then provide a basis for cost allocation keys. & The expected resource consumption of services can be estimated with high accuracy in load tests. Measurements

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and the model hypotheses (see section 3.3), we derived four requirements for resource profiles and the profiling process, which we consider as critical to the practical success of the concept. Requirement 1: Accuracy The resource profiles should be unbiased in the sense that on average it should not over- or underestimate the true resource consumption. If, from the perspective of the stakeholders, the resource profiles are not reliable, it might lead to various acceptance problems (see section 3.2.1) and questioning of the whole approach. This overall requirement has two major implications. On the one hand, instruments to validate the

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allocation keys for customer-oriented services based on their estimated resource consumption. Deriving such an estimator, however, is a nontrivial task. & First of all, the estimator should be unbiased, in the sense that on average it should not over- or underestimate the true resource consumption. & Second, the estimation should be applicable to various IT infrastructures (i.e., different hardware, operating systems and applications), without a need to change the respective systems. & Third, the

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potential sources of bias should be evaluated and, if possible, removed. We identified three major reasons for bias in resource profiles, formulated as sub-requirements in the following. Requirement 1.1: Accurate measurement and analysis tools Inaccuracies of the measurement and analysis tools may introduce a systematic error or also lead to high sample variance. Requirement 1.2: Linear resource consumption The model hypotheses formulated in section 3.3 must be fulfilled. If load-dependent behavior or other nonlinearities in the resource consumption affect a substantial share of the total consumption, the predictive accuracy may become

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infrastructures: & ([1]) The resource consumption of a service request may depend to a certain degree on the workload. A linear extrapolation of a single service request might therefore be biased. & (2) Inaccuracies of the measurement and analysis instruments may introduce a systematic error, or also lead to high sample variance. In order to cause as little extra overhead as possible (e.g., no reimplementation of applications and no additional monitoring software installed), we intend to work with

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behavior If a service requires interaction or parameters entered by the users, wrong assumptions about the user behavior may lead to distorted resource profiles. Requirement 2: Consistency The concept has been proposed for resolving the difficulties of usage-based cost allocation in heterogeneous and distributed client/server infrastructures. The estimation of resource profiles therefore should be in the same manner applicable to various kinds of hardware and software resources. Any dependencies on vendors or technologies should be

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incentive compatibility, the second and third requirements target the viability of the approach. Clearly, direct apportioning of IT infrastructure costs could easily outweigh the benefits of a usage-based cost allocation key. Based on a series of load tests, we derive for every service a so-called resource profile as estimator for its true resource consumption. We consider

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requirements on a cost allocation approach. Hence, it should be possible to translate the forecasted service usage of the business units into IT resource requirements and thus support the IT Capacity Planning. Requirement 4: Operating Efficiency The estimation should cause little extra work and integrate well with existing IT Service Management processes. If the determination of resource profiles is too costly, the advantages of a comprehensive consumption-based and customer-oriented cost allocation are outweighed by the existing approaches (see section 2.4). These requirements are used below as a basis for the development and evaluation of an approach for the determination of resource profiles. 3.5 Software Support In the previous section we specified a number of requirements on resource profiles and on the profiling process. We now focus on the development of a software toolkit realizing the concept. We start with a brief

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consumption. & Second, the estimation should be applicable to various IT infrastructures (i.e., different hardware, operating systems and applications), without a need to change the respective systems. & Third, the estimation should cause little extra work and integrate well with existing IT service management processes. While the first requirement is essential for the cost allocation key to achieve incentive compatibility, the second and third requirements target the viability of the

service-level resource profiles [6] is well motivated in proposals by Funke [6] [Funk99] and Scheeg [Sche05] in the areas [6] of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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processor time and memory allocation. Overall, this kind of information is a valuable input for the estimation of expected resource consumption, but there are two practical restrictions which hamper the application of standard profiling tools for the determination of resource profiles. First, profiling tools are mostly technology- or vendor-dependent, e.g., Java/J2EE (see JavaPerforrnanceTuning, n.d.), .NET (see Schwichtenberg, n.d.) and different ERP/CRM systems (see Symantec, n.d.). In an heterogeneous environment, different tools and a consolidation of measurements would be required.

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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for instance Kriill, 1997). The agents of the accounting and billing software introduced in section 2.4, as well as most of the profiling and load test tools presented above rely on these monitoring facilities. The advantage of Unix, Linux and Windows operating systems is that they offer a broad range of counters which provide comprehensive information about activities at the different hardware components. However, in contrast to the RMF, SMF and subsystem measurement tools available on MVS mainframes (

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compared and tested against the parameters measured in load tests with respective workloads. We conducted several experiments with J^2 EE applications in a distributed client/ server infrastructure consisting of Unix, Linux, and Windows servers in a data center of the BMW Group and achieved very promising results even in a very heterogeneous environment with multiple software modules, operating systems, and

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lack transaction or request-oriented data (see Buzen and Shum, 1996, for a comparative analysis). They do not relate the observed resource consumption with user behavior or application activities and thus are not directly applicable to the determination of resource profiles. 3.5.2 Profiling Process For the determination of resource profiles, we propose combining the strengths of a load test tool with local performance monitors. The basic idea is to use a load generator for systematic service invocations and to meter at the same time the resource consumption at the different components. However, as neither the load test tool nor the performance monitors explicitly determines the resource consumption per service invocation, an additional analysis toolkit is required, which correlates the data and calculates the resource profiles. Overall, the profiling process can be broken down into the following steps: 1. The application system is deployed in a dedicated test environment. Such environments with minimal or no differences to the production environments are typically used in larger organizations for approval tests2 prior to the roll-out of a new software release. It is important to isolate the resources in a test environment as far as possible from the influence of other application systems in the network. Their activities could distort the measurements. 2. The service invocations are recorded in load test scripts. The different services have to be defined in cooperation with the customers and, if possible,

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service-level resource profiles [6] is well motivated in proposals by Funke [6] [Funk99] and Scheeg [Sche05] in the areas [6] of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

consolidates them, together with the results from the load generator, in a database. It then correlates start and end times of service invocations with the performance data and calculates the resource profiles. Finally, a custom reporting package visualizes the results. In order to determine the resource consumption of a single service request, we successively raised the number of parallel

see previous section) . In the experiments we installed the applications under consideration in an isolated test environment, as is usual for operational approval tests [OoOC02] prior to the roll-out of a new software release. Bymeans of the load generator, we then simulated consecutive service invocations, while the performance monitors recorded the system s utilization in log files. After the load

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recorded in load test scripts. The different services have to be defined in cooperation with the customers and, if possible, based on historical usage data. If a service requires multiple user interactions and no information about the expected user behavior is available, different user profiles can be recorded to determine not an exact value, but an interval for the expected resource consumption. 3. The load generator replays the script and thereby successively raises the number of concurrent service invocations, until the first component reaches its bottleneck. The process is depicted in figure 3.5. A measurement interval starts with the first of a set of concurrent service invocations and ends when all these services invocations are completed. The time between two measurement intervals is represented by

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with standard OS performance monitors. The question is, can measurements based on standard log file data be sufficient to derive accurate resource consumption estimates? & (3) Assumptions about the expected user behavior (e.g., parameters passed, interactions with the system) during the setup of the load tests may not reflect reality. Overall, a validation of p can be performed ex-post

and so forth) and then applied a linear regression. We consider the slope of the regression line as average consumption per additional user and as estimate for the expected resource consumption. The Pearson correlation coefficient (r 2 [1; 1]) and the resource profile p for the Pet Store example is shown in table 2. For comparison we included the resource profile of an

behavior. Instead of simultaneous starts and stops, we now put the users in endless loops. After a certain period of time (e.g., 5 minutes), we add additional users, until the first component reaches its bottleneck. After the load test theQN Verifier stores the results in a database. The utilization of servers in our load tests are then compared with the predictions

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linear regressions to the results and derives the values p as slopes of the regression lines. They reflect the average resource consumption per additional user. As the measurements were obtained from the full load spectrum ("until the first component reaches its bottleneck"), possible load-dependent effects are factored in. We thus consider these values to be estimates for the expected resource consumption of a service invocation. To validate the process and the underlying hypotheses, we combined a number of off-the-self and custom software components. An overview of the software and detailed descriptions are presented in the following sections. 3.5.3 Software Overview Three kinds of tool are required for the process: A load test tool to simulate user behavior, performance monitors to meter the resource consumption at the involved components, and an analysis component to calculate the

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behavior. Instead of simultaneous starts and stops, we now put the users in endless loops. After a certain period of time (e.g., 5 minutes), we add additional users, until the first component reaches its bottleneck. After the load test theQN Verifier stores the results in a database. The utilization of servers in our load tests are then compared with the predictions

and so forth) and then applied a linear regression. We consider the slope of the regression line as average consumption per additional user and as estimate for the expected resource consumption. The Pearson correlation coefficient (r 2 [1; 1]) and the resource profile p for the Pet Store example is shown in table 2. For comparison we included the resource profile of

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LoadRunner (see Mercury, n.d.a). The choice was based on the following considerations. The Mercury LoadRunner is the leading product with an estimated market share of 77% in the load testing market worldwide (Hamilton, 2005 cited by Mercury, n.d.b). It supports around 30 protocols for different front- and backend interfaces, including HTTP, J2EE, .NET as well as protocols for major ERP/CRM systems (see Mercury, n.d.c). Thus, we obtain a broad coverage of existing application systems. The tool has been used for load tests at our industrial partner, the BMW Group. We could therefore directly use the software solution for experiments

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sar) and Microsoft Windows (perfmon). These operating system tools allow for a detailed monitoring. We chose the Load- Runner for the simulation of service invocations, as it supports around 30 protocols for different front- and backend interfaces, including HTTP, J2EE, .NET as well as protocols for major ERP/CRM systems. The user behavior is first recorded in a script (see figure 3 for an HTTP script example) , which can then be replayed by the desired number of

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First, the user selects on the command line (sar) or by using a graphical user interface (perfmon) the relevant counters and determines the measurement interval and log runtime. According to these specifications the tools then record the system behavior in log files. The Unix and Linux tool sar creates binary files which can be read out and transformed to space separated text files. The Windows tool perfmon directly creates comma-separated text files. Against the background of resource

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idle phase of 45 seconds (3), the procedure is restarted with 30 concurrent users. During the whole test, the performance monitors at the Web, Application and Database Servers record the system behavior in log files on their local disks. The upper diagram (4) shows the overall CPU utilization at the Application Server. Data about network and storage resources is analyzed in

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Data normalization is required for a comparative analysis. As the performance monitors are totally decoupled from the load generator, the local system times must be exactly synchronized. Whether these kinds of performance monitors are appropriate for the determination of resource profiles is validated by a set of experiments (see section 3.6). 3.5.3.3 Service Profiler For data analysis and calculation of resource profiles we developed a custom software toolkit, the Service Profiler. It consists of three separate components: Import, Analyze and

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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Profiler. It consists of three separate components: Import, Analyze and Visualize (see figure 3.6). The software is implemented in Java 1.5. Database management systems Oracle, MySQL and Microsoft Access are supported. In the following, we first provide an overview of the toolkit and then, in section 3.5.5, detail the determination of the resource profiles. Import The Import component parses the different kinds of log files (see figure 3.6) and consolidates the measurements in the database. In doing so it

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database sizes. To compare the CPU times with measurements on other infrastructures, they must be normalized, e.g., by using standard performance benchmarks [SPECa]. These resource profiles provide an overview of the expected resource consumption for different types of user behavior. If historical usage data is available, an average resource profile can be derived. Otherwise, the determined

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data, for example by converting values measured in milliseconds to seconds. Following these preparatory activities, the tool groups concurrent service invocations to measurement intervals and determines for each measurement interval the total resource consumptions. By means of a linear regression, the Analyze component finally calculates the values Pij. The whole process is detailed in section 3.5.5. Visualize The Visualize component supports three major activities: Report generation, consistency checking and performance analysis. Therefore it offers different kinds of parameterizable

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to determine the resource consumption of a single service request, we successively raised the number of parallel service invocations and determined the increase in resource consumption by means of a linear regression (i.e. the slope of the regression line). 4.2 The Java Pet Store Example In our experiments we used CPU time, network and storage I/O as variables pij of our

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components: Virtual User Generator to record and edit the test scripts, Controller to manage the load tests and Analysis to examine the test results. In the following, we describe how these applications are instrumented for the determination of resource profiles. 3.5.4.1 LoadRunner Virtual User Generator In load tests, the behavior of human users is emulated by virtual users (Vusers). The actions a Vuser performs are specified in a Vuser script. The LoadRunner tool for creating and editing scripts	is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents
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readily tested within the VuGen application. 5. Integrate the Vuser script. If the test was successful, the script can be transferred to the Controller and integrated into a load test scenario (see 94 next section). The scripts for the determination of resource profiles are generated in the same manner. First, VuGen records the service invocations of a human user in a basic script. During the following revision of the script, the following LoadRunner functions are inserted: lr_start..transaction() . . . lr_

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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illustrate it below with a section of a HTTP/HTML script. Thus, we consider as service "search" a single request to a search engine of an example application. 4 3 2 (...) lr_think_time(7); lr_rendezvous("search"); lr_start.transaction(" search"); 5 8 6 7 web_submit_data("search.screen", "Action=(url)/ exampleApplication/search.screen", "Method=GET", 9 "EncType=", 10 " RecContentType=text/html", 11 "Referer=(url)/exampleApplication/main. screen", 12 "Snapshot=t60.inf", is "Mode=HTTP", i4 ITEMDATA, is "Name= keywords", i6 "Value=(random_string_value)", it END ITEM, is LAST) ; 19 20 lr_end_transaction("search", LR_AUT0); 21 22 lr_think_time(7); (...) 24 During the profiling process, subsequent service invocations are framed by think times with no Vuser actions. Thus, potential impact from precedent service

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transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/ main.screen", "Resource=0", "RecContentType=text/html", "Referer=", " Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_ data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", " EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen" , "Snapshot=t60.inf", "Mode=HTTP", ITEMDATA, "Name=keywords", "Value= ExampleSearch1", ENDITEM, LAST); (".) lr_end_transaction("petstore _ shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner

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Completan B B r*títoie_ate.D\t'W*"eWBfV peutote_ate.0 . o te RBR FZ 12\ petaofe_j3ye.usT_cam 16 17 Iocalhost When petsiore_ate_use.ca*es_15 finishes ocahost When peistoie_ate_use_casBS_16 finishes Load All Load All Jntil Completen Jntil Completion <i Ĩ "_J ? - SiartScenatio Sti fieneratoti. tt? Add Group... Refhove Group IS Design Run I Auto ColMe Resufts i Figure 3.8: Screenshot: LoadRunner Controller Typical objectives are the identification of bottlenecks, determining the system capacity, checking system reliability and error handling or analyzing the system behavior in overload situations. For the determination of resource profiles, the following aspects must be considered: 1. For an unambiguous allocation of incurred resource consumption, only one kind of active service is allowed at each moment during the load test. 2. As the average resource consumption is calculated by a linear regression over measurements at different workload levels, the Controller must successively raise the number of concurrent service invocations, until the first component reaches its bottleneck. 3. Interactive services include think times of users. The length of these think times can be generated randomly. This might be reasonable in situations where load peaks should be avoided. However, the parameters of the random generator must be adjusted in a way that the total length of the Filo Edit View Graph Reports Tools Help -J m pe03_15.lra < NewGraph> Summary Report Running Vusers Throughput j Transaction Summary j Average Transaction Response Time S Transaction Performance Summary S Transactions pet Second fc] Windows Resources S UNIX Resources j Retries per Second te] Connections S Connections Per Second *) WebLogK (JMX) t k ; ii ; ft : it? & iV ei Second j Throughput [Tiansaclion Summary | Average Transaction Response T"n Hits pei Seiotitt [1] 'ansaebon Patforrrkance Summers' 1 Transactions pet SeJjJjJ 5 / -A j 4 1 t a. K l A r * -A V /v f. ' w 0010 00.20 00:30 0040 0050 01 00 01:10 01: 20 01:30 01:40 01:50 02:00 Elapsed scenario lime hh mm Legend | Graph Derails] User Notes GiaphDataj Raw Data; Measuiemenl (e.g., number of open connections, data throughput). Additionally, the performance of the involved computing

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

behavior. Instead of simultaneous starts and stops, we now put the users in endless loops. After a certain period of time (e.g., 5 minutes), we add additional users, until the first component reaches its bottleneck. After the load test theQN Verifier stores the results in a database. The utilization of servers in our load tests are then compared with the predictions

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to access the raw data. Fortunately, the Analysis tool internally uses the Microsoft Access database format for data storage. The Service Profiler connects to this database and can thus read out the timestamps of the transactions for the determination of resource profiles. 3.5.5 Resource Profile Determination In section 3.5.3.3 we presented an overview of the Service Profiler. In the following, we focus on the Analyze component and detail the process for the determination of the resource profiles. We assume that the Import component has successfully transferred the raw data into the database. The Analyze component then conducts the

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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points consumption estimates should be calculated and which are intended for performance analysis only. 2. Normalization of measurements Neither measurement points nor measurement units provided by the different performance monitors are standardized. For a comparative performance analysis and the determination of resource profiles, normalized values are required. A normalization is not always trivial. Table 3.1 illustrates how the Service Profiler normalizes the raw data by example of some major measurement points3. The data conversion rules are specified in the

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service-level resource profiles [6] is well motivated in proposals by Funke [6] [Funk99] and Scheeg [Sche05] in the areas [6] of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with

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The performance monitors report average values of the resource consumption during the last second. Furthermore, the sar tools (Unix, Linux) round the timestamps. Hence, a value measured at the point in time 1 could include the resource consumption between 0.0 and 1.0 as well as between 0.9 and 1.9. The Service Profiler uses by default the following formulas for determining the measurement interval for the resource consumption. [L*rtart + 0.5j;Ltend + 0. 5j] (3.4) The parameter tstart represents the exact start time of the first and tend the Experiment

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Each line connects a postcondition of one service with the precondition of another one, where the precondition end is marked with a filled circle. Dependencies are given between P1 and S1 , P2 , P3 as well as between S2 and P2 . The services S1 , P2 , and P3 can only be activated after P1 has been executed, meaning P1 Send Credit Request P3 Timeout P2 Receive and Display AnswerS1 Receive Credit Request S2 Send Credit Response

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illustrate the correlation of transactions and resource consumption measurements with two examples4. Figure 3.10 depicts a 30 second excerpt of a load test in a time series chart. In the lower diagram the raw data of the LoadRunner database is displayed. Each arrow indicates the start (black arrows) or stop (gray arrows) of a transaction. The horizontal line shows the number of concurrent active Vusers (lower y-Axis). In the upper diagram, measurements of the performance monitors are displayed (here: the utiliza-
4The experimental setup and

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increased the number in steps of 10 until we reached 100 users. This process was repeated for each user profile. Figure 4 was generated by our reporting tool. Each arrow indicates the start (black arrows) or stop (grey arrows) of a virtual user. At label (1), 20 concurrent power_shopper start browsing through the Pet Store. To avoid peak loads, we built in arbitrary think

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with the start of the first transaction and ends when the last transaction of a measurement cycle finishes. The measurement interval for the resource consumption is calculated as in the previous example. In the upper diagram an increase of the resource consumption along with the number of concurrent transactions is visible. During the periods with no Vuser activities (here: 20 seconds) the resource consumption of background activities can be observed. 5. Calculation of resource consumption The calculation of the resource 104 consumption per service invocation is implemented according to the process description in section 3.5.2 (step 4). First, for all services i and resources j the values Vij(x) are calculated. Therefore, the consumption values during the measurement intervals

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CPU time [sec] 0,0389 0,5530 0,1293 0,8183 0,0838 0,7577 0,2071 0,8251 0, 830 [1] ,000 DB Server CPU time [sec] 0,0008 0,1474 0,0200 0,9550 0,0089 0, 9449 0,0251 0,8749 3,715 1,000 SAN I/O [blocks] 0 n/a 7,1230 0,7518 0 n/a 0 n/a 159,14 0,970 Network I/O [bytes] 174.521 1,0000 434.651 1,0000 250.183 1,0000 562.443 1,0000 398.283 1,000 2 3 4 based application used for project statustracking at the BMW Group. The linear increase of the resource consumption is most evident for the network resource. In contrast, the transferred bytes of the Pet Store to the SAN seem not to be related with the number of concurrent users. The application is programmed to avoid " expensive" disk accesses as far as possible. Instead most data is kept in the memory of the servers.

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hardware requirements. We therefore propose the use of a wellknown instrument from Analytical Capacity Planning, namely Queuing Network (QN) Theory. The basic idea is to take the processor times from the resource profiles as input parameters for a QN Model of the infrastructure. By means of the respective algorithms for a given user behavior (i.e., service usage) and a given workload scenario (i.e., number of active users and think times between two activities) the expected server utilizations can be calculated. We

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test (II) 6 Software components 6 Figure 5 The interplay between the software components 6 CPU 6 1 6 CPU 6 2 6 CPU 6 1 6 CPU 6 2 6 CPU 6 1 6 CPU 2 2 2 Web Server 2 M/M/2 2 S = 0,024s 2 Application Server 2 M/M/2 2 S = 0,414s 2 Database Server 2 M/M/2 2 S = 0,05s 2 Think time 2 M/G/ 2 Figure 6 QN-Model of the infrastructure

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hold in these scenarios. 2. If the load test simulates different workload levels, for instance by successively increasing the number of active users, nonlinearities in the resource consumption and load-dependent behavior can be discovered. 3. For the estimation of resource profiles, the cumulated processor times during the completion time of concurrent service invocations are analyzed. In contrast, for the validation of the QN Models the average utilizations over longer time intervals are determined. The two analysis and measurement approaches enable a mutual validation of the accuracy and consistency of the results. 4. If the load test has verified the QN Model and its input parameters, it can readily be used for capacity planning. The model enables capacity planners to conduct "what-if" analyses and thus anticipate the effects of changes in the workload composition or the hardware configuration. 108 In chapter 5 we first provide a short introduction to QN

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made. If services are modeled and metered at a very fine-granular level (e.g., single requests) it is not even necessary to make assumptions about user behavior. 4 Estimation of Resource Profiles The overall requirements on the process of estimating resource profiles in heterogeneous environments are detailed in section 1. Against this background, existing profiling tools have two major

the number of concurrently active users. The structure of the resulting Queuing Network Model is depicted in figure [6] . We selected the power_shopper (see section 4.[2] .) for the validation of the resource profile. The mean service times were taken from the resource profile in table 2. As these are non-normalized measurements on a dual-processor machine, we

successful application in a professional IT service management organization. First, the estimators for the resource consumption of single service requests are of a high quality and can be used for capacity planning, as well as for accounting purposes. Second, the estimation process does not depend on certain hardware and software platforms. It can be broadly applied to

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the approach. Thus, it might be reasonable to conduct the load tests for QN Model validation on a regular basis. 3.6.3 Proof of Concept: BMW Group Finally, we present in chapter 6 the results of a proof of concept, conducted in cooperation with our industrial partner, the BMW Group. It is organized in three stages: 1. Analysis of objectives, requirements and practices of IT Cost Accounting and Chargeback at the BMW Group. 2. Development of a proposal how the determination of resource profiles could be integrated into the existing IT Service Management processes. 3. Application of the software in a data center of the BMW Group. The objectives are twofold. First, we intend to underpin the overall considerations on IT Cost Accounting and Chargeback of chapter 2 with a real-world case. Second, we want to test the viability of the concept

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and average consumption vectors. As the problem of allocating infrastructure costs is of a quite general nature, we further followed this idea and analysed its potential in cooperation with our industrial partner, the BMW Group. 4 Results and experiences from the pilot test 4.1 Organisational context At the BMW Group, management and operation of the considered OLTP systems is organised on two

service-level resource profiles [6] is well motivated in proposals by Funke [6] [Funk99] and Scheeg [Sche05] in the areas [6] of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with

different hardware, operating systems and applications), without a need to change the respective systems. & Third, the estimation should cause little extra work and integrate well with existing IT service management processes. While the first requirement is essential for the cost allocation key to achieve incentive compatibility, the second and third requirements target the viability of the

setting a range for virtual memory) and it is possible to take this value as the basis for cost allocation. The experimental infrastructure was set up in a data center of the BMW Group (see table 1). We combined different operating systems (Linux, Windows and Unix) and servers (Apache HTTP, Bea Weblogic and Oracle Database). The tablespaces of the database

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overall considerations on IT Cost Accounting and Chargeback of chapter 2 with a real-world case. Second, we want to test the viability of the concept and the software in an industrial environment and evaluate an integration into existing IT Service Management Processes. 3.6.4 Summary The three different validation approaches are summarized below by means of the requirements presented in section 3.4. Therefore, we list the requirements again and describe whether and how they are addressed by the Service Profiler and the validation approaches. Requirement 1: Accuracy The Service Profiler implements no kind of autocorrection mechanisms for the resource profiles which would guarantee a certain level of accuracy. However, the visualizing components and the

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different hardware, operating systems and applications), without a need to change the respective systems. & Third, the estimation should cause little extra work and integrate well with existing IT service management processes. While the first requirement is essential for the cost allocation key to achieve incentive compatibility, the second and third requirements target the viability of the

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profiles (see section 3.5.5). Requirement 1.1: Accurate measurement and analysis tools This is the basic condition for accurate resource profiles. With regard to the software toolkit it is unclear whether the accuracy of standard performance monitors is sufficient for the determination of resource profiles (see section 3.5.3.2). We address these questions in our experiments in chapter 4 and demonstrate in chapter 5 how QN Models can be used to cross-check the accuracy of the processor time estimates. Requirement 1.2: Linear resource consumption In the experiments in chapter 4 we analyze whether the model hypotheses on the composition of resource consumption holds in the test environment. However, these results cannot be

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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time estimates. Requirement 1.2: Linear resource consumption In the experiments in chapter 4 we analyze whether the model hypotheses on the composition of resource consumption holds in the test environment. However, these results cannot be generalized. During the estimation of resource profiles the visualizing components and the correlation coefficients facilitate the identification of nonlinearities in the resource consumption (see section 3.5.5). The processor time estimates can be further cross-verified by the results of load tests for the

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made. If services are modeled and metered at a very fine-granular level (e.g., single requests) it is not even necessary to make assumptions about user behavior. 4 Estimation of Resource Profiles The overall requirements on the process of estimating resource profiles in heterogeneous environments are detailed in section 1. Against this background, existing profiling tools have two major

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tests for the validation of QN Models (see chapter 5). Requirement 1.3: Correct assumptions about user behavior Generally, a full validation of the assumptions on user behavior is only ex-post and by measurements at the productive system possible. If historical usage data is available, this can be used to derive respective user behavior models. Particularly for web-based applications a variety of different tools (see Ideal Observer, n.d.) and modeling approaches (see Menasce and Almeida, 2000, p. 41-64) exist. In the experiments in chapter 4 we analyze the more difficult case of highly interactive applications and no historical usage

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applications are more difficult and require adequate user behavior models. A variety of different tools [IdOb] and modeling approaches [MeAl00, pp. 41 64], particularly for web-based applications, exist. If historical usage data is available, this can be used to derive respective models. Even for very interactive applications, it is typically possible to get at least a good estimate of how often particular service requests are made. If

available in most organizations. Highly interactive applications are more difficult and require adequate user behavior models. A variety of different tools [IdOb] and modeling approaches [MeAl00, pp. 41 64], particularly for web-based applications, exist. If historical usage data is available, this can be used to derive respective models. Even for very interactive applications, it is typically possible to

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see Ideal Observer, n.d.) and modeling approaches (see Menasce and Almeida, 2000, p. 41-64) exist. In the experiments in chapter 4 we analyze the more difficult case of highly interactive applications and no historical usage data. We present two strategies. First, the definition of very fine-grain services and, second, the profiling of different user behaviors to determine not an exact value, but an interval for the expected resource consumption. 110 Requirement 2: Consistency We combined a professional load generator with the standard performance monitors of Unix, Linux and Windows operating systems to maximize the applicability of the analysis software. The viability of the concept and the accuracy of the results is the subject of the experiments in chapter 4 and the proof-of-concept

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modern enterprise systems. We have chosen a very interactive scenario, because it is typical for web applications. One possibility to cope with this interactivity would be the definition of very fine granular services (e.g., "view catalogue page", "add item to cart"). However, for this paper, we decided to consider the whole Pet Store as single service (Access

and so forth) and then applied a linear regression. We consider the slope of the regression line as average consumption per additional user and as estimate for the expected resource consumption. The Pearson correlation coefficient (r 2 [1; 1]) and the resource profile p for the Pet Store example is shown in table 2. For comparison we included the resource profile of

compared and tested against the parameters measured in load tests with respective workloads. We conducted several experiments with J2 EE applications in a distributed client/ server infrastructure consisting of Unix, Linux, and Windows servers in a data center of the BMW Group and achieved very promising results even in a very heterogeneous environment with multiple software modules, operating systems, and

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parameters for Analytical Capacity Planning based on QN Models (see chapter 5). Requirement 4: Operating Efficiency The experiments presented in chapter 4 and 5 were conducted in a data center of our industrial partner. Thus, we could analyze the efforts required for the determination of resource profiles and evaluate on-site the integration into the existing IT Service Management processes. The results are summarized in chapter 6. 3.7 Related Work We structure the discussion of related work into two parts. First, we refer to concepts, which also propose the usage of customer-oriented services for IT

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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nor illustrate their concepts with real-world examples or experimental results. The present work aims to fill this gap. 3.7.2 Determination of Resource Profiles The problem of determining resource profiles in client/server environments has also been addressed by Nagaprabhanjan and Apte, who recently presented a tool (see Nagaprabhanjan and Apte, 2005) for automated profiling of distributed transactions. Their focus is not the allocation of infrastructure costs, but the determination of input parameters for performance analysis and capacity planning. The differences to our approach are pointed out in table 3.2. Nagaprabhanjan and Apt also combine load generation with performance monitors for the determination of resource consumption. They use a custom load generator which requires measurement agents installed on the different servers. This enables more precise measurements. Accordingly, they require fewer measurement cycles and generate less data for the analysis.

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of overall resource profiles for services on distributed systems is not yet supported by tools available on the software market. This problem had been also addressed by Nagaprabhanjan and Apte who recently presented a tool [NaAp05] for automated resource consumption profiling of distributed transactions. Analogous to our approach, they combine load generation with OS performance monitors for the determination of

of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance

transactions. Analogous to our approach, they combine load generation with OS performance monitors for the determination of resource profiles. However, their focus is not accounting, but the determination of input parameters for performance analysis and capacity planning. The major strength of Nagaprabhanjan and Apte is the run-time coordination of load generation and resource profiling. This enables more precise measurements. Accordingly, they require

the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents installed on [6] the different servers. The use of custom [6] agents limits the flexibility of the

parameters for performance analysis and capacity planning. The major strength of Nagaprabhanjan and Apte is the run-time coordination of load generation and resource profiling. This enables more precise measurements. Accordingly, they require fewer measurement cycles and generate less data for the analysis. Our

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However, the use of custom agents limits the flexibility of the implementation (currently to Linux servers and Web applications, see Nagaprabhanjan and Apte, 2005). In contrast, we use a commercial off-the-shelf load generator and require no additional software installations on the servers. Thus, we gain three major advantages. First, Nagaprabhanjan and Apte (2005) Concept presented in section 3.5 Services A service is defined by an URI (i.e. a single client request) A service can comprise multiple client requests Load generation Custom load

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approach is more flexible concerning the definition of services and the integration of additional resources. However, due to the above mentioned aspects it takes

the determination of input parameters for performance analysis and capacity planning. ⁶ They use a custom load generator, which ⁶ requires measurement agents installed on ⁶ the different servers. The use of custom ⁶ agents limits the flexibility of the implementation (currently to Linux servers and ⁶ Web applications [NaAp05]). In contrast, ⁶ we use a commercial off-the-shelf load ⁶ generator and require no additional software installations on the servers. ⁶ WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 ⁶ Service Profiler ⁶ QN Solver ⁶ QN Verifier ⁶ Resource ⁶ profiles ⁶ Service ⁶ definitions ⁶ Performance ⁶ prediction ⁶ Measured ⁶ performance ⁶ Comparison ⁶ Different ⁶ workload ⁶ scenarios QN Model ⁶ Load ⁶ test (I) ⁶ Load ⁶ test (II) ⁶

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generation Custom load generator (master), which sequentially generates HTTP requests Mercury LoadRunner (various protocols) Performance monitoring Agents (slaves) on the different components collect data from OS tools and an in-process Java profiler OS tools record system behavior in log files Coordination between load generation and performance monitoring The master coordinates the load generation with the monitoring processes at the slaves (start/stop) No direct coordination - exact time synchronization is required Supported Platforms Linux / (Java)

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of 45 seconds (3), the procedure is restarted with 30 concurrent users. During the whole test, the performance monitors at the Web, Application and Database Servers record the system behavior in log files on their local disks. The upper diagram (4) shows the overall CPU utilization at the Application Server. Data about network and storage resources is analyzed in

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industrial partner, the BMW Group. They provided the data center infrastructure as well as an example application system. We could therefore analyze the viability of concept and software under realistic conditions and evaluate the integration into existing IT Service Management processes (see chapter 6). 4.1.1 Test Infrastructure In the experiments we used a multi-tier client/server architecture as typical for J2EE application scenarios (Singh et al., 2002, p. 14). The setup of the infrastructure is oriented toward standards of the BMW Group (see section 6.3.1). Figure 4.1 provides a schematic overview. A detailed specification is given in the 1We do not go into details of the J2EE platform here. The interested reader is referred to Singh et al. (2002) for a comprehensive technology overview. 113 114 Client LoadRunner Windows 2000 2x CISC 2 GB MEM Web server Apache HTTP Red Hat Linux 2x CISC 2 GB MEM App. server BEA Weblogic Windows 2000 2x CISC 2 GB MEM 100 Mbit Ethernet Database

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different hardware, operating systems and applications), without a need to change the respective systems. & Third, the estimation should cause little extra work and integrate well with existing IT service management processes. While the first requirement is essential for the cost allocation key to achieve incentive compatibility, the second and third requirements target the viability of the

virtual memory) and it is possible to take this value as the basis for cost allocation. The experimental infrastructure was set up in a data center of the BMW Group (see table 1). We combined different operating systems (Linux, Windows and Unix) and servers (Apache HTTP, Bea Weblogic and Oracle Database). The tablespaces of the database are

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transactional needs. In contrast, the EJB-centric concept is better for building a large-scale enterprise application where code and performance scalability are prime factors (Singh et al., 2002, p. 356). As database management system (DBMS) we use Oracle Database. Due to performance and security reasons, the data files are located in a Storage Area Network (SAN) connected via fibre channel with the database server. The clients are simulated by a Mercury LoadRunner Controller (see section 3.5.4). 4.1.2 Example Applications We conducted experiments with two very different kinds of application systems to enhance the significance of the results: PASTA, a custom application system of the BMW Group, to analyze the viability of the concept with a real-world example (see section 4.1.2.1). PASTA only uses the web container of the application server. It is designed

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resource consumption. In mainframe environments, with one single resource, this might have been possible, but the approach cannot be transferred to client/ server infrastructures. Second, due to performance and security reasons the original business context of a transaction (e.g., user, service) is mostly not available in the backend. User names are not further transmitted after a successful authorization and connection

We combined different operating systems (Linux, Windows and Unix) and servers (Apache HTTP, Bea Weblogic and Oracle Database). The tablespaces of the database are stored in a Storage Area Network (SAN), which is connected via Fibre Channel to the database server. Within the context of the BMW Group we evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_

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EJB container of the application server. The software architecture is highly scalable and can handle hundreds of concurrent users. Hardware bottleneck of the system is the application server. Both application systems are highly interactive. This complicates the determination of resource profiles. Wrong assumptions about the expected user behavior may lead to distorted consumption estimates (see section 3.4). For the experiments we assumed furthermore that no historical usage data is available. In the previous chapter (see sections 3.5.5 and 3.6.4), we presented two strategies to cope with this problem. First, the definition of very fine-grain services and, second, the profiling of different user behaviors to determine, instead of an exact value, an interval of the expected resource consumption. In the experiments we evaluated both strategies and prepared load test scripts with services including single client requests and load test scripts with services including multiple client requests, which represent different user profiles. 116 PASTA -

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service-level resource profiles [6] is well motivated in proposals by Funke [6] [Funk99] and Scheeg [Sche05] in the areas [6] of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with

work with standard OS performance monitors. The question is, can measurements based on standard log file data be sufficient to derive accurate resource consumption estimates? & (3) Assumptions about the expected user behavior (e.g., parameters passed, interactions with the system) during the setup of the load tests may not reflect reality. Overall, a validation of p can be performed ex-post

normalized, e.g., by using standard performance benchmarks [SPECa]. These resource profiles provide an overview of the expected resource consumption for different types of user behavior. If historical usage data is available, an average resource profile can be derived. Otherwise, the determined bandwidth of the consumption values already allow for an approximate classification, which might be sufficient

modern enterprise systems. We have chosen a very interactive scenario, because it is typical for web applications. One possibility to cope with this interactivity would be the definition of very fine granular services (e.g., "view catalogue page", "add item to cart"). However, for this paper, we decided to consider the whole Pet Store as single service (Access

compare the CPU times with measurements on other infrastructures, they must be normalized, e.g., by using standard performance benchmarks [SPECa]. These resource profiles provide an overview of the expected resource consumption for different types of user behavior. If historical usage data is available, an average resource profile can be derived. Otherwise, the determined bandwidth of the

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pages. Static web content such as image files or stylesheets are located at a separate web server (see section 4.1.1). The data is stored in an Oracle Figure 4.3: Overview of PASTA Use Cases database. PASTA accesses the database using preconfigured connection pools of the application server. In the experiments we worked on a copy of the real database content. Furthermore, PASTA has an interface to the group directory to automatically update the contact information of project team members (e.g.,

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user of the application who submitted the query. Modern database management systems support the allocation of resource consumption (CPU time, query runtimes, etc.) to the connection pools of the application servers, but they cannot reconstruct the original user. Measured usage (HW! App! BU) For accounting and billing of shared IT services, a broad range of commercial

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Web servers, application servers and database servers are shared with certain numbers of different application systems. For each system a single business owner is defined, to whom hardware and server operations costs are allocated on a flat rate basis. The resource consumption is not considered in the cost allocation keys. Basically, two different kinds of PASTA user exists. The majority are read users, who solely browse through the projects. Edit users, in contrast, also change project information (

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considers only the provision of an application in a data center as "IT product" and allocate costs by a flat rate to a single business owner. The actual resource consumption is not considered. The BMW Group uses such flat rates for applications on its J2EE infrastructure. Furthermore, Gartner recommends tiered flat rates [Gart03], based for instance on the required

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in the cost allocation keys. Basically, two different kinds of PASTA user exists. The majority are read users, who solely browse through the projects. Edit users, in contrast, also change project information (see figure 4.3). For estimating an interval of the expected resource consumption of a PASTA user, we created load test scripts with the following user behavior: 118 Welcome to the Bl"eP*tots petsU.i t> MttM)""ft Jult- Datei ßeat betten Ansicht. Favoriten extras ? &p . Z njct - K jj Suchen :- Favoriten

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compare the CPU times with measurements on other infrastructures, they must be normalized, e.g., by using standard performance benchmarks [SPECa]. These resource profiles provide an overview of the expected resource consumption for different types of user behavior. If historical usage data is available, an average resource profile can be derived. Otherwise, the determined bandwidth of the

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from Singh et al., 2002, p. 362) as a showcase in the book of Singh et al. (2002) . Additionally, Sun Microsystems provides on its web site a supplement to the book, containing detailed information on design and implementation of the application (see Sun Microsystems, n.d.b). We chose Pet Store over commercial benchmarks such as TPC-App (see TPPC, n.d.a) for three reasons. First, it is readily available and the experiments are easy to repeat. Second, it covers most J2EE technologies and, third, the software architecture, with several interacting applications in the frontend and backend, is an appropriate representation of the structure of modern enterprise systems. The Java Pet Store is frequently used for performance studies (see for instance Juse et al., 2003). Microsoft and Macromedia have even reimplemented the functionalities of the Java Pet Store to compare the

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LoadRunner script Cost Accounting for Shared IT Infrastructures 87 business applications. As example scenarioin this paper we use the J^2 EE reference implementation Java Pet Store [SuMi]. We chose Pet Store over commercial benchmarks such as TPC-App [TPPCa] for three reasons. Firstly, it is readily available and the experiments are easy to repeat; secondly, it covers most J2EE technologies (EJBs, Servlets, JSPs, Web Services and XML, JMS, CMP, etc.), and, thirdly, the software architecture, with several interacting applications in the front- and back-end, is an appropriate representation of the structure of modern enterprise systems. We have chosen a very interactive scenario, because it is typical for web applications. One possibility to cope with this interactivity would be the definition of

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Compared to PASTA (see section 4.1.2.1), the Java Pet Store is far more complex and user profiles are not so clear-cut. Hence, we created load test scripts for four different kinds of user behavior to estimate an interval of the expected resource consumption of a Pet Store customer. curious_visitor The customer browses to four different item descriptions and then leaves the online store without having used the shopping cart, registering or purchasing functionalities (12 user interactions).

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compare the CPU times with measurements on other infrastructures, they must be normalized, e.g., by using standard performance benchmarks [SPECa]. These resource profiles provide an overview of the expected resource consumption for different types of user behavior. If historical usage data is available, an average resource profile can be derived. Otherwise, the determined bandwidth of the

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LoadRunner scripts for the Java Pet Store and services including single requests and multiple requests (power_shopper) are given in the appendix (see sections A.5.1 and A.5.2). 4.2 Overview of Experiments In the previous chapter we presented a methodology and a software toolkit for the determination of resource profiles. The concept is based on the hypotheses 122 that the resource consumption evolves according to the following function (see sections 3.3 and 3.5.2): Vij(x, t) = Oj(t) + xpij (4.1) We evaluated the hypotheses and the software implementing the concept in a set of experiments. Aims and purposes were

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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and the software implementing the concept in a set of experiments. Aims and purposes were threefold. First, we tried to verify if the model describing the total resource consumption holds in the example environment. Second, we tested the precision of the measurement and analysis tools introduced in section 3.5. Third, we analyzed the effects of parameter changes during the profiling process and compared the experimental results with the model predictions. The experiments were organized into seven test

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The resource consumption of a service request may depend to a certain degree on the workload. A linear extrapolation of a single service request might therefore be biased. & (2) Inaccuracies of the measurement and analysis instruments may introduce a systematic error, or also lead to high sample variance. In order to cause as little extra overhead as possible (e.g., no reimplementation of

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multiple client requests. We first analyzed the correlation coefficients of the linear regression and then, for services including multiple client requests, the influence of varying user behavior on the mean resource consumption (see section 4.3.2). Repeatability - Pij : The process for the determination of resource profiles was repeated five times under equal conditions. We compared the resulting resource profiles and analyzed the repeatability of the results (see section 4.3.3). Load-dependent Behavior - : The total resource consumption Vij(x) was

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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total resource consumption Vij(x) was measured at five different workload levels x. By comparing the normalized values, we could analyze the influence of the workload on the average resource consumption per service (see section 4. 3.4). Linear Regression - pij : The process for the determination of resource profiles was repeated five times. After each test the average think time between two user activities was doubled. By comparing the results we verified whether the linear regression eliminates the influence of

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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may significantly change during the lifecycle of application systems, they are highly relevant for the practicability of the concept (see section 4.3.7). All experiments were conducted on the infrastructure described above and with the example application systems PASTA and Java Pet Store (see section 4.1). After each load test the servers were restarted, the initial system configuration restored and the system clocks synchronized. For each application system we analyzed services including single client requests and services including

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this feature to define the start- and endpoint services. In the example of figure 3 the script replays the behavior of an average shopper in the Java Pet Store (see section 4.2). The whole shopping process is considered as a single service. In the script the service starts with the command lr_start_transaction("petstore_ shopper") and ends

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one service and one user profile per application system. The user profiles edit-user (PASTA) and powershopper (Java Pet Store) were described in sections 4. 1.2.1 and 4.1.2.2. The PASTA service actitemsave.do updates the list of current project activities (see figure 4.2). The Java Pet Store service cart, do adds a product to the shopping cart of the online shop. 124 PASTA Java Pet Store Service type multiple req. single requests multiple req. single requests Example user profile/service edit_

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observed and the predicted server utilization to measure predictive accuracy of our Queuing Network Models. The interplay between the different software components is depicted in figure 5. 5.3 The Java Pet Store Example (Continued) In the load test setup, presented in the previous section, the number of users remains constant during certain time intervals. Therefore, we model

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PA01 (PASTA: Resource profiles and Repeatability). PA01-0 describes the consolidated analysis of all measurements of experiment PA01 (load tests PA01_l-5). The different resources are described and categorized according to the following scheme: Server type - object - instance - counter (see section 3.5.5). In the experiments we determined consumption estimates for the following resources: Application server - Network - all - Bytes total Application server - Processor - all - Processor time Client - Network - all - Bytes total Database server - Processor - all - Processor time Database server -

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one can define a single dialogue step as well as larger number of user interactions as a service. Overall, however, service definition requires careful planning (see previous section) . In the experiments we installed the applications under consideration in an isolated test environment, as is usual for operational approval tests [OoOC02] prior to the roll-out of a new

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load test (see table 4.2). We omitted the remote monitoring of the database server. According to the above considerations, we can expect most influence of background activities on the processor time at the application server (Windows) . 4.3.2 Resource Profiles The experiments with the example application systems PASTA and Java Pet Store started with the determination of resource profiles for the services described above (see sections 4.1.2.1 and sections 4.1. 2.2). The profiling process is detailed 2The lowest 5 % and the highest 5 % of the sample values are discarded. Resource profile - i: PASTA Experiment PA01_ 1: Overview of user profiles including multiple client requests ~ 7.5 . o J *Z 5.0 0 in in 01 u I 2.5 i 0.0 m Application server Database server j: Processor - all - Processor Time Web server edit_user ill read_

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for estimating resource profiles for IT services and describe how we use Queuing Network Models for validation and capacity planning. The concept is illustrated by experiments with the example application Java Pet Store from Sun Microsystems [SuMi]. Section 6 compares the approach with related work. The paper concludes with a short summary in section 7. of setting prices

service-level resource profiles [6] is well motivated in proposals by Funke [6] [Funk99] and Scheeg [Sche05] in the areas [6] of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with

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of user profiles including multiple client requests ~ 7.5 . o J *Z 5.0 0 in in 01 u I 2.5 i 0.0 m Application server Database server j: Processor - all - Processor Time Web server edit_user ill read_user Figure 4.8: Resource Profile: PASTA - Services including multiple Client Requests in section 3.5.2. We specified there that during the load test the number of concurrent service invocations rises until the first component reaches its bottleneck. The maximum capacities of the considered application systems were different. PASTA was able to process 20 concurrent service invocations, while the Java Pet Store could handle 70 concurrent invocations of services including single requests

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deviation for the web server, the application server, and the database server is 0,004 (0,4%), 0,03 (3%) and 0,01 (1%) respectively. Despite the heterogeneity of the infrastructure and the different workloads during the load test, the accuracy of the estimates is surprisingly exact. The quality of the results is comparable to directly related approaches. Kounev and Buchman [KoBu03; BoGM06 pp. 703 et seqq.]

behavior. Instead of simultaneous starts and stops, we now put the users in endless loops. After a certain period of time (e.g., 5 minutes), we add additional users, until the first component reaches its bottleneck. After the load test theQN Verifier stores the results in a database. The utilization of servers in our load tests are then compared with the predictions

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of the user behavior on resource profiles is illustrated in figure 4.8 (PASTA) and figure 4.9 (Java Pet Store). Most interesting is a comparison between the application systems. The by far more complex Java Pet Store caused only a small fraction of the resource consumption of the custom application system PASTA. Certainly, a direct comparison is not fair. Java Pet Store was developed by specialists to demonstrate Java capabilities and performance. Nevertheless, the example underlines the impact and the resource-

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among multiple applications and business units. Typical examples include database servers, application servers or virtualized servers (e.g., using VMware [Vmwa] or Xen [UCCL]). In these cases the resource consumption of the installed applications and the workload generated by the customers is a significant cost driver. An average application server in an industrial data center (e.g., 4 CPU / 16 GB memory)

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background resource consumption a . Again, we used the example applications PASTA and Java Pet Store and services including single and multiple client requests. In the PASTA experiments PA02 and PA04 we conducted load tests with 1, 5, 10, 15 and 20 virtual users and in the Java Pet Store experiments PE02 and PE04 load tests with 1, 10, 30, 50 and (4.2) x According to the model hypotheses, the value should be maximal for x = 1: dij + Pij and then converge for growing x toward Pij. The processor time results

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we used this feature to define the start- and endpoint services. In the example of figure 3 the script replays the behavior of an average shopper in the Java Pet Store (see section 4.2). The whole shopping process is considered as a single service. In the script the service starts with the command lr_start_transaction(" petstore_shopper")

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application server), the results confirm the above assumptions. However, although the impact of background activities at the database server (Unix) and the web server (Linux) is clearly measurable, the absolute amount is negligible. A results table with data from network and storage resources is provided in the appendix (see section A.3.6). As in the previous experiments, the network resource consumption confirmed the processor time results. The number of read/write blocks at the SAN again showed high

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record the system behavior in log files on their local disks. The upper diagram (4) shows the overall CPU utilization at the Application Server. Data about network and storage resources is analyzed in the same manner. After the experiment, the Service Profiler computed the consumption per resource and user profile. Therefore, it first summed up the

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Size Resource profiles, determined according to the concept described above, are associated with a certain infrastructure configuration. While changes to hardware or software configurations typical require a manual intervention, content and size of databases change dynamically during regular operations. Obviously, the resource consumption of a service including database requests may depend to a a certain 142 Database size - i: Java Pet Store - powershopper Resource consumption of load tests with empty and full database 0.5   0.462 0. 47 Application server Database server Web server j: Processor - all - Processor

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Summary Cost allocation of shared IT infrastructure such as server capacity or network equipment is technically difficult. We propose a method to derive adequate estimators for the resource consumption of a service invocation, which can then provide a basis for cost allocation keys. & The expected resource consumption of services can be estimated with high accuracy in load tests.

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the Java Pet Store store information on business transactions (e.g., order details) and in a real world scenario a constant database growth would be expected. The resource profiles, determined during the experiments on repeatability (see section 4.3.3), are based on the default database content as provided by Sun Microsystems. To assess the impact of the database size on the resource profiles, we conducted a further experiment (PE07). For this, we added more than 400,000 order entries to the database, so that the

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shopper has relatively high consumption values. This is caused by the functions for registering a new user. We conducted the Pet Store experiments with the standard database content as provided by SUN. However, in real-world scenarios it is important to use realistic database sizes. To compare the CPU times with measurements on other infrastructures, they must

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on resource consumption and performance. 4.4 Summary The aims and purposes of the experiments were threefold. First, we tried to verify if the model describing the total resource consumption holds in the example environment. Second, we tested the precision of the measurement and analysis tools introduced in section 3.5. Third, we analyzed the effects of parameter changes during the profiling process and compared the experimental results with the model predictions. The results can be summarized as follows: 1. The model hypotheses could be confirmed for the computing resources (processor time) and the communication resources (transferred bytes). At the storage resource (read/write blocks) we observed high variations of the consumption

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The resource consumption of a service request may depend to a certain degree on the workload. A linear extrapolation of a single service request might therefore be biased. & (2) Inaccuracies of the measurement and analysis instruments may introduce a systematic error, or also lead to high sample variance. In order to cause as little extra overhead as possible (e.g., no reimplementation of

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time) and the communication resources (transferred bytes). At the storage resource (read/write blocks) we observed high variations of the consumption values. Mean consumption values determined during a single load test can be considered only as very rough estimates for the expected resource consumption during regular operations. 2. Although the performance monitors record only coarsely-grained consumption data, we achieved through multiple measurements very precise and repeatable results. 3. We analyzed the robustness and consistency of the results

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and so forth) and then applied a linear regression. We consider the slope of the regression line as average consumption per additional user and as estimate for the expected resource consumption. The Pearson correlation coefficient (r 2 [1; 1]) and the resource profile p for the Pet Store example is shown in table 2. For comparison we included the resource profile of

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observed. 144 4. In particular we could demonstrate that the resource profiles are independent of the client think times during the profiling process. Thus, the think times could be minimized during the load tests. This accelerated the whole process significantly. In the Java Pet Store example a load test with four different user profiles required less than 45 minutes (see section 4.3.2). 5. Resource profiles are always tied to a certain infrastructure configuration. Through experiments with an empty and a full database, we

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we used this feature to define the start- and endpoint services. In the example of figure 3 the script replays the behavior of an average shopper in the Java Pet Store (see section 4.2). The whole shopping process is considered as a single service. In the script the service starts with the command lr_start_transaction(" petstore_shopper")

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on the overall dimension of the resource consumption. Instead, it was predefined by the software design of the application system. Chapter 5 Experiments: Analytical Models 5.1 Motivation In the previous chapters we presented a method, a software toolkit and experimental results on the determination of resource profiles for customer-oriented services. We will now analyze whether the determined consumption estimates are appropriate input parameters for analytical performance models. The basic approach is to set up a performance model according to

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service-level resource profiles [6] is well motivated in proposals by Funke [6] [Funk99] and Scheeg [Sche05] in the areas [6] of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with

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arrival rates or prioritization strategies, and can emulate system behavior that cannot be captured (or only approximated) in analytical models. Both kind of models, however, require a validation, if possible against real systems, to verify that the chosen abstraction is an appropriate representation of reality. Once validated, capacity planners can use the model to conduct "what-if" analyses. So, they can study how changes in the workload composition, hardware configuration or system architecture affect the expected

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EJBs, Servlets, JSPs, Web Services and XML, JMS, CMP, etc.), and, thirdly, the software architecture, with several interacting applications in the front- and back-end, is an appropriate representation of the structure of modern enterprise systems. We have chosen a very interactive scenario, because it is typical for web applications. One possibility to cope with this

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usually require time-consuming and costly system reconfigurations. Against this background, load test-based methods are typically applied for the basic validation of performance models or rules-of-thumb estimates and for the final approval of a system configuration prior to the roll-out of a new software release (Office of Government Commerce, 2002a, ch. 5.3.4). Despite the numerous advantages of model-based approaches (e.g., flexibility, efficiency, costs), they are rarely used in practice. A major reason for this is that necessary input parameters such as service demands are

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see previous section) . In the experiments we installed the applications under consideration in an isolated test environment, as is usual for operational approval tests [OoOC02] prior to the roll-out of a new software release. Bymeans of the load generator, we then simulated consecutive service invocations, while the performance monitors recorded the system s utilization in log files. After the load

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et al., 1995). We chose standard Queueing Network Models over those approaches because a broad range of modeling guidelines (see for instance Menascé et al., 2004) and comparable experimental results are available (see section 5.7). 5.3 Queueing Network Theory Queueing Network Theory (QN Theory) is a well-studied methodology for the mathematical analysis of systems with waiting lines and service stations. It was first introduced by Erlang (1909) for the study of traffic in telephone networks. Today, QN Theory is used in various domains, ranging from manufacturing system planning via transportation and logistics to telecommunication and computer performance modeling (see Bolch et al., 2006, pp .703-806, for several case-studies on real-world applications). The study objects of QN Theory are queueing systems. Figure 5.2

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that our estimates for CPU time are not only unbiased in a statistical sense, but also independent of the system workload. 5.1 The QN Solver Queuing Network Theory is a well-studied methodology for the mathematical analysis of systems with waiting lines and service stations. Today, Queuing Network Models are used in various domains, ranging from manufacturing system planning [TeKu98] to computer performance modeling [BoRi97; MeAD04; BoGM06]. A queue consists of one or more service stations with a joint waiting room. Jobs arrive at the queue

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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case-studies on real-world applications). The study objects of QN Theory are queueing systems. Figure 5.2 shows an example of an elementary queueing system consisting of a service station and a waiting room. Jobs (customers) arrive at the back of the queue with an arrival rate A and are served at the front of the queue in an average time s. Arrival 150 arriving jobs arrival rate A Figure 5.2: Elementary Queueing System with a single Service Station rate as well as service time may be deterministic

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system planning [TeKu98] to computer performance modeling [BoRi97; MeAD04; BoGM06]. A queue consists of one or more service stations with a joint waiting room. Jobs arrive at the queue with an arrival rate l and are served in an average time S. If the service stations are all occupied, jobs have to line up. The so-called Kendall notation [Kend53] is typically used

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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front of the queue in an average time s. Arrival 150 arriving jobs arrival rate A Figure 5.2: Elementary Queueing System with a single Service Station rate as well as service time may be deterministic or stochastic variables. If the service station is occupied, jobs have to line up. QN Theory provides mathematical means to analyze such and related processes. Thus, central performance measures such as mean utilization, waiting time, throughput or queue lengths can be determined. Several kinds of elementary

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joint waiting room. Jobs arrive at the queue with an arrival rate l and are served in an average time S. If the service stations are all occupied, jobs have to line up. The so-called Kendall notation [Kend53] is typically used to classify different types of queues: A / B / C (where A stands for the distribution of interarrival times of customers, B

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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can be distinguished: Load independent, load-dependent and delay systems (Menasce et al., 2004, p. 46). Figure 5.3 provides an overview of this classification and the corresponding graphical notations. The three categories can be described as follows: Load independent: The service rate is not dependent on the current workload, i.e., the number of jobs in the queue. Load-dependent The service rate is a function of the number of jobs in the queue. Typical examples are queueing systems with multiple service stations (e.g., models of multi-processor machines). The effective service rate increases as the number of current jobs grows from 1 to m (number of service stations).

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number of service stations indicates that independent from the actual load no queuing effects occur. This reflects reality as the think time of a virtual user is not dependent on the number of concurrently active users. The structure of the resulting Queuing Network Model is depicted in figure [6] . We selected the power_shopper (see section 4.[2] .) for

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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an (assumed) infinite capacity and thus requires (and has) no waiting line. In computer performance models, delay systems are typically used to represent human users, resources dedicated to certain jobs or third party components. Beyond this rough classification, the so-called Kendall notation (see Kendall, 1953) is widely used to describe elementary queueing systems. Its basic form takes into account stochastic characteristics of the arrival process and of the service times, the number of parallel service stations and the queueing discipline: arrival process | service time | no. of service stations - queueing discipline The basic Kendall notation is occasionally extended by the number of places in the queue or the

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the queue with an arrival rate l and are served in an average time S. If the service stations are all occupied, jobs have to line up. The so-called Kendall notation [Kend53] is typically used to classify different types of queues: A / B / C (where A stands for the distribution of interarrival times of customers, B for distribution of service times, C

calculates the resource profiles. Finally, a custom reporting package visualizes the results. In order to determine the resource consumption of a single service request, we successively raised the number of parallel service invocations and determined the increase in resource consumption by means of a linear regression (i.e. the slope of the regression line). 4.2 The Java Pet Store Example In

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

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service times. The queueing discipline is FCFS (default). The exponential distribution is of paramount importance in QN Theory because it has some pleasant mathematical properties and because it is an appropriate mathematical representation of many real-world processes. The exponential distribution is the only continuous distribution with the memoryless property. This implies for the arrival process that if the time between two consecutive arrivals is exponentially distributed with parameter A, then the distribution of the residual time until the next

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the fundamental properties of the Poisson process which has a dynamic independent existence. But it shows the relationship between the two processes as illustrated in Table 3.1. The exponential distribution is the only continuous distribution with lack of memory, and the geometrical distribution is the only discrete distribution with lack of memory. For example, the next outcome of a throw of a die

- **10** Teletraffic engineering and network..., 2005, S. 3

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users (terminals, clients) interact with the system in a request/reply fashion. As think time is defined the time elapsed since a reply to a request is received, until the next request (job) is submitted by the same user. The workload intensity is specified by the number of users and their think times. 2In earlier works mostly referred to as terminal workload (see for instance Allen, 1990, p. 378). 154 Transaction workload Jobs from outside arrive at the system and leave the

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profile in table 2. As these are non-normalized measurements on a dual-processor machine, we had to double them for the Queuing Network model. The load intensity is specified by the total think time of a user. In the example we assume an arbitrary chosen think time of 38s. For the solution of the Queuing Network Model we

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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Allen, 1990, p. 378). 154 Transaction workload Jobs from outside arrive at the system and leave the system after their service is completed. In contrast to interactive workload, the job arrivals are independent of the internal system state (e.g., queue length). The workload intensity is specified by the arrival rate. Batch workload The system has to serve a fixed number of batch jobs. The workload intensity is defined by that number of jobs. QN Theory furthermore supports workloads consisting of single

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profile in table 2. As these are non-normalized measurements on a dual-processor machine, we had to double them for the Queuing Network model. The load intensity is specified by the total think time of a user. In the example we assume an arbitrary chosen think time of 38s. For the solution of the Queuing Network Model we

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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be determined from measurements on real systems. This can be costly and time consuming or even impossible, if the system is not (yet) available3. 3For an overview of parameterization techniques for models of existing, evolving and proposed systems, we refer the interested reader to Lazowska (1984, pp. 273 et seqq.). - 1 --0 ? -o Open Queueing Network Model Closed Queueing Network Figure 5.4: Open and closed Queueing Network Models 5.3.3 Queueing Network Models QN Theory provides analysis techniques for elementary queueing systems (see section 5.3.1) as

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exact Mean Value Analysis (MVA) [ReLa80] or, for networks with a large numbers of users and multiple job classes, the Self Correcting Approximation Technique (SCAT) [NeCh81]. We refer the interested reader to [MeAD04] and [BoRi97; BoGM06] for a more detailed description of these algorithms. 5.2 The QN Verifier For the validation of the Queuing Network computations, we first developed

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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unreasonably large (see Bolch et al., 2006, pp. 332-335). However, if all queueing systems in the network fulfill certain assumptions concerning the distribution of interarrival rates and service times and the queueing discipline, each single queueing system can be examined on its own, in isolation from the rest of the network. Networks fulfilling these conditions are referred to as separable or product-form networks. Efficient analysis techniques exist for productform networks. Jackson (1957, 1963) and Gordon and Newell (1967) found first product-form solutions for

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Lausanne Covenant for separating evangelism and social action. In his estimation both are integral to mission. He argues against one component being given "a life of its own in isolation from the rest of the life and ministry of the church."158 It has been noted that the Presbyterian theology of providence could be used to

- **11** Chinese Protestant Theologies of So..., 2007, S.

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MVA-based approximation techniques, based on the MVA, overcome this problem and yet give very accurate results (Bolch et al., 2006, p. 421). An often used approximation technique was suggested by Bard (1979) and Schweitzer (1979) for queueing systems with single service stations. The Self-Correcting Approximation Technique (SCAT) extended the Bard-Schweitzer approximation to queueing systems with multiple service stations and improved its accuracy (see Neuse and Chandy, 1981). An alternative to MVA-based approximation techniques is the Summation Method (SUM).

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those closed QNs we apply either the exact Mean Value Analysis (MVA) [ReLa80] or, for networks with a large numbers of users and multiple job classes, the Self Correcting Approximation Technique (SCAT) [NeCh81]. We refer the interested reader to [MeAD04] and [BoRi97; BoGM06] for a more detailed description of these algorithms. 5.2 The QN Verifier For the validation of

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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to extend the network by a queueing system that represents the external world of the open classes so that the network can be analyzed with the same exact and approximate techniques as closed networks (see also Bolch et al., 2006, pp. 507-512). For the mathematical analysis of non-product-form queueing networks, three basic approaches exist (Bolch and Riedel, 1997, p. 171): 1. Approximation by a pro duct-form network The model can then be analyzed with one of the techniques introduced above. 2. Numerical

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time are not only unbiased in a statistical sense, but also independent of the system workload. 5.1 The QN Solver Queuing Network Theory is a well-studied methodology for the mathematical analysis of systems with waiting lines and service stations. Today, Queuing Network Models are used in various domains, ranging from manufacturing system planning [TeKu98] to computer performance

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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an approximation technique for nonproductform networks (approach 3) instead (see Bolch et al., 2006, p. 489). Figure 5.5 provides an overview of analysis techniques for QN Models. Further details on the algorithms can be found in various textbooks on QN Theory. In particular, we refer the interested reader to Bolch et al. (2006); Gross and Harris (1998); Tjims (1995) (general aspects of QN Theory and comprehensive sets of algorithms), Kleinrock (1976); Lazowska (1984); Menasce et al. (2004) (special focus on computer system applications) and Bolch and Riedel (1997) (

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exact Mean Value Analysis (MVA) [ReLa80] or, for networks with a large numbers of users and multiple job classes, the Self Correcting Approximation Technique (SCAT) [NeCh81]. We refer the interested reader to [MeAD04] and [BoRi97; BoGM06] for a more detailed description of these algorithms. 5.2 The QN Verifier For the validation of the Queuing Network computations, we first developed

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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appropriate off-the-shelf tools that enable an integrated analysis and validation of Queueing Network Models. We therefore propose a software toolkit which combines a commercial load generator and standard performance monitors with two custom software tools, the QN Solver and the QN Verifier (see figure 5.6). QN Solver The QN Solver implements several algorithms for the analysis of open and closed QN Models. It consists of a single software component (Analyze). Model and workload parameters are specified in a

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computation of Queuing Network Models, we implemented a software component, the QN Solver. It relies on the same data model as the Service Profiler presented above and the QN Verifier (see next section). A number of alternative tools are available as open source software [Hlyn]. The QN Solver implements algorithms for Queuing Networks with unbounded number of

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therefore directly reuse the Import and the Visualize component from the Service Profiler (see section 3.5.3.3). The Analysis component and the load test process are detailed in section 5.4.3. The Service Profiler, the QN Solver and the QN Verifier operate on the same data model. This allows for a direct transfer of data from resource profiles into QN Models and for an automated analysis of the model accuracy. The interplay of the software tools is further described in

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rarely used for the capacity planning of IT systems. For the computation of Queuing Network Models, we implemented a software component, the QN Solver. It relies on the same data model as the Service Profiler presented above and the QN Verifier (see next section). A number of alternative tools are available as open source software [Hlyn]. The

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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of data from resource profiles into QN Models and for an automated analysis of the model accuracy. The interplay of the software tools is further described in section 5.4.4. 5.4.2 Analysis of Queueing Network Models The QN Solver is implemented for the mathematical analysis of QN Models. It calculates, on the basis of a queueing network specification and given workload pa- 162 rameters, the following performance measures: Utilization, throughput, response time and queue length. We opted for the development

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time are not only unbiased in a statistical sense, but also independent of the system workload. 5.1 The QN Solver Queuing Network Theory is a well-studied methodology for the mathematical analysis of systems with waiting lines and service stations. Today, Queuing Network Models are used in various domains, ranging from manufacturing system planning [TeKu98] to computer performance

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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other hand, Microsoft Excel provides an appropriate user interface for the manual entry of parameter values. The QN Solver supports open and closed product-form networks, workloads consisting of single or multiple job classes, and queueing systems with one or more service stations. The following algorithms are used (references to the textbooks that served as the basis for the implementation are given in brackets): Open QN: Exact formulas based on Jackson (1957, 1963) (see Menasce et al., 2004, p. 400) Closed QN: Mean Value Analysis (MVA) - exact algorithm based on Reiser (1981); Reiser and Lavenberg (1980) (Menasce et

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Today, Queuing Network Models are used in various domains, ranging from manufacturing system planning [TeKu98] to computer performance modeling [BoRi97; MeAD04; BoGM06]. A queue consists of one or more service stations with a joint waiting room. Jobs arrive at the queue with an arrival rate l and are served in an average time S. If the service stations are

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Jackson (1957, 1963) (see Menasce et al., 2004, p. 400) Closed QN: Mean Value Analysis (MVA) - exact algorithm based on Reiser (1981); Reiser and Lavenberg (1980) (Menasce et al., 2004, p. 389) Closed QN: Mean Value Analysis (MVA) - approximation based on Bard (1979); Schweitzer (1979) (Menasce et al., 2004, p. 395) Closed QN: Self-Correcting Approximation Technique (SCAT) - approxi- 5Hlynka (n.d.) provides a comprehensive list of tools for QN Analysis. mation based on Neuse and Chandy (1981) (Bolch and Riedel, 1997, p. 152- 153) Due to the robustness property (see section 5.3.4), closed non-product-form networks can

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closed QNs we apply either the exact Mean Value Analysis (MVA) [ReLa80] or, for networks with a large numbers of users and multiple job classes, the Self Correcting Approximation Technique (SCAT) [NeCh81]. We refer the interested reader to [MeAD04] and [BoRi97; BoGM06] for a more detailed description of these algorithms. 5.2 The QN Verifier For the validation of

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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they can be visualized and compared to measurements obtained during load tests with the real system. 5.4.3 Validation of Queueing Network Models The predictive accuracy of the analytical performance models is validated in load tests with real systems. As for the determination of resource profiles, we use Mercury LoadRunner for the emulation of user behavior (see section 3.5.4) and operating system performance monitors to record the resource consumption at the components involved (see section 3.5.3.2). A custom software tool, the QN Verifier, then analyzes the measurement

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

of these algorithms. 5.2 The QN Verifier For the validation of the Queuing Network computations, we first developed an appropriate load test setup. Again (see section 4.1), we use Mercury LoadRunner for the simulation of users and the performance monitors of the different operating systems to record the system behavior. Instead of simultaneous starts and stops, we now

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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the QN Verifier, then analyzes the measurement data and prepares it for comparison with the analytical results. The software architecture of the QN Verifier is the same as for the Service Profiler (see figures 5.6 and 3.6). The Import component parses the different log files and consolidates the measurements in the database. The Analyze component then processes the data according to the parameter settings specified in the configuration files. The Visualize component finally displays the results in interactive application

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generator, we then simulated consecutive service invocations, while the performance monitors recorded the system s utilization in log files. After the load test, the Service Profiler parses the different log files and consolidates them, together with the results from the load generator, in a database. It then correlates start and end times of service invocations with the performance data

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

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Visualize component finally displays the results in interactive application windows or writes them to graphic files. The Import and the Visualize component could be directly reused from the Service Profiler (see section 3.5.3 for further descriptions). The load tests for the determination of resource profiles are characterized by synchronous service invocations of a continuously increasing number of virtual users 164 Experiment PE08_1: Java Pet Store - single client requests 2006-10-22 17:51:13.0-2006-10-22 19:21:33.0 Time [seconds since scenario start] Application server - Processor - all Virtual

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [

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and the mean think times are configured in the load test scenario (see section 3. 5.4.2). These values equal the workload intensity parameters in the analytical model (see section 5.4.2). During a load test, the workload intensity can be varied by changing the number of concurrently active Vusers. We illustrate the approach with an example. Figure 5.7 shows a time series chart of a 90-minute load test. The horizontal line in the lower diagram indicates the number of concurrent active Vusers (lower y-

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indicates that independent from the actual load no queuing effects occur. This reflects reality as the think time of a virtual user is not dependent on the number of concurrently active users. The structure of the resulting Queuing Network Model is depicted in figure [6] . We selected the power_shopper (see section 4.[2] .) for the validation of the

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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in the lower diagram indicates the number of concurrent active Vusers (lower y-axis). In the upper diagram, measurements of the performance monitors are displayed (here: processor utilization of an application server). The load test starts with ten Vusers in an endless loop. Every five minutes, ten more users are added until the load test stops after 90 Application server - Java Pet Store - single client requests Exp. PE08_1: Mean processor utilization during intervals with constant number of users 100 0 -1- ' -i-i-r --> -1--! 25 50 75 100 125 150 175 Number of virtual users -Application server - Processor - all Figure 5.8: Example: Mean Processor Utilization during Intervals with constant Numbers of Users minutes and with 180 concurrently active Vusers. The upper diagram shows how the utilization of the application server evolves with the increasing workload. The Import component transfers the log files of the performance monitors and of the load generator into the database. The Analyze component then conducts the following steps6: 1.

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we set up the load test according to the description in section 5.2. Like in the QN calculations, the load test was started with ten users in an endless loop. Every five minutes we added ten more users until we reached the predicted bottleneck of 220 concurrent users. The QN Verifier then analyzed the data and computed for the

one minute with constant load, we assume the system has arrived in a steady state. In table 3 the arithmetic means of the measured utilization during time intervals with constant number of users are compared to the values predicted by the Queuing Network Model. Overall, the predictive accuracy, as measured by the mean absolute deviation for the web

we added ten more users until we reached the predicted bottleneck of 220 concurrent users. The QN Verifier then analyzed the data and computed for the intervals with constant numbers of users the average utilization of the involved servers. As the sudden and simultaneous start of 10 new users may lead to a non-steady transient behavior in the

Mbps [2] Fibre Channel [2] Memory 2 GB 2 GB 2 GB 2 GB [2] Server Type HP DL360 IBM X360-03 HP DL360 HP N4000 [2] Network Name xxxxxx20 xxxxxx03d xxxxxx15 xxxxxx01a [2] 88 Reinhard Brandl, Martin Bichler, Michael Ströbel [1] 1 [1] CPU Utilization of the Application Server [1] (Measured by theW2K Performance Monitor) [1] Starts and stops of virtual users [1] (extracted from the LoadRunner log files) [1] Figure 4 Determination of the resource profile for a Pet

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.
- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [

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transaction log file contains, besides the transaction name and a timestamp, a unique identifier of the Vuser that executed the transaction. The Analyze component processes this data and derives measurement intervals 6Steps 1 and 2 were taken over without any modifications from the determination of resource profiles (see section 3.5.5 for a description). 166 with constant workload from it. As the start or stop of virtual users may lead to a non-steady transient behavior in the system, the Analyze component can exclude a configurable time period after a change in the workload from the further analysis. In the example of figure 5.7, the white areas indicate the measurement intervals and the gray areas represent the time periods excluded from the analysis (here: 1 minute after a change in the number of concurrently active users). 4. Calculation of mean performance values The measurement points of interest for a comparison with analytical values are specified in the configuration files. The Analyze component reads out this list and calculates for each

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service-level resource profiles [6] is well motivated in proposals by Funke [6] [Funk99] and Scheeg [Sche05] in the areas [6] of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with

and computed for the intervals with constant numbers of users the average utilization of the involved servers. As the sudden and simultaneous start of 10 new users may lead to a non-steady transient behavior in the system, we excluded the first minute of each interval from the analysis. After one minute with constant load, we assume the system has arrived in a steady

arbitrary input data for forms and to integrate user-defined transactions. In our experiments we used this feature to define the start- and endpoint services. In the example of figure 3 the script replays the behavior of an average shopper in the Java Pet Store (see section 4.2). The whole shopping process is considered as a single service. In

indicates that independent from the actual load no queuing effects occur. This reflects reality as the think time of a virtual user is not dependent on the number of concurrently active users. The structure of the resulting Queuing Network Model is depicted in figure [6] . We selected the power_shopper (see section 4.[2] .) for the validation of the resource

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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configuration files. The Analyze component reads out this list and calculates for each measurement interval the arithmetic mean of the values recorded by the performance monitors. This step is illustrated by figure 5.8. The graph shows the mean processor utilization of the application server during the 18 measurement intervals depicted in figure 5.7. Besides the performance of the involved components, the tool also analyzes the LoadRunner transactions and determines mean values for transaction throughput and execution times. 5. Preparation

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Mbps [2] Fibre Channel [2] Memory 2 GB 2 GB 2 GB 2 GB [2] Server Type HP DL360 IBM X360-03 HP DL360 HP N4000 [2] Network Name xxxxxx20 xxxxxx03d xxxxxx15 xxxxxx01a [2] 88 Reinhard Brandl, Martin Bichler, Michael Ströbel [1] 1 [1] CPU Utilization of the Application Server [1] (Measured by theW2K Performance Monitor) [1] Starts and stops of virtual users [1] (extracted from the LoadRunner log files) [1] Figure 4 Determination of the resource profile for a Pet

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [

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hand, whether the consumption estimates determined for resource profiles are also unbiased in scenarios with multiple concurrently active services and varying workloads, and on the other hand, whether the estimates are Service definitions t Different workload scenarios Load test (I) Service Profiler ?" QN Solver QN Model- Load test (ID QN Verifier Software tools Resource profiles Performance prediction A Comparison T Measured performance Figure 5.9: Interplay of the different Software Tools appropriate input parameters for analytical performance models (see section 5.1). Figure 5.9	servers and [6] Web applications [NaAp05]). In contrast, [6] we use a commercial off-the-shelf load [6] generator and require no additional software installations on the servers. [6] WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 [6] Service Profiler [6] QN Solver [6] QN Verifier [6] Resource [6] profiles [6] Service [6] definitions [6] Performance [6] prediction [6] Measured [6] performance [6] Comparison [6] Different [6] workload [6] scenarios QN Model [6] Load [6] test (I) [6] Load [6] test (II) [6] Software components [6] Figure 5 The interplay between

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In load tests as described in section 5.4.3, the number of concurrently active Vusers is constant during each measurement interval. The Vusers interact with the system in endless loops. This kind of workload requires a closed QN Model (see section 5.3.3). We modeled solely the processors, since the disk times and the network delay were negligible. Hard disks would be typically modeled as M|M|n - FCFS queueing system (see Bolch et al., 2006, p. 340). Load-independent network delay could be represented as M|G|oo queueing system (delay system) . A processor can very often be modeled as M|G|1 - PS queueing system (see Bolch et al., 2006, p. 340). In our test infrastructure we use dual-processor machines, which would be modeled accordingly as M|G|2 - PS queueing systems. Unfortunately, product-form solutions for queueing systems with multiple service stations exist only for M|M|m - FCFS systems. With regard to the robustness of closed networks (see Bolch et al., 2006, pp. 488- 489) , we opted

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model the infrastructure as closed QN and compute for each interval separate results. Furthermore, for the Pet Store example, we made the following modeling assumptions: & We modeled solely the processors, since the disk times were negligible during the profiling. Hard disks would be typically modeled as M/M/n FCFS queues [BoRi97, p. 73]. & A processor can be modeled as M/G/1 PS queue [BoRi97, p. 73] In our test infrastructure we use dual-processor machines, which would be modeled accordingly as M/G/2 PS queue. Unfortunately, an efficient solution algorithm for a network containing queues with multiple service stations exists only if the queues are of M/M/m FCFS type (see previous

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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FCFS systems. With regard to the robustness of closed networks (see Bolch et al., 2006, pp. 488- 489), we opted for an approximation based on M|M|2 - FCFS queueing systems. Alternatively, we could have used two separate M|G|1 - PS systems (see section 5.7 for an example). The think time of the users is represented by a M|G|oo queueing system (delay system). The infinite number of service stations indicates that independent from the actual load no queueing effects occur. This reflects reality 170 Think time Web Server Application Server Database Server M/G/ M/M/2 M/M/2 M/M/2 Figure 5.10: QN Model of the Test Infrastructure as the think time of a user is not dependent on the number of concurrently active users. The structure of the resulting QN Model is depicted in figure 5.10. The model conforms to the product-form conditions (see section 5.3.4) and can be analyzed by the QN Solver either with the exact MVA algorithm or with one of the implemented approximation techniques.

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time distributions [BoRi97, p. 172]. Thus, we approximated the non-exponential service time distribution by an exponential distribution. In this approach only one job class is permitted. & The think time of the users is represented by an M/G/1 queue. The infinite number of service stations indicates that independent from the actual load no queuing effects occur. This reflects reality as the think time of a virtual user is not dependent on the number of concurrently active users. The structure of the resulting Queuing Network Model

Comparison [6] Different [6] workload [6] scenarios QN Model [6] Load [6] test (I) [6] Load [6] test (II) [6] Software components [6] Figure 5 The interplay between the software components [6] CPU [6] 1 [6] CPU [6] 2 [6] CPU [6] 1 [6] CPU [6] 2 [6] CPU [6] 1 [6] CPU [2] 2 [2] Web Server [2] M/M/2 [2] S = 0,024s [2] Application Server [2] M/M/2 [2] S = 0,414s [2] Database Server [2] M/M/2 [2] S = 0,05s [2] Think time [2] M/G/ [2] Figure 6 QN-Model

is represented by an M/G/1 queue. The infinite number of service stations indicates that independent from the actual load no queuing effects occur. This reflects reality as the think time of a virtual user is not dependent on the number of concurrently active users. The structure of the resulting Queuing Network Model is depicted in figure [6] . We selected the power_shopper (see section 4.[2] .) for the validation of the resource profile. The mean service times were taken from the resource profile in

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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As service demands, we used processor time estimates determined during the experiment PE03 (analysis PE03.0, see section 4.3.3). In the LoadRunner script for experiment PE08, we specified that each Vuser subsequently submits one request of each kind (see section A.5.1). During the load test, the Vusers ran in endless loops (see section 5.4.3). We therefore assumed in the model that the time between the submission of two requests of the same kind by a certain user is composed of

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deviation for the web server, the application server, and the database server is 0, 004 (0,4%), 0,03 (3%) and 0,01 (1%) respectively. Despite the heterogeneity of the infrastructure and the different workloads during the load test, the accuracy of the estimates is surprisingly exact. The quality of the results is comparable to directly related approaches. Kounev and Buchman [KoBu03; BoGM06 pp. 703 et seqq.]

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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certain user is composed of the total user think time plus the execution time of the other 12 requests. We analyzed the predictive accuracy of the analytical model in 18 different workload scenarios. The load test started with ten Vusers in an endless loop. Every five minutes, we added ten more users until the load test stopped after 90 minutes and with 180 concurrently active Vusers. The mean think time between two subsequent requests was 1 second (random range: 50% to 150%) for all Vusers and at all workloads. A times series

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up. We use the same scripts as for the determination of the resource profiles. However, instead of simultaneous starts and stops, we put the users in an endless loop. Every five minutes, we added ten more users until the first component reaches its bottleneck. During the load test, performance monitors record the system behaviour in log files. The data is afterwards copied into a database,

- **3** Einflussfaktoren f r den Einsatz vo..., 2007, S. 938

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the load test stopped after 90 minutes and with 180 concurrently active Vusers. The mean think time between two subsequent requests was 1 second (random range: 50% to 150%) for all Vusers and at all workloads. A times series graph of the load test is depicted in figure 5.7. The load test measurements were analyzed by the QN Verifier according to the process description in section 5.4. 3. The load test configuration (numbers of users and mean think times) served as input parameter (workload

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difference between the observed and the predicted server utilization to measure predictive accuracy of our Queuing Network Models. The interplay between the different software components is depicted in figure 5. 5.3 The Java Pet Store Example (Continued) In the load test setup, presented in the previous section, the number of users remains constant during certain time intervals.

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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provided in the appendix (see section A.4.1). Regarding the accuracy of the processor time estimates and their appropriateness for Capacity Planning, most interesting is how well the performance model predicts the processor utilizations. In figures 5.11, 5.12 and 5.13 the mean processor utilization of the application server, the database server and the web server during each measurement interval is compared to the analytically determined values. Basically, the processor utilizations evolved with increasing load, as we had expected in our

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Mbps [2] Fibre Channel [2] Memory 2 GB 2 GB 2 GB 2 GB [2] Server Type HP DL360 IBM X360-03 HP DL360 HP N4000 [2] Network Name xxxxxx20 xxxxxx03d xxxxxx15 xxxxxx01a [2] 88 Reinhard Brandl, Martin Bichler, Michael Ströbel [1] 1 [1] CPU Utilization of the Application Server [1] (Measured by theW2K Performance Monitor) [1] Starts and stops of virtual users [1] (extracted from the LoadRunner log files) [1] Figure 4 Determination of the resource profile for a Pet

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [

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whole load test. The highest predictive accuracy, however, could be achieved for the throughput values (see figure 5.15 for an example). As long as the system is not close to its capacity limit the throughput grows approximately linearly with the number of concurrently active users. Therefore, the throughput graph is a valuable cross check whether the modeled workload intensity equals the workload intensity emulated by the load generator. In experiment PE08 the analytically determined and the measured throughput

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indicates that independent from the actual load no queuing effects occur. This reflects reality as the think time of a virtual user is not dependent on the number of concurrently active users. The structure of the resulting Queuing Network Model is depicted in figure [6] . We selected the power_shopper (see section 4.[2] .) for the validation of the resource

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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accuracy of the results indicated the appropriateness of consumption estimates from resource profiles as input parameters for analytical performance models (see section 5.1). 5.6.2 Services including multiple Client Requests In experiment PE09, we analyzed whether the model-based validation approach is also applicable to services including multiple client requests (and hence user think times). This was unclear, as we could not identify any related experimental results with QN Models and such kind of job classes. As an

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Information system , see section 3). Our intention was, first, to compare the resource consumption of different user profiles and, second, to verify that Queuing Network Theory is also applicable to services consisting of multiple user interactions with the system (see section 5.3). Thus, we defined the following user profiles: The curious_visitor enters the store and visits

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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The script and the modifications are documented in the appendix (see section A.5). In total, it contains 40 customer requests to the shop application. The configuration of the load test PE09-1 is similar to the configuration of load test PE08_1 presented in the previous section. Due to a less resource-intensive workload composition, we could analyze the predictive accuracy of the analytical model in 20 instead of 18 different workload scenarios. The load test started 176 Application server - Java Pet Store -

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Queuing Network Models. The interplay between the different software components is depicted in figure 5. 5.3 The Java Pet Store Example (Continued) In the load test setup, presented in the previous section, the number of users remains constant during certain time intervals. Therefore, we model the infrastructure as closed QN and compute for each interval separate results.

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requests Exp. PE09_1: Comparison of mean processor utilization with model predictions o J ,-:-1-; -i-,-1-i- 25 50 75 100 125 150 175 200 Number of virtual users -Application server - Processor - all ----Model prediction Figure 5. 16: QN Model Validation: Application Server Processor Utilization - Services including multiple Client Requests again with ten Vusers in an endless loop. Every five minutes, we added ten more users until the load test stopped after 100 minutes and with 200 concurrently active Vusers. The mean think time between two subsequent requests was 1 second (random range: 50% to 150%) for all Vusers and at all workloads. Thus, the

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up. We use the same scripts as for the determination of the resource profiles. However, instead of simultaneous starts and stops, we put the users in an endless loop. Every five minutes, we added ten more users until the first component reaches its bottleneck. During the load test, performance monitors record the system behaviour in log files. The data is afterwards copied into a database,

- **3** Einflussfaktoren f r den Einsatz vo..., 2007, S. 938

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server (dual processor machine). The QN Model of Kounev and Buchmann is slightly different to the model presented in section 5.5.2: CPU Application Server: -|M|1 - PS CPU Database Server: -|M|1 - PS Disk Database Server: -|M| 1 - FCFS Client: -|M|oo - FCFS 180 Production Line Stations: -|M|oo - FCFS In the Java Pet Store example, the time consumed by the SAN was negligible, so we omitted it in the model. Production Line Stations representing a " manufacturing think time" are a specific characteristic of the SPECjAppServer2002 example. The model above does not conform to the product-form conditions (see section 5.3.4). While we opted for an approximation by a product-form network (see section 5.3.4,

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we used this feature to define the start- and endpoint services. In the example of figure 3 the script replays the behavior of an average shopper in the Java Pet Store (see section 4.2). The whole shopping process is considered as a single service. In the script the service starts with the command lr_start_transaction(" petstore_shopper")

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

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algorithms, which are more accurate than the summation method (Bolch et al., 2006, p. 460). Kounev and Buchmann solely analyzed their model for services (job classes) including single client requests (analogous to experiment PE08, see section 5.6.1). They distinguished five request classes: NewOrder places a new order in the system ChangeOrder modifies an existing order OrderStatus retrieves the status of a given order CustStatus lists all orders of a given customer WorkOrder controls the order production The service demands were retrieved manually by analysis of the server utilization (application server) and of data monitored by an Oracle agent (database server). As in the Java Pet Store example, most of the service time was consumed by the processors. The disk time was minimal. During the experiments, Kounev and Buchmann applied a certain workload to different numbers of parallel application servers.

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in the customer domain and the manufacturing application in the manufacturing domain. Recall that the order entry application is running the following four transaction types: 1. NewOrder : places a new order in the system 2. ChangeOrder : modifies an existing order 3. OrderStatus: retrieves the status of a given order 4. CustStatus: lists all orders of a given customer We map each of them to a separate request class in our workload model. The manufacturing application, on the other hand, is running production lines. The

we used this feature to define the start- and endpoint services. In the example of figure 3 the script replays the behavior of an average shopper in the Java Pet Store (see section 4.2). The whole shopping process is considered as a single service. In the script the service starts with the command lr_start_transaction(" petstore_shopper")

- **12** Kounev, Samuel/Buchmann, Alejandro:..., 2003, S. 3
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

Textstelle (Prüfdokument) S. 40

Pet Store example, most of the service time was consumed by the processors. The disk time was minimal. During the experiments, Kounev and Buchmann applied a certain workload to different numbers of parallel application servers. They could therefore evaluate 1 Application Server 2 Application Servers Metric Model Measured Error Model Measured Error NewOrder Throughput 14.59 14.37 1.5% 14.72 14.49 1.6% ChangeOrder Throughput 4.85 4.76 1.9% 4.90 4.82 1.7% OrderStatus Throughput 24.84 24.76 0.3% 24.89 24.88 0.0% CustStatus Throughput 19.89 19.85 0.2% 19.92 19.99 0.4% WorkOrder Throughput 12.11 12.19 0.7% 12.20 12.02 1.5% NewOrder Response Time 56 ms 68 ms 17.6% 37ms 47 ms 21.3% ChangeOrder Response Time 58 ms 67 ms 13.4% 38 ms 46 ms 17.4% OrderStatus Response Time 12 ms 16 ms 25.0% 8 ms 10 ms 20.0% CustStatus Response Time 11 ms 17ms 35.2 % 7 ms 10 ms 30.0% WorkOrder Response Time 1127 ms 1141ms 1.2% 1092 ms 1103 ms 1. 0% WebLogic Server CPU Utilization 66% 70% 5.7% 33% 37% 10.8% Database Server CPU Utilization 36% 40% 10% 36% 38% 5.2% Table 5.1: Experimental Results of Kounev and Buchmann (2003) the predictive accuracy of the model in scenarios with varying capacities. Mean results of experiments with 1 and 2 application servers are given in table 5.1. Additional experiments with three different workloads and 3, 4, 6 and 9 parallel application servers led to comparable results (see full result tables in Kounev and Buchmann, 2003). The experiments presented in the previous sections are complementary to that approach. In contrast to Kounev and

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on. The additional load leads to higher utilization of system resources and in this way impacts the measured Table 3: Analysis Results for Scenario 1 - Low Load1 Application Server 2 Application Servers METRIC Model Measured Error Model Measured Error NewOrder Throughput 14.59 14.37 1.5% 14.72 14.49 1.6% ChangeOrder Throughput [4] .85 4.76 1.9% 4.90 4.82 1.7% OrderStatus Throughput 24.84 24.76 0.3% 24.89 24.88 0.0% CustStatus Throughput 19.89 19.85 0.2% 19.92 19.99 0.4% WorkOrder Throughput 12.11 12.19 0.7% 12.20 12.02 1.5% NewOrder Response Time 56ms 68ms 17.6% 37ms 47ms 21.3% ChangeOrder Response Time 58ms 67ms 13.4% 38ms 46ms 17.4% OrderStatus Response Time 12ms 16ms 25.0% 8ms 10ms 20.0% CustStatus Response Time 11ms 17ms 35.2% 7ms 10ms 30.0% WorkOrder Response Time 1127ms 1141ms 1.2% 1092ms 1103ms 1.0% WebLogic Server CPU Utilization 66% 70% 5.7% 33% 37% 10.8% Database Server CPU Utilization 36% 40% 10% 36% 38% 5.2% Table 4: Analysis Results for Scenario 2 - Moderate Load 3 Application Servers 6 Application Servers METRIC Model Measured Error Model Measured Error NewOrder Throughput 24.21 24.08 0.5% 24.29 24.01 1.2% ChangeOrder Throughput 19. 36 18.77 3.1% 19.43 19.32 0.6% OrderStatus Throughput 49.63 49.48 0.3% 49. 66 49.01 1.3% CustStatus Throughput 34.77 34.24 1.5% 34.80 34.58 0.6%

• **12** Kounev, Samuel/Buchmann, Alejandro:..., 2003, S. 3

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determined in their experiments with a single application server a relative deviation of 5.7% at the application server and 10% at the database server (see table 5.1). At a comparable workload level we measured relative deviations of 5.8% and 1.3% respectively (see table A. 19: 90 concurrent 182 users and 66.1 % utilization of the application server). 5.8 Summary The motivation for the development of the software tools, QN Solver and QN Verifier, and for the experiments described in the previous sections was twofold (see section 5.1). First, we wanted to analyze whether the consumption estimates determined for resource

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Mbps [2] Fibre Channel [2] Memory 2 GB 2 GB 2 GB 2 GB [2] Server Type HP DL360 IBM X360-03 HP DL360 HP N4000 [2] Network Name xxxxxx20 xxxxxx03d xxxxxx15 xxxxxx01a [2] 88 Reinhard Brandl, Martin Bichler, Michael Ströbel [1] 1 [1] CPU Utilization of the Application Server [1] (Measured by theW2K Performance Monitor) [1] Starts and stops of virtual users [1] (extracted from the LoadRunner log files) [1] Figure 4 Determination of the resource profile for a Pet

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [

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often not readily available input parameters hamper their application in practice. We claim that there resource profiles and the validation methodology presented in the previous sections could fill a gap. Chapter 6 Proof of Concept: BMW Group 6.1 Motivation The initial objective of the work presented in this thesis was to contribute a viable alternative to existing cost allocation methodologies (see section 1.2). To evaluate the "viability" of the approach presented in the previous chapters we conducted a proof of concept in cooperation with our industrial partner, the BMW Group. The project was organized into three stages. First, we analyzed the cost allocation practices for IT infrastructure services and verified whether the situation is in accord with our general assumptions on IT

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against chemotherapy by introducing resistance genes. However, the success of HSC gene therapy is limited by the low transfection efficiency in those primitive HSC. The objective of the work presented in this thesis was to improve retroviral gene transfer efficiency in human HSC. Clinically relevant culture and transfection conditions of HSC were studied. HSC were collected from chemotherapy and cytokine-

IT service management processes. While the first requirement is essential for the cost allocation key to achieve incentive compatibility, the second and third requirements target the viability of the approach. Clearly, direct apportioning of IT infrastructure costs could easily outweigh the benefits of a usage-based cost allocation key. Based on a series of load tests, we

and average consumption vectors. As the problem of allocating infrastructure costs is of a quite general nature, we further followed this idea and analysed its potential in cooperation with our industrial partner, the BMW Group. 4 Results and experiences from the pilot test 4.1 Organisational context At the BMW Group , management and operation of the considered OLTP systems is organised on two

- **13** hellip -mediated retroviral gene tr..., 1998, S. 136
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.
- **3** Einflussfaktoren f r den Einsatz vo..., 2007, S. 932

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cost allocation practices for IT infrastructure services and verified whether the situation is in accord with our general assumptions on IT Cost Accounting and Chargeback (see chapter 2). Second, by example of Java/J2EE-based application systems we examined how the determination of resource profiles could be integrated into the existing IT Service Management processes. Finally, we applied method and software to two different application systems in a data center of the BMW Group. Results from experiments on that infrastructure were already presented in chapters 4 and 5. During the proof of concept, we put a particular analysis focus on the following two requirements (see section 3.4): 1. Consistency This requirement means that the estimation should be applicable to various IT infrastructures, without a need to change the respective systems. We deliberately chose Java/J2EE technologies for the proof of concept, as the respective guidelines at the BMW Group facilitate the design of distributed and heterogeneous software and hardware architectures. 183 184 So, we combined

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service-level resource profiles [6] is well motivated in proposals by Funke [6] [Funk99] and Scheeg [Sche05] in the areas [6] of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with

different hardware, operating systems and applications), without a need to change the respective systems. & Third, the estimation should cause little extra work and integrate well with existing IT service management processes. While the first requirement is essential for the cost allocation key to achieve incentive compatibility, the second and third requirements target the viability of the

setting a range for virtual memory) and it is possible to take this value as the basis for cost allocation. The experimental infrastructure was set up in a data center of the BMW Group (see table 1). We combined different operating systems (Linux, Windows and Unix) and servers (Apache HTTP, Bea Weblogic and Oracle Database). The tablespaces of the database

First of all, the estimator should be unbiased, in the sense that on average it should not over- or underestimate the true resource consumption. & Second, the estimation should be applicable to various IT infrastructures (i.e., different hardware, operating systems and applications), without a need to change the respective systems. & Third, the estimation should cause little extra work and integrate well with existing IT service management processes. While the

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [
- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.
- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2
- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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systems. We deliberately chose Java/J2EE technologies for the proof of concept, as the respective guidelines at the BMW Group facilitate the design of distributed and heterogeneous software and hardware architectures. 183 184 So, we combined in the test infrastructure three different operating systems (Linux, Windows, Unix) with server software from Apache, Bea and Oracle. All hardware and software components were typical enterprise products. By means of this rather heterogeneous, but realistic, infrastructure, we tried to gather significant

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this value as the basis for cost allocation. The experimental infrastructure was set up in a data center of the BMW Group (see table 1). We combined different operating systems (Linux, Windows and Unix) and servers (Apache HTTP, Bea Weblogic and Oracle Database). The tablespaces of the database are stored in a Storage Area Network (SAN), which is

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

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All hardware and software components were typical enterprise products. By means of this rather heterogeneous, but realistic, infrastructure, we tried to gather significant results on the consistency of the estimation process and the determined resource profiles. 2. Operating Efficiency The determination of resource profiles should integrate well with existing IT Service Management processes and cause little extra work. We addressed this requirement with a feasibility study with Java/J2EE-based application systems. We first developed an integration into existing processes and then conducted a number of test series

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service-level resource profiles [6] is well motivated in proposals by Funke [6] [Funk99] and Scheeg [Sche05] in the areas [6] of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with

various IT infrastructures (i.e., different hardware, operating systems and applications), without a need to change the respective systems. & Third, the estimation should cause little extra work and integrate well with existing IT service management processes. While the first requirement is essential for the cost allocation key to achieve incentive compatibility, the second and third requirements target the viability of the

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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then conducted a number of test series with two example application systems. Thereby, we tried to adhere to all relevant process and architectural guidelines to get sound estimates for the expected efforts and the operating efficiency of the approach for the determination of resource profiles. In the following, we first introduce the case of the BMW Group and discuss the current cost allocation practices of the Central IT unit (section 6.2). In section 6.3 we then present the results of the feasibility study with Java/J2EE-based application systems. As experimental results were already provided in chapters 4 and 5, we focus in this section on the integration into existing IT Service Management processes and our experiences regarding the operating efficiency and the efforts required for the determination of resource profiles. Section 6.4 summarizes the findings from the proof of concept and describes some potential benefits of resource profiles beyond Cost Accounting. 6.2 Organizational Context The BMW AG is an independent automobile and motorcycle

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

tests with respective workloads. We conducted several experiments with J[2] EE applications in a distributed client/ server infrastructure consisting of Unix, Linux, and Windows servers in a data center of the BMW Group and achieved very promising results even in a very heterogeneous environment with multiple software modules, operating systems, and hardware infrastructures. The estimation procedure could be integrated with

different hardware, operating systems and applications), without a need to change the respective systems. & Third, the estimation should cause little extra work and integrate well with existing IT service management processes. While the first requirement is essential for the cost allocation key to achieve incentive compatibility, the second and third requirements target the viability of the

is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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and sells cars and motorcycles manufactured by itself and by foreign subsidiaries. The vehicles are sold through the company's own branches, independent dealers, subsidiaries and importers (BMW Group, 2006, p. 52). The BMW AG is the parent company of the BMW ~ S c co cd co II o 13 il O cd c g o a o "O O) cd = co 1 CD J CO S co cd o c co c y I co -q ' c cd ts cd Business units Business units Departmental IT I I Business units Departmental IT I Business units Departmental IT I Business units Departmental IT J J. Business units Departmental IT I Departmental IT Central IT Figure 6.1:

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CM LO p LO LO CN p d LO O LO CO L L O U N . Lop iq CN p d c CO o c o o 111 o c o ' *-> CO Lc a) a c o o LU CT O o TJ i_co c r- CD O O ' - CO Q =5 ~ CO ! 2 n cu - -Q LO C 0 . 3 0 CN TJ o a c o . o * o -o "_ CD c CL> CO O X J 4- CD O CO o CD X ! O c CD CO CD UU <*) +1 T C C CO CO CD c E c _ o CL O CD - C -* ' CO -4 ' c CD CO CD l _ Q_ x: CJ o § § a: O co O TJ LU _ CD CD "CO CL ?" CD 5 C i_ o O § CO CD C L % E § 2 c o CD CD JJ. _ CD . 2 CO * i CO CO o Lc CD o c o o LLT h- Q TJ CD

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Solution Mgmt. Build Service / Ops. Mgmt. Run IT Strategy and IT Innovation Management IT Strategy Management IT Innovation Management IT Communication Management IT Program / IT Project Management Relationship Management Planning and Control (incl. Requirements Management) Enterprise Architecture Management Service Support Incident Management Problem Management Change Management Release Management Configuration Management IT Quality, Process and Target Management Solution Development Application Development Infrastructure Development Component Development Service Delivery Availability Mgmt Capacity Mgmt. Service Level Mgmt. Service Continuity Mgmt. IT Resource Management Solution Lifecycle Mgmt. (

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Complimentary Guidance (Sekundärliteratur) Eigentliche Dienstmanagement-Prozesse in 2 Bänden: Service Support und Service Delivery Insgesamt 10 Prozesse, je ein Kapitel (zwischen 24 und 81 Seiten) Hauptsächlich Fließtext, uneinheitliche Struktur 12 Service Support Incident Management Problem Management Change Management Release Management Configuration Management Service Level Management Capacity Management Availability Management Financial Management Continuity Ermitteln der Kapazitätsanforderungen, Erstellen eines Kapazitätsplans Planung der Dienstaufrechterhaltung oder -wiederherstellung für Ausnahme- und Katastrophenfälle

- **15** Werkzeugunterst, 2007, S.

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from the shortcomings of the approach. First, the chargeback system suffers from a lack of acceptance and trust by the customers. Second, it does not achieve an alignment of business and IT planning. The correlation between actual and future costs for the provision of IT services and business operations figures is not transparent. So, on the one hand, customers are mostly not aware of the consequences of their decisions on IT costs. On the other hand, IT Capacity Planning, which determines to a large extent future resource costs, is often imprecise. 6.2.5 Customer-oriented Services and Resource Profiles The basic question to answer, prior to any feasibility considerations, is whether

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cost accounting (full and variable costing) as well as for process- or activity-based costing approaches. Generally, we propose a three-stage process (see figure [2]). Budgeted costs for the provision of shared IT resources are apportioned among the services according to services expected resource consumption and forecasts of the resources total usage. Thus, for every service a

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complement to the existing IT Controlling perspectives, seems promising. The management has recognized this and forces process-costing initiatives. As service-orientation has been widely discussed in literature (see sections 2.2 and 3.7), we focus in the following on the determination of resource profiles. By means of the Java/J2EE infrastructure at the BMW Group, we analyze whether this second building block of the concept (see section 3.2) is applicable in an industrial environment and how it integrates into the existing IT Service Management processes. 6.3 Feasibility Study: Java/J2EE Application Systems At the BMW Group, Java/J2EE is the predominant platform technology for custom software development. The Center of Competence IT Architectures has therefore published two master solution guidelines (

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level resource profiles [6] is well motivated in proposals by Funke [6] [Funk99] and Scheeg [Sche05] in the areas [6] of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with

different hardware, operating systems and applications), without a need to change the respective systems. & Third, the estimation should cause little extra work and integrate well with existing IT service management processes. While the first requirement is essential for the cost allocation key to achieve incentive compatibility, the second and third requirements target the viability of the

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systems, first, because of their strategic relevance for the BMW Group and, second, because of their distributed and heterogeneous nature, combined with widely shared resources, which is usually not compatible with common Cost Accounting approaches (see section 2.4). 6.3.1 Java/J2EE at the BMW Group The basis for custom Java/ J2EE-based applications systems are the master solution guidelines J2EE/EJB and J2EE/Servlet. The guidelines are mandatory for software projects and aim at standardizing system and software architectures as well as the necessary build and run processes (see section 6.2.2) . For the documentation of guidelines and architectures the BMW Group uses a simple graphical notation similar to UML (see figures 6.5 and 6.6). In both master solution guidelines a

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Server CPU time [sec] 0,0064 0,9249 0,0130 0,9836 0,0076 0,9812 0,0122 0, 9677 0,040 0,999 App. Server CPU time [sec] 0,0389 0,5530 0,1293 0,8183 0, 0838 0,7577 0,2071 0,8251 0,830 [1] ,000 DB Server CPU time [sec] 0,0008 0, 1474 0,0200 0,9550 0,0089 0,9449 0,0251 0,8749 3,715 1,000 SAN I/O [blocks] 0 n/a 7,1230 0,7518 0 n/a 0 n/a 159,14 0,970 Network I/O [bytes] 174. 521 1,0000 434.651 1,0000 250.183 1,0000 562.443 1,0000 398.283 1,000 2 3 4 based application used for project statustracking at the BMW Group. The linear increase of the resource consumption is most evident for the network resource. In contrast, the transferred bytes of the Pet Store to the SAN

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for the processor time, while the processor time consumed by databases on Unix servers is "free". Although this cost allocation approach is quite efficient, such inconsistencies cause acceptance and free-rider problems (see section 6.2.4). 6. 3.2 Integration into existing Processes Resource profiles for cost accounting and capacity planning should be based on the final version of application system and infrastructure configuration. Thus, the optimal moment for their determination is after completed development and test phases, but before productive operations begins.

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the above described requirements, such as customer-orientation (e.g., through non-technical accounting metrics) and the integration of relevant cost drivers the resource consumption in particular. 3 Resource Profiles for Cost Accounting and Capacity Planning 3.1 Concept In the following, we consider an IT system from the customers (e.g., end-users, business units) perspective. For them the complexity of the underlying software

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new server components, communication protocols, interfaces) change in the software architecture (e.g., major changes to the user navigation, use of new software patterns) change of specifications (e.g., performance requirements, workload mix, system load) The mandatory approval tests provide optimal occasions for the determination of resource profiles. We therefore analyzed during the feasibility study how the existing test procedures can be appropriately extended (see gray-shaded boxes in figure 6.7). Once determined, services and resource profiles can serve as

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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serve as inputs for neighbored IT Service Management Processes (see figure 6. 8). A stronger focus on services would primarily address shortcomings of the current IT Cost Accounting and Chargeback approach concerning Planning and Control (see section 6.2.5). Furthermore, the resource profiles would be valuable inputs for the alignment of business forecasting and IT Capacity Planning and thus support the Capacity Management process (Service Delivery) . Finally, if the resource consumption per service and user becomes transparent during the approval test, it can be used as a criterion for the evaluation of software and for the specification of targets for developers and architects (Solution Development). DC IT Business Mgmt. Plan IT Strategy and IT nnovalion Management IT Sfttftagy Maf"iqt*nem !T innovation

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constitute the basis for cost allocation keys. The elaborate process of measuring and consolidating log data from different components could be bypassed. Furthermore, these estimates would be valuable inputs for the alignment of business forecasting and IT capacity planning. The concept is not dependent on a specific costing methodology. It is applicable for traditional cost accounting (full and variable costing) as well as for process-

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capacity planning Figure 6.8: Integration into the IT Service Management Process Map (adapted from internal documentation) 6.3.3 Identification of Services According to the concept description (see section 3.2.1), possible kinds of services could be the execution of a business transaction or the access to an information system. In the context of Java/J2EE at the BMW Group, we propose considering the access or the logon to an application system as default form of service invocation. The decision is based on

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fine granular services (e.g., "view catalogue page", "add item to cart"). However, for this paper, we decided to consider the whole Pet Store as single service (Access to an Information system , see section 3). Our intention was, first, to compare the resource consumption of different user profiles and, second, to verify that Queuing Network Theory is also

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based on logons constitute a consistent and comprehensible accounting basis in this heterogeneous application landscape. 2. Compared to packaged application suites (e.g., for ERP, CRM, HR, SCM), the majority of the custom application systems are relatively small (regard- 200 ing for instance the number of concurrent users or the implemented use cases). We claim that one service per system is a reasonable granularity for cost allocation. 3. Most Java/J2EE applications use a central infrastructure service for user authentication and authorization. This component

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is most evident for the network resource. In contrast, the transferred bytes of the Pet Store to the SAN seem not to be related with the number of concurrent users. The application is programmed to avoid "expensive" disk accesses as far as possible. Instead most data is kept in the memory of the servers. Accordingly,

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load test engineers involved, these assumptions often do not match with reality. Charges based on these expected user behaviors would introduce additional bias and stimulate conflicts. In that case, we propose determining an interval instead of a discrete estimate of the expected resource consumption. We argue that is easier for new application systems to estimate different user profiles as the average user behavior. The information about scale and range of the resource consumption might be sufficient

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compare the CPU times with measurements on other infrastructures, they must be normalized, e.g., by using standard performance benchmarks [SPECa]. These resource profiles provide an overview of the expected resource consumption for different types of user behavior. If historical usage data is available, an average resource profile can be derived. Otherwise, the determined bandwidth of the

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different user profiles as the average user behavior. The information about scale and range of the resource consumption might be sufficient for a classification and the determination of charges. 6.3.4 Summary of Experiences We applied the concepts and the software for the determination of resource profiles (see chapter 3) and analytical capacity planning (see chapter 5) to application systems in a data center of the BMW Group. In particular, we analyzed the extra efforts and the preconditions required for an integration of the approach into the existing approval tests (see section 6.3.2). To achieve significant results, we tried to adhere

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

setting a range for virtual memory) and it is possible to take this value as the basis for cost allocation. The experimental infrastructure was set up in a data center of the BMW Group (see table 1). We combined different operating systems (Linux, Windows and Unix) and servers (Apache HTTP, Bea Weblogic and Oracle Database). The tablespaces of the database

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In the previous section we proposed considering the logon to an application system as the default form of service invocation. PASTA as well as Java Pet Store are interactive web applications and we assumed that for both no historical usage data is available. Accordingly, we determined intervals instead of discrete estimates of the expected resource consumption (see section 6.3.3). For the feasibility of the approach it is crucial whether information about scale and range of the resource consumption is sufficient for the allocation of charges. In the experiments we therefore measured the resource consumption of two different PASTA user profiles and four different Java Pet Store user profiles (see section 4.1.2). The resulting intervals of the expected resource consumption are summarized in table 6.1. The complete resource profiles are provided in the appendix (see section A.3.1). The results were surprising. In the examples the impact of system and software design was far greater

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normalized, e.g., by using standard performance benchmarks [SPECa]. These resource profiles provide an overview of the expected resource consumption for different types of user behavior. If historical usage data is available, an average resource profile can be derived. Otherwise, the determined bandwidth of the consumption values already allow for an approximate classification, which might be sufficient

compare the CPU times with measurements on other infrastructures, they must be normalized, e.g., by using standard performance benchmarks [SPECa]. These resource profiles provide an overview of the expected resource consumption for different types of user behavior. If historical usage data is available, an average resource profile can be derived. Otherwise, the determined bandwidth of the

time [sec] 0,0389 0,5530 0,1293 0,8183 0,0838 0,7577 0,2071 0,8251 0,830 [1] ,000 DB Server CPU time [sec] 0,0008 0,1474 0,0200 0,9550 0,0089 0,9449 0, 0251 0,8749 3,715 1,000 SAN I/O [blocks] 0 n/a 7,1230 0,7518 0 n/a 0 n/a 159, 14 0,970 Network I/O [bytes] 174.521 1,0000 434.651 1,0000 250.183 1,0000 562.443 1,0000 398.283 1,000 2 3 4 based application used for project statustracking at the BMW Group. The linear increase of the resource consumption is most evident for the network resource. In contrast, the transferred bytes of the Pet Store to the SAN seem not to be related with the

compare the CPU times with measurements on other infrastructures, they must be normalized, e.g., by using standard performance benchmarks [SPECa]. These resource profiles provide an overview of the expected resource consumption for different types of user behavior. If historical usage data is available, an average resource profile can be derived. Otherwise, the determined bandwidth of the

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on aspects such as the ease of integration of backend systems, the complexity of server configurations or the use cases in the load test scripts. If this is already achieved, as in obligatory approval tests, the extra effort for the determination of resource profiles is acceptable. During the feasibility study we required approximately half a day for the adaption of an existing load test scenario (~ 1 h), the execution of the load test (~ 1-3 h) and the data analysis (~ 2 h). The

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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found that a lot of potential bottlenecks are hidden in the system configuration (e.g., web server connections, session beans, database connection pool). As these software bottlenecks limit the throughput and thus the hardware utilization, the comparison with predicted values fails. For the determination of resource profiles those effects are less relevant, as they typically increase response times, but do not change the absolute resource consumption. However, the QN models cannot be validated until the configured bottlenecks are

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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Java/J2EE, Microsoft/ .NET, Mainframe (z/OS) and SAP. In the following we analyze whether and how the Java/ J2EE-based experiences of the previous sections can be transferred to the other platforms. Microsoft/.NET The process and the software toolkit for the determination of resource profiles is directly applicable to Microsoft/.NET based application systems. Load test scripts for web-based applications can be recorded with the Virtual User Generator (see section 3.5.4.1). For Windows GUI applications Mercury

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technical considerations, an overall organizational problem is that for Microsoft/.NET, Mainframe (z/OS) and SAP-based application systems an approval test is not obligatory. This hampers the direct transfer of the concept and significantly increases the effort required for the determination of resource profiles. 6.4 Summary During the proof of concept we analyzed whether the concept and the software for the determination of resource profiles and capacity planning is applicable in an industrial data center. Prior to a concrete feasibility study, we verified if the overall assumptions on requirements, objectives and practiced approaches of IT Infrastructure Cost Allocation are in accord with the situation of the BMW Group (see chapter 2). As this could be confirmed and customer-oriented services emerged as a promising complement to the existing planning and control perspectives, we tested the determination of adequate resource profiles by means of

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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In these cases the resource consumption of the installed applications and the workload generated by the customers is a significant cost driver. An average application server in an industrial data center (e.g., 4 CPU / 16 GB memory) can easily host dozens of light-weight applications, whereas in other workload scenarios, the same server may be fully utilized by one

virtual memory) and it is possible to take this value as the basis for cost allocation. The experimental infrastructure was set up in a data center of the BMW Group (see table 1). We combined different operating systems (Linux, Windows and Unix) and servers (Apache HTTP, Bea Weblogic and Oracle Database). The tablespaces of the database are

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customer-oriented services emerged as a promising complement to the existing planning and control perspectives, we tested the determination of adequate resource profiles by means of Java/J2EE-based application systems and proposed an integration of the concept into the existing IT Service Management Processes. The majority of the considered application systems were relatively small, e.g., regarding the number of concurrent users or the implemented use cases, and ran on shared hardware. During the feasibility study most efforts were required for setting up the systems in a dedicated environment and preparing the load tests. If

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different hardware, operating systems and applications), without a need to change the respective systems. & Third, the estimation should cause little extra work and integrate well with existing IT service management processes. While the first requirement is essential for the cost allocation key to achieve incentive compatibility, the second and third requirements target the viability of the

is most evident for the network resource. In contrast, the transferred bytes of the Pet Store to the SAN seem not to be related with the number of concurrent users. The application is programmed to avoid "expensive" disk accesses as far as possible. Instead most data is kept in the memory of the servers. Accordingly,

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and ran on shared hardware. During the feasibility study most efforts were required for setting up the systems in a dedicated environment and preparing the load tests. If this is already achieved, e.g., for obligatory approval tests, the extra efforts for the determination of resource profiles are acceptable. Concerning the definition of services we introduced two simplifications. First, we considered the logon to an application system as the default form of service invocation. Thus, we could use

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is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

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form of service invocation. Thus, we could use the authentication and authorization infrastructure as a central meter for service invocation and avoided the analysis of application log files and operational databases. Second, we determined an interval instead of a discrete estimate for the expected resource consumption. In the example scenarios these simplifications turned out to be viable and significantly enhanced the practicability of the concept. However, for evaluating their general applicability more experiments are required. Overall, we could

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users, and so forth) and then applied a linear regression. We consider the slope of the regression line as average consumption per additional user and as estimate for the expected resource consumption. The Pearson correlation coefficient (r 2 [Ł 1]) and the resource profile p for the Pet Store example is shown in table 2. For comparison we included the resource profile of

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resource consumption into the determination of cost allocation keys. Furthermore, we identified a number of additional advantages of resource profiles, beyond cost accounting. 1. Capacity planning for dedicated resources In the experiments we could demonstrate that the resource profiles include valuable inputs for analytical capacity planning. While the motivating cost allocation concept mainly addresses shared resources, the support for capacity planning is particularly relevant for sizing dedicated resources. From the corporate perspective, at that point in time costs

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load tests for different workload scenarios, these values should satisfy (1) and (2) and also be sufficiently accurate for cost allocation keys. Overall, these parameter estimates provide valuable inputs for analytical capacity planning and infrastructure sizing, which are not readily available in most organizations. Highly interactive applications are more difficult and require adequate user behavior models. A variety of

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The experiments illustrated the large impact of system and software architectures on the resource consumption (see for instance table 6.1). Today, the resource consumption can barely be considered in the early project phases when architectural alter- 206 natives are evaluated2. At the BMW Group the supported alternatives are specified by the Center of Competence IT Architectures in master solution guidelines. We recommend enhancing these guidelines with a section including example resource profiles to improve the basis for decision-making. 3. Definition of targets for developers and architects Once, resource profiles can be determined and appropriate benchmark values are specified in master solution guidelines, they can be used as targets for software developers

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Server CPU time [sec] 0,0064 0,9249 0,0130 0,9836 0,0076 0,9812 0,0122 0, 9677 0,040 0,999 App. Server CPU time [sec] 0,0389 0,5530 0,1293 0,8183 0, 0838 0,7577 0,2071 0,8251 0,830 [1] ,000 DB Server CPU time [sec] 0,0008 0, 1474 0,0200 0,9550 0,0089 0,9449 0,0251 0,8749 3,715 1,000 SAN I/O [blocks] 0 n/a 7,1230 0,7518 0 n/a 0 n/a 159,14 0,970 Network I/O [bytes] 174. 521 1,0000 434.651 1,0000 250.183 1,0000 562.443 1,0000 398.283 1,000 2 3 4 based application used for project statustracking at the BMW Group. The linear increase of the resource consumption is most evident for the network resource. In contrast, the transferred bytes of the Pet Store to the SAN

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appropriate benchmark values are specified in master solution guidelines, they can be used as targets for software developers and architects. Up to now, apart from response time behavior, it is only verified whether the average processor and memory utilization at the application server remains under certain absolute thresholds. The respective load tests are conducted with the expected number of concurrent users. The resource consumption is not analyzed on a per service or per user basis and the results are only relevant if the application system is installed on shared server resources. So, if the performance

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at the Web, Application and Database Servers record the system behavior in log files on their local disks. The upper diagram (4) shows the overall CPU utilization at the Application Server. Data about network and storage resources is analyzed in the same manner. After the experiment, the Service Profiler computed the consumption per resource and user

most evident for the network resource. In contrast, the transferred bytes of the Pet Store to the SAN seem not to be related with the number of concurrent users. The application is programmed to avoid "expensive" disk accesses as far as possible. Instead most data is kept in the memory of the servers. Accordingly, most

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is installed on shared server resources. So, if the performance requirements are fulfilled, no more incentives for economic resource usage exist today. At that point an analysis of potential savings was out of scope, but we assume that the determination of resource profiles would already positively influence the cost consciousness of developers and architects. Against this background, we propose the enhancement of the existing approval tests by the determination of resource profiles. More and more resource profiles of different application systems will then become available. On this basis our assumptions on services and on resource consumption can be verified. Depending on the operational experiences

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service-level resource profiles [6] is well motivated in proposals by Funke [6] [Funk99] and Scheeg [Sche05] in the areas [6] of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with

service-level resource profiles [6] is well motivated in proposals by Funke [6] [Funk99] and Scheeg [Sche05] in the areas [6] of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with

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and resource profiles. 2Scheeg (2005) analyzes this problem and proposes an alternative solution based on performance benchmarks (see section 3.7). Chapter 7 Conclusions 7.1 Summary of Results The starting point of this thesis was the question of how IT Service providers can determine usage-based cost allocation keys for shared IT infrastructures. We analyzed the question in the context of operational, interactive OLTP systems and proposed estimates for the expected resource consumption of customer-oriented services as a basis for cost allocation. In this way, we aimed to avoid elaborate and costly measurements during regular operations. For an assessment of the concept's technical viability, we

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fact that a business user probably would not accept technical accounting metrics as the CPU times of different servers). In this paper, we propose a method to determine usage-based cost allocation keys for customer-oriented services based on their estimated resource consumption. Deriving such an estimator, however, is a nontrivial task. & First of all, the estimator should be unbiased,

and so forth) and then applied a linear regression. We consider the slope of the regression line as average consumption per additional user and as estimate for the expected resource consumption. The Pearson correlation coefficient (r 2 [1; 1]) and the resource profile p for the Pet Store example is shown in table 2. For comparison we included the resource profile of

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between a database server and a Storage Area Network (read/write blocks). There, high variations in the sample measurements complicated the determination of unbiased estimates. Furthermore, we evaluated the method and the software toolkit with regard to four major requirements that we consider essential for the successful application in a professional IT Service Management organization: 1. Accuracy For computing and communication resources, we obtained in all experiments very precise and repeatable results. In particular, we verified in 207 208 experiments with Queuing Network Models that the determined processor time estimates

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we have proposed a method for the calculation of cost allocation keys based on estimated resource consumption of IT services. The approach satisfies a number of criteria that we consider essential for successful application in a professional IT service management organization. First, the estimators for the resource consumption of single service requests are of a high quality and can be used for capacity planning, as well as

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anticipate them in the resource profiles. 2. Consistency The software toolkit fully relies on standard operating system tools for resource consumption measurements during the profiling process. It is therefore equally applicable to various kinds of hardware and software infrastructures without a need to change the respective systems or install additional software. We successfully verified this consistency concept in experiments with Windows, Unix and Linux operating systems. 3. Capacity Planning By means of Queuing Network Theory, we could demonstrate the appropriateness

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should not over- or underestimate the true resource consumption. & Second, the estimation should be applicable to various IT infrastructures (i.e., different hardware, operating systems and applications), without a need to change the respective systems. & Third, the estimation should cause little extra work and integrate well with existing IT service management processes. While the first requirement is essential for the

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operating systems. 3. Capacity Planning By means of Queuing Network Theory, we could demonstrate the appropriateness of processor time estimates as input parameters for analytical performance models. We compared forecasted server utilizations with measurements from a load test and determined a surprisingly high accuracy of the model predictions. 4. Operating Efficiency We analyzed in a proof-of-concept the integration of the approach for the determination of resource profiles into the existing IT Service Management processes at the BMW Group. In a feasibility study with Java/ J2EE-based application systems, the most effort was required to fulfill preconditions such as setting up the systems in a dedicated environment and preparing the

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be omitted. & We use Queuing Networks to validate the estimated resource profiles under different workloads. & Experiments with multi-tier database applications in a heterogeneous environment yield surprisingly high accuracy of the estimated resource profiles. The estimates also provide the necessary input for analytical capacity planning, which often suffers from a lack of data to parameterize respective Queuing

is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with performance [6] monitors for the determination of resource [6] consumption. Their focus lies on the determination of input parameters for performance analysis and capacity planning. [6] They use a custom load generator, which [6] requires measurement agents

different hardware, operating systems and applications), without a need to change the respective systems. & Third, the estimation should cause little extra work and integrate well with existing IT service management processes. While the first requirement is essential for the cost allocation key to achieve incentive compatibility, the second and third requirements target the viability of the

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study with Java/ J2EE-based application systems, the most effort was required to fulfill preconditions such as setting up the systems in a dedicated environment and preparing the load tests. In professional IT organizations similar load tests are typically conducted prior to the roll-out of a new software release. If the determination of resource profiles could be combined with such obligatory approval tests, the extra efforts are acceptable. During the feasibility study we required approximately half a day for the adaption of an existing load test scenario, the

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see previous section) . In the experiments we installed the applications under consideration in an isolated test environment, as is usual for operational approval tests [OoOC02] prior to the roll-out of a new software release. Bymeans of the load generator, we then simulated consecutive service invocations, while the performance monitors recorded the system s utilization in log files. After the load

service-level resource profiles [6] is well motivated in proposals by Funke [6] [Funk99] and Scheeg [Sche05] in the areas [6] of Cost Accounting and IT Controlling. [6] Concerning the determination of resource [6] profiles our concept is related to Nagaprabhanjan and Apte, who recently presented a tool [NaAp05] for automated profiling of distributed transactions. They also [6] combine load generation with

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Second, as the software toolkit fully relies on the standard performance monitors of operating systems, no additional measurement agents are required and new resources can be easily integrated. Nevertheless, in spite of precise measurement and analysis techniques, uncertainties about the expected user behavior, variations as observed at the Storage Area Network and infrastructure changes such as growing database sizes can bias the consumption estimates. Against this background, we propose considering intervals rather than exact consumption estimates as the basis for cost allocation. We argue that intervals already allow for a classification of services. This might be sufficient for cost allocation. Furthermore, they could compensate to a certain degree variations of mean resource consumption values. So, extra

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with standard OS performance monitors. The question is, can measurements based on standard log file data be sufficient to derive accurate resource consumption estimates? & (3) Assumptions about the expected user behavior (e.g., parameters passed, interactions with the system) during the setup of the load tests may not reflect reality. Overall, a validation of p can be performed ex-post

memory a server can allocate on a machine is typically determined at startup (e.g., by setting a range for virtual memory) and it is possible to take this value as the basis for cost allocation. The experimental infrastructure was set up in a data center of the BMW Group (see table 1). We combined different operating systems (Linux, Windows and Unix) and

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cost allocation based on services and resources profiles is an appropriate means to achieve their organization-level objectives on IT Cost Accounting and Chargeback. 210 7.2 Outlook Topics such as IT Cost Accounting and Chargeback or IT Capacity Planning fall under the realm of IT Service Management. Despite the development of widely accepted standards such as ITIL or CobiT and the increasing importance of IT Service Management for the industry, little academic research has focused on this

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Journal of Information Technology 11 (1996) 2, pp. 101 117. [Vmwa] VMware, Inc.: Virtualization software. httpwwwvmwarecom, Last accessed: 2006- 08-29. WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 [2] 2 Survey of Literature [2] and Current Practice [2] Cost accounting for IT infrastructures falls [2] under the realm of IT (Infrastructure) Controlling (see for instance [Karg99; KrBR00; [2] GaMa05]) or, from the ITIL perspective [2] [OoOC01], IT Financial Management. [2] Several concepts exist (e.g., cost-center accounting, process costing).

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discipline, further contributions in that direction are required. Appendix A Appendix A.l List of Symbols a Resource consumption of background activities b Baseline (load-independent) resource consumption of a service % Service (i = 1... m) j Resource (j = 1... n) Pi Resource profile of service i consisting of n values pij Pij Estimate of the expected resource consumption of service i at resource r Pearson product-moment correlation coefficient (r e [1; 1]) t Time (length of a measurement interval) u Load-dependent resource consumption of a service Constant approximation of u x Number of concurrent or subsequent service invocations y Total resource consumption 231 232 A.[2] Test Infrastructure Load Generator Web Server Application Server Database Server Application Vuser scripts and load test scenario static web content (*.html, *.gif, *JPg) *.ear and *.war Oracle tablespace Software and Server Infrastructure LoadRunner 8.0 J RE 1.5.0 Apache http 2.0.54 Bea Weblogic 8.1 JRE 1.[3] .1 Oracle 9.1 Operating Systems Windows 2000 Advanced Server Red Hat Linux Advanced Server 2.1 (Pensacola) Windows 2000 Advanced Server HP-UX 11.11 Number of CPUs 2 2 2 2 CPU Performance [100] MHz 1400 MHz 1000 MHz 440 MHz CPU Type Intel x86 Pentium III Coppermine Intel x86 Xeon MP Intel x86 Pentium III Coppermine PA 8500 CPU Module 2.3 CPU Architecture CISC (32 bit) CISC (32 bit) CISC (32 bit) RISC (64 bit) Disk Storage A.3 Experimental Results: Resource Profiles A.3.1 Resource Profiles A.3.1.1 PASTA Experiment Load test 1 Runtime (test 1) No. of users x No. of services i No. of intervals PA01-1 2006-08-14 22:41:15.0 - 2006-08-14 23:53:12.0 1 h 11 min 57 sec 1 - 20 (20 steps) 2 40 (20 per service) Resource j i P r Application server -

2 * 36,4 GB RAID 1 and 13 GB LUN on SAN (HP XP128) via FC

3 * 73 GB RAID 5

100 Mbps

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compare the CPU times with measurements on other infrastructures, they must be normalized, e.g., by using standard performance benchmarks [SPECa]. These resource profiles provide an overview of the expected resource consumption for different types of user behavior. If historical usage data is available, an average resource profile can be derived. Otherwise, the determined bandwidth of the

is shown in table 2. For comparison we included the resource profile of an edit_user of a simple Servlet- WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 Table 1 Infrastructure used in the experiments Load Generator Web Server Application Server Database Server Pet Store Application petstore.usr Vuser script & load scenario /petstore (static content) petstore.ear Oracle petstore tablespace Software / Server Infrastructure LoadRunner 8.0 JRE 1.5.0 Apache http 2.0.54 Bea Weblogic 8.1 JRE 1.3.1 Oracle 9.1 Operating Systems Windows 2000 Advanced Server Red Hat Linux Advanced Server 2.1 (Pensacola) Windows 2000 Advanced Server HP-UX 11.11 Number of CPUs 2 2 2 2 CPU Performance 1000 MHz 1400 MHz 1000 MHz 440 MHz CPU Type Intel x86 Pentium III Coppermine Intel x86 Xeon MP Intel x86 Pentium III Coppermine PA 8500 CPU Module 2.3 CPU Architecture CISC (32 bit) CISC (32 bit) CISC (32 bit) RISC (64 bit) Disks 3 * 73 GB (RAID 5) 3 * 72 GB (RAID 5) 3 * 18 GB (RAID 5) WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94Table 2 Resource profiles for the Pet Store frontend application and an example application of the BMW Group

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screen 0.001 Web server - Processor - all - Processor Time enter.order-information.screen 0.001 Table A. 18: QN Model Input Parameter: Processors - Services including single Client Requests. Service demands (sd) taken from Experiment PE03-0 248 Column titles in tables A.19 and A.21: Mean processor utilization during interval with a constant number of users QN Model prediction for mean processor utilization during the interval absolute deviation relative deviation I u~,"qn I user Application Server Database Server Web Server u tí lAqn e u Uqn u uqn e u Uqn e 10 0.067 0.079 -0.013 18.8% 0.023 0.011 0.011 50.3% 0.008 0.006 0.002 23.1% 20 0.152 0.159 -0.007 4.5% 0.037 0.022 0.015 40.1% 0.012 0.012 -0.000 1.9% 30 0.231 0.238 -0.007 3.1% 0.040 0.034 0.006 15.2% 0.017 0.018 -0.001 7.3% 40 0.254 0.317 -0.063 24.8% 0.050 0.045 0.005 9.7% 0.020 0.024 -0.003 17.1% 50 0.444 0.397 0.047 10.5% 0.062 0.056 0.005 8.9% 0.025 0.030 -0.005 20.9% 60 0.344 0.475 -0.131 38.2% 0.070 0.067 0.003 4.5% 0.029 0.036 -0.007 25.0% 70 0.550 0.552 -0.001 0.2% 0.082 0.078 0.004 4.8% 0.034 0.042 -0.008 23.2% 80 0.574 0.627 -0.053 9.1% 0.096 0.089 0.008 7.8% 0.038 0.047 -0.009 23.9% 90 0.661 0.700 -0.039 5.8% 0.100 0.099 0.001 1.3% 0.043 0.053 -0.010 23.1% 100 0.819 0.768 0.051 6.3% 0.117 0.109 0.008 6.7% 0.045 0.058 -0.013 27.7% 110 0.809 0.826 -0.017 2.1% 0.131 0.117 0.014 10.7% 0.049 0.062 -0.013 26.7% 120 0.929 0.877 0.052 5.6% 0. 133 0.124 0.009 6.8% 0.053 0.066 -0.013 25.1% 130 0.958 0.908 0.050 5.2% 0.140 0.129 0.012 8.3% 0.056 0.069 -0.013 22.9% 140 0.974 0.934 0.040 4.1% 0.148 0.132 0.016 10.7% 0.056 0.071 -0.014 25.0% 150 0.980 0.948 0.032 3.3% 0.147 0.134 0.013 8.9% 0.057 0.072 -0.014 24.8% 160 0.981 0.961 0.020 2.1% 0.148 0.136 0.012 8.0% 0.057 0.073 -0.015 26.7% 170 0.978 0.966 0.013 1.3% 0.152 0.137 0.016 10.3% 0.057 0.073 -0.016 29.0% 180 0.981 0.973 0.008 0.8% 0.143 0.138 0.005 3.6% 0.058 0.073 -0.015 26.6% Table A. 19: QN Model Validation: Processor

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same manner. After the experiment, the Service Profiler computed the consumption per resource and user profile. Therefore, it first summed up the measurements for each interval with constant number of users (e.g., the CPU times for 10 users, 20 users, and so forth) and then applied a linear regression. We consider the slope of the regression line as average consumption

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PetStore logo). Modifications of the scripts for experiments PE08 and PE09: Services including single client requests require a synchronous fulfillment of the requests. Those kinds of services are not applicable to asynchronous backend applications such as the order processing center in the Java Pet Store example (see section 4.1.2.2). Thus, the asynchronous "order.do" request could not be analyzed during experiment PE08 (script in section A.5.1). Hence, we removed in experiment PE09 this request from the power_shopper

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we used this feature to define the start- and endpoint services. In the example of figure 3 the script replays the behavior of an average shopper in the Java Pet Store (see section 4.2). The whole shopping process is considered as a single service. In the script the service starts with the command lr_start_transaction(" petstore_shopper")

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wanted to emulate unsynchronized service invocations, we omitted the rendezvous points in both scripts. A.5.1 Services including single Client Requests 1 3 include "web.api.h" n 12 ActionO 13 (14 web_reg_find("Text= petstore", LAST); 15 lr_rendezvous("main.screen"); 16 lr_start_transact ion(" main.screen"); 17 18 web_url("main.screen", 19 "URL=(url)/main.screen", 20 " Resource=0", 21 "RecContentType=text/html", 22 "Referer=", 23 "Snapshots1. inf", 24 "Mode=HTTP", 25 LAST); 26 27 (... pictures ...) 28 29 lr_end_ transaction("main.screen", LR_AUT0); 30 31 lr_think_time(7); 32 33 web_reg_ find("Text=petstore", LAST); 34 lr_rendezvous("signon_welcome.screen"); 35 lr_start_transaction("signon_

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database server. Within the context of the BMW Group we evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", " RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/ petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/ html", "Referer=(

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html", 22 "Referer=", 23 "Snapshots1.inf", 24 "Mode=HTTP", 25 LAST); 26 27 (... pictures ...) 28 29 lr_end_transaction("main.screen", LR_AUT0); 30 31 lr_think_time(7); 32 33 web_reg_find("Text=petstore", LAST); 34 lr_ rendezvous("signon_welcome.screen"); 35 lr_start_transaction("signon_ welcome.screen"); 36 37 web_url("Sign in", 38 "URL=-Curl)/signon_welcome. screen", 39 "Resource=0", 40 "RecContentType=text/html", 41 "Referer=(url)/ main.screen", 42 "Snapshot=t2.inf", 43 "Mode=HTTP", 44 LAST); 45 46 (... pictures ...) 47 48 lr_end_transaction("signon_welcome.screen", LR_AUT0); 49 50 lr_think_time(7); 51 52 web_reg_find("Text=petstore", LAST); 53 lr_ rendezvous("j_signon_check"); 54 lr_start_transaction("j_signon_check"); 55 56 web_submit_data("j_signon_check", 57 "Action=(url)/j_signon_check", 58 " Method=P0ST", 59 "RecContentType=text/html", 60 "Referer=(url)/signon_ welcome.screen", 61 "Snapshot=t3.inf", 62 "Mode=HTTP", 63 ITEMDATA, 64 " Name=j_username", "Value=(user)", ENDITEM, 65 "Name=j_password", " Value=(password)", ENDITEM, 66 "Name=submit", "Value=Sign In", ENDITEM, 67 LAST); 68 69 (... pictures ...) 70 71 lr_end_transaction("j_ signon_check", LR_AUT0); 72 73 lr_think_time(7); 74 75 web_reg_find("Text= petstore", LAST); 76 lr_rendezvous("customer.do"); 77 lr_start_transaction(" customer.do"); 78 79 web_url("Account", 80 "URL=(url)/customer.do", 81 " Resource=0", 82 "RecContentType=text/html", 83 "Referer=(url)/signon_ welcome.screen", 252 84 "Snapshot=t4.inf", 85 "Mode=HTTP", 86 LAST); 87 88 (... pictures . ..) 89 90 lr_end_transaction("customer.do", LR.AUTO); 91 92 lr_think_time(7); 93 94 web_reg_find("Text=petstore", LAST); 95 lr. rendezvous("update.customer.screen"); 96 lr_start_transaction("update_ customer.screen"); 97 98 web_url("Edit Your Account Information", 99 "URL= (url)-/update_customer .screen", 100 "Resource=0", 101 "RecContentType= text/htmr', 102 "

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Group we evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction(" petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot= t60.inf", "Mode=HTTP", ITEMDATA, "Name=keywords", "Value= ExampleSearch1", ENDITEM, LAST); (".) lr_end_transaction("petstore _ shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner script Cost Accounting for Shared IT Infrastructures 87

RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/ petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/ html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.inf", "Mode=HTTP", ITEMDATA, "Name=keywords", "Value=ExampleSearch1", ENDITEM, LAST) ; (".) lr_end_transaction("petstore _shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner script Cost Accounting for Shared IT Infrastructures 87 business applications.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _ shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", " Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot= t60.inf", "Mode=HTTP", ITEMDATA, "Name=keywords", "Value= ExampleSearch1", ENDITEM, LAST); (".) lr_end_transaction("petstore _ shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner script Cost Accounting for Shared IT Infrastructures 87

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Referer=(url)/customer.do", 103 "Snapshot=t5.inf", 104 "Mode=HTTP", 105 LAST); 106 107 (... pictures ...) 108 109 lr_end_transaction("update_customer. screen", LR_AUT0); 110 111 lr_think_time(7); 112 113 web_reg_find("Text= petstore", LAST); 114 lr_rendezvous("customer.do_updated"); 115 lr.start. transaction("customer.do_updated"); 116 117 web_submit_data("customer.do", 118 "Action=(url)7 customer.do", 119 "Method=PQST", 120 " RecContentType=text/html", 121 "Referer=(url)/update_customer.screen", 122 "Snapshot=t6.inf", 123 "Mode=HTTP", 124 ITEMDATA, 125 "Name=action", "Value=update", ENDITEM, 126 "Name=given_name.a", "Value=XYZ", ENDITEM, 127 "Name=family_name_a", "Value=ABC", ENDITEM, 128 " Name=address_l_a", "Value=1234 Anywhere Street", ENDITEM, 129 "Name= address_2_a", "Value=Unit 555", ENDITEM, 130 "Name=city_a", "Value= Palo Alto", ENDITEM, 131 "Name=state_or_province_a", "Value=California", ENDITEM, 132 "Name=postal code.a", "Value=94303", ENDITEM, 133 " Name=country_a", "Value=USA", ENDITEM, 134 "Name=telephone_number_ a", "Value=555-16-48", ENDITEM, 135 "Name=email_a", "Value=reinhard. ba.brandiabmw.de", ENDITEM, 136 "Name=credit_card_number", "Value= 123456789", ENDITEM, 137 "Name=credit_card_type", "Value=California", ENDITEM, 138 "Name=credit_card_expiry_month", "Value=01", ENDITEM, 139 "Name=credit card_expiry_year", "Value=01", ENDITEM, 140 "Name= language", "Value=en_US", ENDITEM, 141 "Name=favorite.category", " Value=REPTILES", ENDITEM, 142 "Name=mylist_on", "Value=on", ENDITEM, 143 "Name=banners_on", "Value=on", ENDITEM, 144 LAST); 145 146 (... pictures ...) 147 148 lr_end_transaction("customer.do_updated", LR.AUTO); 149 150 lr_think_time(7); 151 152 web_reg_find("Text=petstore", LAST); 153 lr_rendezvous("search.screen"); 154 lr_start_transaction("search. screen"); 155 156 web_submit_data("search.screen", 157 11 Action=(url)/ search. screen", 158 "Method=GET", 159 "EncType=", 160 "RecContentType= text/html", 161 "Referer=(url)/customer.do", 162 "Snapshot=t16.inf", 163 "Mode= HTTP", 164 ITEMDATA, 165 "Name=keywords", "Value=Test(zufall)", ENDITEM, 166 LAST); 167 168 (... pictures ...) 169 170 lr_end_transaction(" search.screen", LR_AUT0); 171 172 lr_think_time(7); 173 174 web_reg_find("Text=petstore", LAST); 175 lr_rendezvous("category.screen"); 176 lr_start_ transaction("category.screen"); 177 178 web_url("Birds", 179 "URL=(url)/ category.screen?category_id=BIRDS", 180 "Resource=0", 181 " RecContentType=text/html", 182 "Referer=(url>/search.screen", 183 "

● 7% Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous(" petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main. screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType= text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_ time(12); web_submit_data("search.screen", "Action=(url)/petstore/search. screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer= (url)/petstore/main.screen", "Snapshot=t60.inf", "Mode=HTTP", ITEMDATA, "Name=keywords", "Value=ExampleSearch1", ENDITEM, LAST); (".) lr_end_ transaction("petstore _shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner script Cost Accounting for Shared IT Infrastructures 87 business applications.

transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/ main.screen", "Resource=0", "RecContentType=text/html", "Referer=", " Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_ data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", " EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen" , "Snapshot=t60.inf", "Mode=HTTP", ITEMDATA, "Name=keywords", " Value=ExampleSearch1", ENDITEM, LAST); (".) lr_end_transaction(" petstore _shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner script Cost Accounting for Shared IT Infrastructures 87 business applications. As example

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _ shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", " Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(url)/petstore/main.screen", "

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

Textstelle (Prüfdokument) S. 253

Snapshot=t7.inf", 184 "Mode=HTTP", 185 LAST); 186 187 (... pictures ...) 188 189 lr_end_transaction("category.screen", LR.AUTO); 190 191 lr_think_time(7); 192 193 web_reg_find("Text=petstore", LAST); 194 lr.rendezvous(" product.screen"); 195 lr_start_transaction("product.screen"); 196 197 web.urK" Amazon Parrot", 198 "URL=-[url)/product. screen?product_id=AV-CB-01" , 199 "Resource=0", 200 "RecContentType=text/html", 201 "Referer=(url>/ category.screen?category_id=BIRDS", 202 "Snapshot=t8.inf", 203 "Hode=HTTP" , 204 LAST); 205 206 (... pictures ...) 207 208 lr_end_transaction("product. screen", LR_AUT0); 209 210 lr_think_time(7); 211 212 web_reg_find("Text= petstore", LAST); 213 lr_rendezvous("item.screen"); 214 lr_start_transaction(" item.screen"); 215 216 "

● **0%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

Snapshot=t60.inf", "Mode=HTTP", ITEMDATA, "Name=keywords", "Value= ExampleSearch1", ENDITEM, LAST); (".) lr_end_transaction("petstore _ shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner script Cost Accounting

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _ shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", " Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(

• **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

Textstelle (Prüfdokument) S. 253

lr_end_transaction("product.screen", LR_AUT0); 209 210 lr_think_time(7); 211 212 web_reg_find("Text=petstore", LAST); 213 lr_rendezvous("item. screen"); 214 lr_start_transaction("item.screen"); 215 216 "eb_url("Adult Male Amazon Parrot", 217 "URL=(url)/item.screen?item_id=EST-18", 218 " Resource=0", 219 "RecContentType=text/html", 220 "Referer=(url)/product. screen?product_id=AV-CB-01", 221 "Snapshot=t9.inf", 222 "Mode=HTTP", 223 LAST); 224 225 (... pictures ...) 226 227 lr_end_transaction("item.screen", LR_AUT0); 228 229 lr_think_time(7); 230 231 web_reg_find("Text=petstore", LAST); 232 lr_rendezvous("cart.do"); 233 lr_start_transaction("cart.do"); 234 235 web_url("Add to Cart", 236 "URL=(url)/cart.do?action=purchase&itemId= EST-18", 237 "Resource=0", 238 "RecContentType=text/html", 239 "Ref erer= (url)/item. screen?item_id=EST-18", 240 "Snapshot=tlO.inf", 241 "Mode=HTTP" , 242 LAST); 243 244 (... pictures ...) 245 APPENDLXA. APPENDIX [254] 246 lr_end_transaction("cart.do", LR_AUTO); 247 248 lr_think_time([7]); 249 250 web_reg_find("Text=petstore", LAST); 251 lr_rendezvous("cart.do_update"); 252 lr_start_transaction("cart.do_update"); 253 17 web_url("main.screen", 18 " URL=(url)/petstore/main.screen", 19 "Resource=0", 20 "RecContentType=text/ html", 21 "Referer=", 22 "Snapshot=t59.inf", 23 "Mode=HTTP", 24 LAST); 25 26 (... pictures ...) 27 28 lr_think_time(1); 29 30 web_submit_data("search. screen", 31 "Action=(url)/petstore/search.screen", 32 "Hethod=GET", 33 " EncType=", 34 "RecContentType=text/html", 35 "Referer=(url]7petstore/main. screen", 36 "Snapshot=t[60] .inf", 37 "Mode=HTTP", 38 ITEMDATA, 39 "Name= keywords", "Value=iguna", ENDITEM, 40 LAST); 41 42 (... pictures ...) 43 44 lr_think_time(1); 45 46 web.submit_data("search.screen_2", 47 "Action=(url)/ petstore/search.screen", 48 "Method=GET", 49 "EncType=", 50 " RecContentType=text/html", 51 "Referer=(url)/petstore/search.screen? keywords=iguna", 52 "Snapshot=t61.inf", 53 "Mode=HTTP", 54 ITEMDATA, 55 "Name=keywords", "Value=reptile", ENDITEM, 56 LAST); 57 58 (... pictures ...) 59 256 98 "Name=itemQuantity_EST-ll", "Value=(Zufallszahl)", ENDITEM, 99 LAST); 100 101 (... pictures ...) 102 103 lr_think_time(1); 104 105 ueb_url("Birds", 106 "URL=(url)/petstore/category.screen?

● **14%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _ shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", " Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot= t60.

database server. Within the context of the BMW Group we evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", " RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/ petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/ html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.inf", "Mode=HTTP", ITEMDATA, "Name=keywords", "Value=ExampleSearch1", ENDITEM, LAST) ; (".) lr_end_transaction("petstore _shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner script Cost Accounting for Shared IT Infrastructures 87 business applications. As example

shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", " URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", " Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/ petstore/main.screen", "Snapshot=t60.inf", "Mode=HTTP", ITEMDATA, "Name= keywords", "Value=ExampleSearch1", ENDITEM, LAST); (".) lr_end_ transaction("petstore _shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner script Cost Accounting for Shared IT Infrastructures 87 business applications. As example

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007)

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

Textstelle (Prüfdokument) S. 256

category_id=BIRDS", 107 "Resource=0", 108 "RecContentType=text/html", 109 "Referer=(url)/petstore/cart.do?action=update&itemQuantity_EST-ll=l", 110 "Snapshot=t65.inf", 111 "Mode=HTTP", 112 LAST); 113 114 (... pictures ...) 115 116 lr_think_time(1); 117 118 web_url("Finch", 119 "URL=(url)/petstore/product. screen?product_id=AV-SB-02", 120 "Resource=0", 121 "RecContentType=text/html", 122 "Referer=(url)/petstore/category.screen?category_id=BIRDS", 123 "Snapshot=t66.inf", 124 "Mode=HTTP", 125 LAST); 126 127 (... pictures ...) 128 129 lr_think_time(1); 130 131 web_url("Adult Male Finch", 132 "URL=(url)/petstore/item.screen?item_id=EST-19", 133 "Resource=0", 134 "RecContentType=text/html", 135 "Ref erer=-[url)/petstore/product. screen?product_id=AV-SB-02" , 136 "Snapshot=t67.inf", 137 "Mode=HTTP", 138 LAST); 139 140 (... pictures ...) 141 142 lr_think_time(1); 143 144 web_url("Add to Cart_2", 145 "URL=(url)/petstore/cart.do?action=purchase&itemId=EST-19", 146 "Resource=0", 147 "RecContentType=text/html", 148 "Referer=(url)/petstore/item.screen?item_id=EST-19", 149 "Snapshot=t68.inf", 150 "Mode=HTTP", 151 LAST); 152 153 (... pictures ...) 154 155 lr_think_time(1); 156 157 web_submit_data("cart.do_2", 158 "Action=-f.url)/petstore/cart .do", 159 "Method=GET", 160 "EncType=", 161 "RecContentType=text/html", 162 "Referer=(url)/petstore/cart.do?action=purchase&itemId=EST-19", 163 "Snapshot=t69.inf", 164 "Mode=HTTP", 165 ITEMDATA, 166 "Name=action", "Value=update", ENDITEM, 167 "Name=itemQuantity_EST-ll", "Value=(Zufallszahl)", ENDITEM, 168 "Name=itemQuantity EST-19", "Value=(Zufallszahl)", ENDITEM, 169 LAST); 170 171 (... pictures ...) 172 173 lr_think_time(1); 174 175 web_url("Fish", 176 "URL=(url)/petstore/category.screen?

● **8%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.

custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.inf", "Mode=HTTP", ITEMDATA, "Name=keywords", "Value=ExampleSearch1", ENDITEM, LAST); (".) lr_end_transaction("petstore _

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

Textstelle (Prüfdokument) S. 256

category_id=FISH", 177 "Resource=0", 178 "RecContentType=text/html", 179 "Referer=(url)/petstore/cart.do?action=update&itemQuantity_EST-ll 180 =l& itemQuantity_EST-19=l", 181 "Snapshot=t70.inf", 182 "Mode=HTTP", 183 LAST); 184 185 (... pictures ...) 186 187 lr_think_time(1); 188 189 web_url(" Goldfish", 190 "URL=(url)/petstore/product.screen?product_id=FI-FW-02", 191 "Resource=0", 192 "RecContentType=text/html", 193 "Ref erer=(url)/ petstore/category. screen?category_id=FISH", 194 "Snapshot=t71.inf", 195 " Mode=HTTP", 196 LAST); 197 198 (... pictures ...) 199 200 lr_think_time(1); 201 202 web_url("Adult Male Goldfish", 203 "URL=(url>/petstore/item. screen?item_id=EST-20", 204 "Resource=0", 205 "RecContentType=text/html" , 206 "Referer=(url)/petstore/product.screen?product_id=FI-FW-02", 207 " Snapshot=t72.inf", 208 "Mode=HTTP", 209 LAST); 210 211 (... pictures ...) 212 213 lr_think_time(1); 214 215 web_url("Fish_2", 216 "URL=(url)/ petstore/category.screen?category_id=FISH", 217 "Resource=0", 218 " RecContentType=text/html", 219 "Referer=(url)/petstore/item.screen?item_id= EST-20", 220 "Snapshot=t73.inf", 221 "Mode=HTTP", 222 LAST); 223 224 (... pictures ...) 225 226 lr_think_time(1); 227 228 web_url("Goldfish_2", 229 " URL=(url)/petstore/product.screen?product_

● **5%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner script Cost Accounting for Shared IT Infrastructures 87 business applications.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _ shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", " Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot= t60.

custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous(" petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main. screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType= text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_ time(12); web_submit_data("search.screen", "Action=(url)/petstore/search. screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer= (url)/petstore/main.screen", "Snapshot=t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _ shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", " Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot= t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _ shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", " Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

Textstelle (Prüfdokument) S. 257

id=FI-FW-02", 230 "Resource=0", 231 "RecContentType=text/html", 232 " Referer=(url)/petstore/category.screen?category_id=FISH", 233 "Snapshot=t74. inf", 234 "Mode=HTTP", 235 LAST); 236 237 (... pictures ...) 238 239 lr_ think_time(1); 240 241 web_url("Adult Female Goldfish", 242 "URL=(url)/ petstore/item.screen?item_id=EST-21", 243 "Resource=0", 244 " RecContentType=text/html", 245 "Referer=(url)/petstore/product.screen? product_id=FI-FW-02", 246 "Snapshot=t75.inf", 247 "Mode=HTTP", 248 LAST) ; 249 250 (... pictures ...) 251 252 lr_think_time(1); 253 254 web_url("Add to Cart_3", 255 "URL=(url)/petstore/cart.do?action=purchase&itemId=EST-21", 256 "Resource=0", 257 "RecContentType=text/html", 258 "Referer=(url)/ petstore/item.screen?item_id=EST-21", 259 "Snapshot=t76.inf", 258 260 "Mode= HTTP", 261 LAST); 262 263 (... pictures ...) 264 265 lr_think_time(1); 266 267 web_submit_data("cart.do_3", 268 "Action=(url)/petstore/cart.do", 269 " Method=GET", 270 "EncType=", 271 "RecContentType=text/html", 272 " Referer=(url)/petstore/cart.do?action=purchase&itemId=EST-21", 273 " Snapshot=t77.inf", 274 "Mode=HTTP", 275 ITEMDATA, 276 "Name=action", "Value=update", ENDITEM, 277 "Name=itemQuantity_EST-ll", "Value=(Zufallszahl)", ENDITEM, 278 "Name=itemQuantity_EST-21", "Value=(Zufallszahl)", ENDITEM, 279 "Name=itemQuantity_EST-19", "Value=(Zufallszahl)", ENDITEM, 280 LAST); 281 282 283 (... pictures ...) 284 285 lr_ think_time(1); 286 287 web_url("Bulldog", 288 "URL=(url)/petstore/product. screen?

● **7%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot= t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _ shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", " Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot= t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _ shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", " Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot= t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _ shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", " Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot= t60.inf", "Mode=HTTP", ITEMDATA, "Name=keywords", "Value= ExampleSearch1", ENDITEM, LAST); (".) lr_end_transaction("petstore _ shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner script Cost Accounting for Shared IT Infrastructures 87 business applications.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

Textstelle (Prüfdokument) S. 258

product_id=K9-BD-01", 289 "Resource=0", 290 "RecContentType=text/html", 291 "Referer=(url)/petstore/category.screen?category_id=DOGS", 292 "Snapshot=t79.inf", 293 "Mode=HTTP", 294 LAST); 295 296 (... pictures ...) 297 298 lr_think_time(1); 299 300 web_url("Male Adult Bulldog", 301 "URL=(url)/petstore/item.screen?item_id=EST-6", 302 "Resource=0", 303 "RecContentType=text/html", 304 "Referer=(url)/petstore/product.screen?product_id=K9-BD-01", 305 "Snapshot=t80.inf", 306 "Mode=HTTP", 307 LAST); 308 309 (... pictures ...) 310 311 lr_think_time(1); 312 313 web_url("Add to Cart_4", 314 "URL=(url)/petstore/cart.do?action=purchase&itemId=EST-6", 315 "Resource=0", 316 "RecContentType=text/html", 317 "Ref erer=(url)/petstore/item.screen?item_id=EST-6", 318 "Snapshot=t81.inf", 319 "Mode=HTTP", 320 LAST); 321 322 (... pictures ...) 323 324 lr_think_time(1); 325 326 web_submit_data("cart.do_4", 327 "Action=(url)/petstore/cart.do", 328 "Method=GET", 329 "EncType=", 330 "RecContentType=text/html", 331 "Referer=(url)/petstore/cart.do?action=purchase&itemId=EST-6", 332 "Snapshot=t82.inf", 333 "Mode=HTTP", 334 ITEMDATA, 335 "Name=action", "Value=update", ENDITEM, 336 "Name=itemQuantity_EST-ll", "Value=(Zufallszahl)", ENDITEM, 337 "Name=itemQuantity_EST-21", "Value=(Zufallszahl)", ENDITEM, 338 "Name=itemQuantity_EST-19", "Value=(Zufallszahl)", ENDITEM, 339 "Name=itemQuantity_EST-6", "Value=(Zufallszahl)", ENDITEM, 340 LAST); 341 342 (... pictures ...) 343 344 lr_think_time(1); 345 346 web_url("Reptiles", 347 "URL=(url)7petstore/category.screen?category_id=REPTILES", 348 "Resource=0", 349 "RecContentType=text/html", 350 "Referer=(url)/petstore/cart.do?action=updatefcitemQuantity_EST-ll 351 =l&itemQuantity_EST-21=lltitemQuantity_EST-19=l& 352 itemQuantity_EST-6=l", 353 "Snapshot=t83.inf", 354 "Mode=HTTP", 355 LAST); 356 357 (... pictures ...) 358 359 lr_think_time(1); 360 361 web.url("Iguana", 362 "URL=(url)/petstore/product.

● **8%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.

custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.inf", "Mode=HTTP", ITEMDATA, "Name=keywords", "Value=ExampleSearch1", ENDITEM, LAST); (".) lr_end_transaction("petstore _shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner script Cost Accounting for Shared IT Infrastructures 87 business applications.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

Textstelle (Prüfdokument) S. 259

screen?product_id=RP-LI-02", 363 "Resource=0", 364 "RecContentType=text/html", 365 "Referer=(url)/petstore/category.screen?category_id=REPTILES", 366 "Snapshot=t84.inf", 367 "Mode=HTTP", 368 LAST); 369 370 (... pictures ...) 371 372 lr_think_time(1); 373 374 web_url("Green Adult Iguana", 375 "URL=(url)/petstore/item.screen?item_id=EST-13", 376 "Resource=0", 377 "RecContentType=text/html", 378 "Referer=(url)/petstore/product.screen?product_id=RP-LI-02", 379 "Snapshot=t85.inf", 380 "Mode=HTTP", 381 LAST); 382 383 (... pictures ...) 384 385 lr_think_time(1); 386 387 web_url("Add to Cart_5", 388 "URL=(url)/petstore/cart .do?action=purchase&itemId=EST-13", 389 "Resource=0", 390 "RecContentType=text/html", 391 "Referer=(url)/petstore/item.screen?item_id=EST-13", 392 "Snapshot=t86.inf", 393 "Mode=HTTP", 394 LAST); 395 396 (... pictures ...) 397 398 lr_think_time(1); 399 400 web_ur1("Cat s", 401 "URL=(url)/petstore/category.screen?category_id=CATS", 402 "Resource=0", 403 "RecContentType=text/html", 404 "Referer=(url)/petstore/cart.do?action=purchasefeitemId=EST-13", 405 "Snapshot=t87.inf", 406 "Mode=HTTP", 407 LAST); 408 409 (... pictures ...) 410 411 lr_think_time(1); 412 413 ueb.url("Persian", 414 "URL=(url)7petstore/product.screen?product_

● **5%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.

we evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen",

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

Textstelle (Prüfdokument) S. 259

id=FL-DLH-02" , 415 "Resource=0", 416 "RecContentType=text/html", 417 " Referer=(url)/petstore/category.screen?category_id=CATS", 418 "Snapshot= t88.inf", 419 "Mode=HTTP", 420 LAST); 421 260 422 (.. pictures ...) 423 424 lr_think_time(1); 425 426 web_url("Adult Male Persian", 427 "URL=(url)/ petstore/item.screen?item_id=EST-17", 428 "Resource=0", 429 " RecContentType"=text/html", 430 "Referer=(url)/petstore/product.screen? product_id=FL-DLH-02", 431 "Snapshot=t89.inf", 432 "Mode=HTTP", 433 LAST); 434 435 (... pictures ...) 436 437 lr_think_time(1); 438 439 web_url(" Cats_2", 440 "URL=(url)/petstore/category.screen?category_id=CATS", 441 " Resource=0", 442 "RecContentType=text/html", 443 "Referer=(url)/petstore/ item.screen?item_id=EST-17", 444 "Snapshot=t90.inf", 445 "Mode=HTTP", 446 LAST); 447 448 (... pictures ...) 449 450 lr_think_time(1); 451 452 web_ url("Manx", 453 "URL=(url)/petstore/product.screen?product_id=FL-DSH-01", 454 "Resource=0", 455 "RecContentType=text/html", 456 "Referer=(url)/ petstore/category.screen?category_id=CATS", 457 "Snapshot=t91.

6% Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

"Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot= t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _ shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", " Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot= t60.

we evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction(" petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot= t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _ shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", " Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot= t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _ shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", " Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " _

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

Textstelle (Prüfdokument) S. 260

inf", 458 "Mode=HTTP", 459 LAST); 460 461 (... pictures ...) 462 463 lr_think_time(1); 464 465 web_url("Tailless Manx", 466 "URL=(url)/petstore/item.screen?item_id=EST-14", 467 "Resource=0", 468 "RecContentType=text/html", 469 "Referer=(url>/petstore/product.screen?product_id=FL-DSH-01", 470 "Snapshot=t92.inf", 471 "Mode=HTTP", 472 LAST); 473 474 (... pictures ...) 475 476 lr_think_time(1); 477 478 web_url("Cats_3", 479 "URL=(url)/petstore/category.screen?category_id=CATS", 480 "Resource=0", 481 "RecContentType=text/html", 482 "Referer=(url)/petstore/item.screen?item_id=EST-14", 483 "Snapshot=t93.inf", 484 "Mode=HTTP", 485 LAST); 486 487 (... pictures ...) 488 489 lr_think_time(1); 490 491 web_url("Persian_2", 492 "URL=(url)/petstore/product.screen?product_id=FL-DLH-02", 493 "Resource=0", 494 "RecContentType=text/html", 495 "Referer=(url)/petstore/category.screen?category_id=CATS", 496 "Snapshot=t94.inf", 497 "Mode=HTTP", 498 LAST); 499 500 501 (... pictures ...) 502 503 lr_think_time(1); 504 505 web_url("Add to Cart_6", 506 "URL=(url)/petstore/cart.do?action=

● **4%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "

• 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

Textstelle (Prüfdokument) S. 261

purchase&itemId=EST-17", 507 "Resource=0", 508 "RecContentType=text/html", 509 "Referer=(url)/petstore/item.screen?item_id=EST-17", 510 "Snapshot=t96.inf", 511 "Mode=HTTP", 512 LAST); 513 514 (... pictures ...) 515 516 lr_think_time(1); 517 518 web_submit_data("cart.do_5", 519 "Action=(url)/petstore/cart.do", 520 "Method=GET", 521 "EncType=", 522 "RecContentType=text/html", 523 "Referer=(url)/petstore/cart.do?action=purchase&itemId=EST-17", 524 "Snapshot=t97.inf", 525 "Mode=HTTP", 526 ITEMDATA, 527 "Name=action", "Value=update", ENDITEM, 528 "Name=itemQuantity_EST-ll", "Value=(Zufallszahl)", ENDITEM, 529 "Name=itemquantity_EST-21", "Value=(Zufallszahl)", ENDITEM, 530 "Name=itemQuantity_EST-19", "Value=(Zufallszahl)", ENDITEM, 531 "Name=itemQuantity EST-17", "Value=(Zufallszahl)", ENDITEM, 532 "Name=itemQuantity_EST-13", "Value=(Zufallszahl)", ENDITEM, 533 "Name=itemQuantity_EST-6", "Value=(Zufallszahl)", ENDITEM, 534 LAST); 535 536 (... pictures ...) 537 538 lr_think_time(1); 539 540 web_url("Check Out", 541 "URL=(url)/petstore/enter_order_information.screen", 542 "Resource=0", 543 "RecContentType=text/html", 544 "Referer=(url)/petstore/cart.do?action=update&itemQuantity_EST-ll 545 =l&itemQuantity_EST-21=lfeitemQuantity_EST-19 546 =l&itemQuantity_EST-17=l&itemQuantity_EST-13 547 =l&itemQuantity_EST-6=l", 548 "Snapshot=t98.inf", 549 "Mode=HTTP", 550 LAST); 551 552 (... pictures ...) 553 554 lr_think_time(1); 555 556 web_submit_data("j_sienon_check", 557 "Action=(url)/petstore/j_signon_check", 558 "Method=POST", 559 "RecContentType=text/html", 560 "Referer=(url)/petstore/enter_order_information.screen", 561 "Snapshot=t99.inf", 562 "Mode=HTTP", 563 ITEMDATA, 564 "Name=j_username", "Value=(user)", ENDITEM, 565 "Name=j_password", "Value=(password)", ENDITEM, 566 "Name=submit", "Value=Sign In", ENDITEM, 567 LAST); 568 569 (... pictures ...) 570 571 lr_think_time(1); 572 573 web_submit_data("order.do", 574 "Action=(url)/petstore/order.do", 575 "Method=POST", 576 "RecContentType=text/html", 577 "Referer=(url)/petstore/enter_order_information.screen", 578 "Snapshot=t100.inf", 579 "Mode=HTTP", 580 ITEMDATA, 581 "Name=given_name_a", "Value=XYZ", ENDITEM, 582 "Name=family_name_a", "Value=ABC", ENDITEM, 583 "Name=address_l_a", "Value=1234 Anywhere Street", ENDITEM, 262 584 "Name=address_2_a", "Value=Unit 555", ENDITEM, 585 "Name=city_a", "Value=Palo Alto", ENDITEM, 586 "Name=state_or_province_a", "Value=California", ENDITEM, 587 "Name=postal_code_a", "

● **12%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.inf", "Mode=HTTP", ITEMDATA, "Name=keywords", "Value=ExampleSearch1", ENDITEM, LAST); (".) lr_end_transaction("petstore _shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner script Cost Accounting for Shared IT Infrastructures 87 business applications.

Group we evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.inf", "Mode=HTTP", ITEMDATA, "Name=keywords", "Value=ExampleSearch1", ENDITEM, LAST); (".) lr_end_transaction("petstore _shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner script Cost Accounting for Shared IT Infrastructures 87 business applications.

shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", "RecContentType=text/html", "Referer=(url)/petstore/main.screen", "Snapshot=t60.inf", "Mode=HTTP", ITEMDATA, "Name=

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

Textstelle (Prüfdokument) S. 262

Value=94303", ENDITEM, 588 "Name=country_a", "Value=California", ENDITEM, 589 "Name=telephone_number_a", "Value=555-(Zufallszahl)-48", ENDITEM, 590 "Name=email a", "Value=reinhard.ba.brandl9bmw.de", ENDITEM, 591 "Name=given name b", "Value=XYZ", ENDITEM, 592 "Name= family_name_b", "Value=ABC", ENDITEM, 593 "Name=address_1_b", " Value=1234 Anywhere Street", ENDITEM, 594 "Name=address_2_b", "Value= Unit 555", ENDITEM, 595 "Name=city_b" "Value=Palo Alto", ENDITEM, 596 "Name=state_or_province_b", "Value=California", ENDITEM, 597 "Name= postal_code_b", "Value=94303", ENDITEM, 598 "Name=country_b", "Value= California", ENDITEM, 599 "Name=telephone_number_b", "Value=555-(Zufallszahl)-48", ENDITEM, 600 "Name=email_b", "Value=reinhard.ba. brandiabmw.de", ENDITEM, 601 LAST); 602 603 (... pictures ...) 604 605 lr_ think_time(1); 606 607 web_url("Sign out", 608 "URL=(url)/petstore/signoff. do", 609 "Resource=0", 610 "RecContentType=text/html", 611 "Referer=(url)/ petstore/order.do", 612 "Snapshot=tl01.infl1, 613 "Mode=HTTP", 614 LAST); 615 616 (... pictures ...) 617 618 lr_think_time(1); 619 620 web_ur1("Java Pet Store Demo logo", 621 "URL=(url)/petstore/main.screen", 622 "Resource= 0", 623 "RecContentType=text/html", 624 "Referer=(url)/petstore/signoff.do", 625 "Snapshot=tl02.inf", 626 "Mode=HTTP", 627 LAST); 628 629 (... pictures ...) 630 631 lr_end_transaction("power_shopper", LR_AUTD); 632 633 web_cleanup_cookies(); 634 web_cache_cleanup(); 635 636 lr_think_time(15); 637 638 return 0; 639) 640 641 PFT1(4)4 Experiments: Resource

254 web_submit_data("cart.do",

7 return 0;

60 lr_think_time(1);

● **0%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

keywords", "Value=ExampleSearch1", ENDITEM, LAST); (".) lr_end_ transaction("petstore _shopper", LR_AUTO); Figure 3 Excerpt from a LoadRunner script Cost Accounting for Shared IT Infrastructures 87 business applications.

evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_shopper"); lr_start_transaction("petstore _ shopper"); web_url("main.screen", "URL=(url)/petstore/main.screen", " Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", " Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", "Method=GET", "EncType=", " RecContentType=text/html", "Referer=(

context of the BMW Group we evaluated the approach with custom WIRTSCHAFTSINFORMATIK 49 (2007) 2, S. 83 94 lr_rendezvous("petstore_ shopper"); lr_start_transaction("petstore _shopper"); web_url("main.screen", " URL=(url)/petstore/main.screen", "Resource=0", "RecContentType=text/html", "Referer=", "Snapshot=t59.inf", "Mode=HTTP", LAST); lr_think_time(12); web_submit_data("search.screen", "Action=(url)/petstore/search.screen", " Method=GET", "EncType=", "RecContentType=text/html", "Referer=(

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

Textstelle (Prüfdokument) S. 262

its bottleneck. Then it is restarted with the second service. the load test the log data of the performance monitors and of the load [1] tests tools are correlated. For the data analysis it is assumed, first, that

1 user

Textstelle (Originalquellen)

new software release. Bymeans of the load generator, we then simulated consecutive service invocations, while the performance monitors recorded the system s utilization in log files. After the load test, the Service Profiler parses the different log files and consolidates them, together with the results from the load generator, in a database. It then correlates start and

- 1 Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. 2

2% Einzelplagiatswahrscheinlichkeit

Textstelle (Prüfdokument) S. 262

Textstelle (Originalquellen)

including multiple Client Requests Requests

0% Einzelplagiatswahrscheinlichkeit

Textstelle (Prüfdokument) S. 38

Requests of the application server, the database server and confirm the conclusions drawn in the previous section. The analysis of load test measurements provided no indications of

0% Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

Mbps [2] Fibre Channel [2] Memory 2 GB 2 GB 2 GB 2 GB [2] Server Type HP DL360 IBM X360-03 HP DL360 HP N4000 [2] Network Name xxxxxx20 xxxxxx03d xxxxxx15 xxxxxx01a [2] 88 Reinhard Brandl, Martin Bichler, Michael Ströbel [1] 1 [1] CPU Utilization of the Application Server [1] (Measured by theW2K Performance Monitor) [1] Starts and stops of virtual users [1] (extracted from the LoadRunner log files) [1] Figure 4 Determination of the resource profile for a Pet

Network Models. The interplay between the different software components is depicted in figure 5. 5.3 The Java Pet Store Example (Continued) In the load test setup, presented in the previous section, the number of users remains constant during certain time intervals. Therefore, we model the infrastructure as closed QN and compute for each interval separate results. Furthermore,

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [
- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S.

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RAID 5 HP XP128) via FC

● **2%** Einzelplagiatswahrscheinlichkeit

Textstelle (Originalquellen)

Business processs [1] Services [1] Customer [2] 2 [2] Customer [3] 3 [3] Customer [3] 4 [3] Customer [5] 5 [5] IT cost centres / units [5] Figure 2 Cost allocation using resources profiles [5] 86 Reinhard Brandl, Martin Bichler, Michael Ströbel [2] 2 * 36,4 GB [2] (RAID 1) [2] 13 GB LUN on SAN [2] (HP XP128) via FC [2] Network 100 Mbps 100 Mbps / 1Gbit 100 Mbps 100 Mbps [2] Fibre Channel [2] Memory 2 GB 2 GB 2 GB 2 GB [2] Server Type HP DL360 IBM X360-03 HP DL360 HP N4000 [2] Network Name xxxxxx20 xxxxxx03d xxxxxx15 xxxxxx01a [2] 88 Reinhard Brandl,

- **1** Brandl, Reinhard: /Bichler, Martin/Ströbel, Michael: ..., 2007, S. #P12#Ströbel [

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Glossar

- Ampel — Entsprechend der Gesamtwahrscheinlichkeit wird ein Rating der Schwere durch die Ampelfarbe berechnet: grün (bis 19 %) = wenige Indizien unterhalb der Bagatellschwelle; gelb (20 bis 49 %) - deutliche Indizien enthalten, die eine Plagiatsbegutachtung durch den Prüfer notwendig machen; rot (ab 50 %) = Plagiate liegen mit sehr hoher Wahrscheinlichkeit vor, die eine Täuschungsabsicht dokumentieren. Bei publizierten Dissertationen sollte ein offizielles Verfahren zur Prüfung und/oder zum Entzug des Doktortitels eröffnet werden.
- Anteil Fremdtexte (brutto) — Anteil aller durch die Software automatisch gefundenen Bestandteile aus anderen Texten am Prüftext (von mindestens 7 Wörtern) in Prozent und Anzahl der Wörter gemessen. Dabei wird noch keine Interpretation auf Plagiatsindizien oder korrekte Übernahmen (z.B. Zitat, Literaturquelle) vorgenommen.
- Anzahl Fremdtext (netto) — Anteil aller durch die Software automatisch gefundenen und als Plagiatsindizien interpretierten Bestandteile aus anderen Texten am Prüftext (von mindestens 7 Wörtern) in Prozent und Anzahl der Wörter gemessen.
- Bauernopfer — Fehlende Quellenangabe bei einer inhaltlichen oder wörtlichen Textübernahme, wobei die Originalquelle an anderer Stelle des Textes (außerhalb des Absatzes, des Satzes, des Hablsatzes oder des Wortes) angegeben wird.
- Compilation — Zusammensetzen des Textes als "Patchwork" aus verschiedenen nicht oder unzureichend zitierten Quellen.
- Eigenplagiat — Übernahme eines eigenen Textes des Autors ohne oder mit unzureichender Kennzeichnung des Autors. Auch wenn hier nur eigene Texte und Gedanken übernommen werden, handelt es sich um eine Täuschung. Der Prüfer geht davon aus, dass es sich hier um neue Texte und Gedanken des Autors handelt.
- Einzelplagiatswahrscheinlichkeit — Grobe Berechnung der Wahrscheinlichkeit des Vorliegens eines Plagiates des einzelnen Treffers (oder der Treffer) auf einer Seite im Prüfbericht.
- Gesamtplagiatswahrscheinlichkeit — Berechnung der Wahrscheinlichkeit des Vorliegens von Plagiaten durch Verknüpfung der Indizienanzahl, des Netto-Fremdtextanteils und der Schwere der

einzelnen Plagiatsindizien.

- **Ghostwritersuche** — Über den statistischen Vergleich der Texte (Stilometrie) wird eine Wahrscheinlichkeit berechnet, ob die Texte von demselben Autor stammen.
- **Indizien** — Dieser Prüfbericht gibt nur die von der Software automatisch ermittelten Indizien auf eine bestimmte Plagiatsart wieder. Die Feststellung eines Plagiats kann nur durch den Gutachter erfolgen.
- **Literaturanalyse** — Die im Prüftext enthaltenen Literatureinträge im Literaturverzeichnis werden analysiert: Wird die Quelle im Text zitiert? Handelt es sich um eine wissenschaftliche Quelle? Wie alt sind die Quellen?
- **Mischplagiat - eine Quelle** — Der Text wird hierbei aus verschiedenen Versatzstücken einer einzigen Quelle zusammengesetzt, also gemischt.
- **Mischplagiat - mehrere Quellen** — Der Text wird hierbei aus verschiedenen Versatzstücken aus verschiedenen Quellen zusammengesetzt, also gemischt.
- **Phrase** — Die übernommenen Textstellen stellen allgemeintypische oder fachspezifische Wortkombinationen der deutschen Sprache dar, die viele Autoren üblicherweise verwenden. Solche Übernahmen gelten nicht als Plagiate.
- **Plagiat** — Übernahme von Leistungen wie Ideen, Daten oder Texten von anderen - ohne vollständige oder ausreichende Angabe der Originalquelle.
- **Plagiatsanalyse** — Gefundene gleiche Textstellen (= Treffer) werden durch die Software automatisch auf spezifische Plagiatsindizien analysiert.
- **Plagiatssuche** — Mit Hilfe von Suchmaschinen wird im Internet, in der Nationalbibliothek und im eigenen Dokumentenbestand nach Originalquellen mit gleichen oder ähnlichen Textstellen gesucht. Diese Quellen werden alle vollständig Wort für Wort mit dem Prüftext verglichen. Plagiatsindizien werden für Textstellen ab 7 Wörtern berechnet.

Glossar

- Plagiatswahrscheinlichkeit — Grobe Berechnung der Wahrscheinlichkeit des Vorliegens eines Plagiates auf der Basis der Plagiatsindizien. Die Ampel zeigt drei Ergebnisse an: grün - keine Wahrscheinlichkeit des Vorliegens eines Plagiates und somit keine weitere Überprüfung notwendig, gelb - mögliches Vorliegen eines Plagiates und somit eine weitere Überprüfung empfohlen, rot - hohe Wahrscheinlichkeit des Vorliegens eines Plagiates und somit weitere Überprüfung unbedingt notwendig.
- Stilometrie — Texte werden dabei einzeln nach statistischen Kennzahlen (z.B. durchschnitliche Länge der Wörter, Häufigkeit bestimmter Wörter) analysiert. Sind diese Kennzahlen für zwei Texte ähnlich, liegt hier statistisch der gleiche "Stil" und somit mit hoher Sicherheit der selbe Autor vor.
- Teilplagiat — Ein Textbestandteil einer Quelle wurde vollständig ohne ausreichende Zitierung kopiert.
- Textanalyse — Der einzelne Text wird durch die Software automatisch für sich allein analysiert, z.B nach statistischen Kennzahlen, benutzter Literatur, Rechtschreibfehlern oder Bestandteilen. Je nach Stand der Softwareentwicklung sind die absoluten Ergebnisse (z.B. Erkennung von Abbildungen, Fußnoten, Tabellen, Zitaten) im einzelnen eingeschränkt aussagefähig. Aufgrund der immer für alle Texte durchgeführten Analysen sind die relativen Unterschiede zwischen den Spalten (z.B. Diplomarbeit vs. Dissertation) uneingeschränkt aussagefähig.
- Textvergleich — Jeder Text wird mit anderen älteren Texten vollständig verglichen. Gefundene gleiche Texstellen werden in einem weiteren Schritt z.B. auf Plagiatsindizien hin untersucht.
- Übersetzungsplagiat — Nutzung eines fremdsprachigen Textes durch Übersetzung.
- Verschleierung — Ein Text wird ohne eindeutige Kennzeichnung (i.d.R. durch Anführungszeichen) Wort für Wort übernommen, aber mit Angabe der Quelle in der Fußnote. Dadurch wird der Prüfer getäuscht, der von einer nur inhaltlichen Übernahme ausgehen muss.
- Vollplagiat — Der gesamte Text wird vollständig ohne Zitierung kopiert.

Glossar

- Zitat - wörtlich — Übernommener Text wird z.B. mit Anführungszeichen korrekt dargestellt. Dieses wörtliche Zitat darf keine Veränderungen, Ergänzungen oder Auslassungen enthalten. Fehlt für das Zitat nach der Plagiatssuche ein Nachweis in einer Originalquelle, so wird der Treffer als "Zitat-wörtlich-im Text" bezeichnet.
- Zitat - wörtlich - Veränderung — Einzelne Wörter einer korrekt gekennzeichneten wörtlichen Übernahme werden verändert oder weggelassen, ohne dass der Sinn verändert wird. Z.B.: " Unternehmung" wird durch "Unternehmen" ersetzt.
- Zitat - wörtlich - Verdrehung — In dem korrekt gekennzeichneten übernommenen wörtlichen Text wird der Sinn durch Austauschung einzelner Wörter deutlich verändert. Beispiel: " überentwickelten" statt "unterentwickelten".
- Zitierungsfehler — Arbeitsbezeichnung für eine wörtliche Textübernahme, die nur als inhaltliche Textübernahme (Paraphrase) gekennzeichnet wird.