Integration of Information Systems in Cloud Computing for Establishing a Long-term Profitable Customer Portfolio

Michael Mohaupt, *Member, IAENG*, Andreas Hilbert

***Abstract*— Cloud service providers are interested both in a revenue maximizing allocation of their limited capacity resources (as goal of revenue management) and the establishment of long-term business relations with their clients (as goal of customer relationship management). Confronted with these partly diametric objectives, the paper introduces a framework for integrating the information systems that are assigned to often separate departments and have to meet the increased requirements of information processing due to the desired incorporation of both management concepts. Promising aspects of the integrated information system for supporting the development of a long-term profitable customer base are then demonstrated. Finally, revenue potentials of a customer value-based booking policy and said increase in worthiness of the customer portfolio are evaluated via simulation.**

***Index Terms*— integration, cloud computing, customer relationship, information system, revenue management**

I. Introduction

CLOUD Computing has emerged as a paradigm to deliver on-demand resources to customers similar to traditional utilities, such as water, electricity, gas and telephony [10], [16]. It represents a fundamental change in the way information technology (IT) services are invented, developed, deployed, scaled, updated, maintained and paid for [30]. Enterprises no longer require the large capital outlays in hardware to deploy their services or human expense to operate it [16]. They need not be concerned about over- or underprovisioning for services, thus wasting costly IT-resources vs. missing potential customers and revenue [5]. So, companies deploying various IT applica-tions (e.g. data mining, simulations), services (e.g. hosting) and large batch-oriented tasks with a highly fluctuating demand for IT resources [21], [50] are freed from the low-level task of setting up IT infrastructure and thus enabled a more focus on innovation and creating business value for their services [16], [30]. This elasticity of resources, without paying a premium for large scale, is unprecedented in the history of IT [5].

Manuscript received May 1st, 2013.

Michael Mohaupt is doctoral candidate at Dresden University of Technology, Germany (corresponding author, e-mail: mohaupt@wiid.wiwi.tu-dresden.de).

Prof. Dr. Andreas Hilbert is chair of Business Intelligence Research at Dresden University of Technology, Germany (e-mail: hilbert@wiid.wiwi.tu-dresden.de).

Cloud computing as a promising approach has shown a considerable increase in interest from both researchers and practitioners as it allows for the accommodation of the IT users' variable demand for IT services at reasonable costs [4]. Cloud computing comprises a large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services) that can be dynamically re-configured to adjust to a variable load scale [20], [56]. In so-called clouds, resources such as CPU, memory, storage and bandwidth are bundled into single services which are then offered to cloud users at different prices. Facing constantly growing competitive pressure, companies can then concentrate on core areas of expertise in order to develop new products and services for customers and optimization of processes – with the aim of keeping IT costs as low as possible [5]. By using these cloud services, about 60 to 80 percent of the IT costs can be reduced [23]. As a result of all such promise, Cloud Computing is expected to be a $150 billion business by 2014 [30].

In the market environment, cloud service providers face uncertain, temporally distributed demand for service classes of different worthiness [4]. This requires a non-trivial decision to control the acceptance or denial of booking requests [55]. But also because the risk of miscalculating the client's future IT demand is transferred from the customer to the cloud provider [23], the latter is more than interested in the efficient usage of its limited, inflexible and perishable capacity [31]. The concept of revenue management tries to meet the main objective of (short-term) revenue maximizing resource allocation by means of sophisticated information systems with complex booking control methods and a large data base [55]. As the customers in cloud computing attach great importance to permanent availability of IT resources [16], [56], the booking control decisions of the provider to accept or deny incoming requests can therefore have an effect on loyalty [40], [60]. So, a denial (meaning a refused service consumption) can prove to be critical for the requesting client's core business and success of its own services. Hence, the availability of IT services (typically arranged by service level agreements [1]) is considered as a quality criterion in judging the cloud provider and assures customer satisfaction and trust [15], [18], [56].

However, the focus of revenue management on short-term maximization only, may negatively impact customer relationship [31]. But by strengthening business relations to long-term profitable clients (as goal of customer relationship management) increasing intensity of competition should be countered. In order to allow for the establishment of such relationships, customer value-related information should be regarded by revenue management [32]. Customer value (as a key figure) represents the long-term value of a customer for the provider [17] and is regarded as being closely connected to shareholder value [31]. Here, a realignment of all business processes towards customer orientation and the appliance of integrated information systems are of crucial importance [18]. In a holistic approach, the integration of both management concepts, each of decisive competitive impact, is suggested [33].

Even though the essential function of integrating information systems from separate departments and increased requirements on data processing had been underlined oftentimes [31], [37], [57], their specific design and aspects of integration (as design objective in computer science [39]) are only poorly examined. Thus, after further addressing the set of revenue optimization problems in a Cloud Computing environment (see section II), a framework for integrating the information systems in customer value-based revenue management is developed (see section III). It will disclose which requisites on information systems arise and how they have to be designed to support the development of a long-term profitable customer base. Based on this work and the specification of decision variables how limited capacity resources should be provided to most valuable customers, a further gap is analyzed: regardless of emphasized benefits of long-term customer relationships [18], [57], to the best of our knowledge, there is as yet no investigation concerning a service provider with inflexible capacity that examines a customer base's growth in value over several consecutive booking periods (see section IV). By means of simulation (as common research method [3]) such performance is analyzed for a cloud service provider and potential revenues are evaluated (see section V). The paper then discusses results and limitations (see section VI) and ends with a conclusion (see section VII).

II. Revenue Management in Cloud Computing

A. Traditional View

The participation and integration of the customer implies an uncertain influencing factor for the cloud provider in terms of amount, value and arrival of requests and the client's reaction if the desired service is not available [55]. Confronted with inflexible and perishable capacity, the absence of an adequate booking control policy can result in a situation where majority of capacity is reserved for early, but low-class requests, available capacity is overbooked or cancelled reservations are causing costs of unutilized capacity [31], [41]. By bundling capacity resources to service classes of different worthiness, services (and therefore requesting customers as well) compete for those resources. In situations where uncertain and heterogeneous demand from different market segments exceeds supply and expanding of resources is not possible in the short run, e.g. problems in practice, such as

1) additional scheduling of suddenly incoming major order for reference purposes [3],
2) increased demand for hosting services due to seasonally-induced rise in hits on websites and online shops [40],
3) strategic limitation in order to keep service quality like accessibility high [47],
4) increased provider's demand for IT resources used for own services [1],
5) a pricing seeking continuously high capacity utilization,
6) or a pricing inducing an unexpectedly high number of new customers to request,

the provider needs to develop a tactical decision policy to obtain the best usage of available capacity resources [12], [50] in order to maximize short-term revenues [35], see goal and constraints in Fig. 1. So, despite facing uncertain and heterogeneous demand, for each incoming booking request a decision whether to accept or deny is needed. The acceptance of a lower-value booking requests may prevent sufficient capacity from being available for later booking requests of higher value (*revenue displacement*) [33]. Conversely, declining too many low-class requests may lead to idle capacity if such higher-value requests fail to appear (*revenue loss*) [55]. Revenue management governs the proper control and balance between these contrary revenue-relevant effects [41].

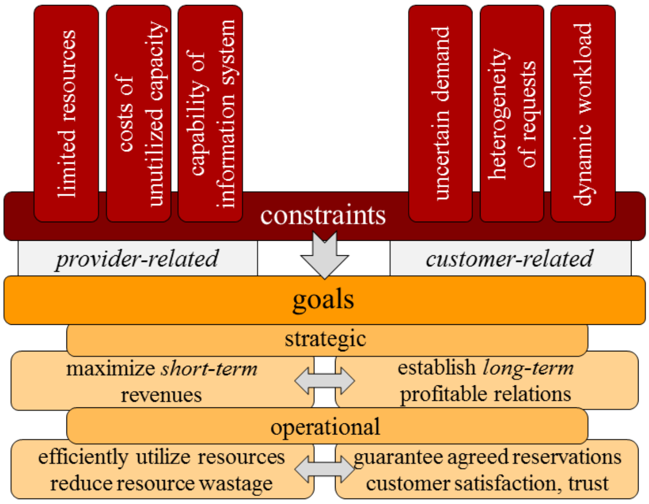

Fig. 1. System of goals and constraints in revenue management.

B. Customer-centric View

Revenue Management in Cloud Computing is mainly transaction-based so far. The acceptance decision is thereby primarily determined by the price of the requested IT-service, often ignoring the potential negative impact on the provider's relationship with customers, such as loss in satisfaction, loyalty, trust and perceived price fairness [38], [60]. By contrast, relationship-based marketing postulates the consideration of value-oriented success indicators to establish long-term relations to profitable customers [52], see goal in Fig. 1. By broadening the decision perspective from one transaction to the lifetime value of the customer [28], the cloud provider can reduce the risk to misleadingly decline *prospective customers* (low current, but high potential future contributions) and *reference customers* (not necessarily high own but high induced contributions of other customers [26], [32], [60]. In particular, the latter can be of strategic importance to the provider. In an electronic market environment like cloud computing, strengthening relations to the *right* clients is vital as only loyal customers are profitable in the long run due to high costs of acquisition [51]. Facing a complexity of customer lifetime values causes an adequate differentiation of the provider's (booking control) actions [45] in order to make the limited capacity available for the most valuable customers [32]. Hence, a number of authors emphasize the importance of incorporating customer lifetime value-related information into booking control methods (see *customer-centric revenue management*, [11], [33], [40], [41]) to establish a long-term profitable customer base.

In general, the booking control decisions of the cloud provider can have effects on customer relations. Whereas an acceptance can have a positive influence on customer loyalty, a denial can put the customer loyalty at risk [29], [60]. In particular, non-availability of IT services can lead to negative customer reactions like dissatisfaction, product change, decrease in buying frequency and even customer churn [31], [40], [46], [57]. These changes in customer loyalty will have an impact on the amount of future business and cross selling [17], [45].

C. Intelligent Information Systems

Revenue Management as a promising field of Decision Support System application has received increased attention recently. The revenue maximizing systems have become a competitive necessity [49]. The specific circumstances and conditions in the market environment, such as customer behavior, provider characteristics, and interaction interface have a fundamental influence on the decision whether a short-term revenue maximization or more long-term customer orientation is to be preferred and which requirements placed on information systems will arise (see Fig. 2). If capacity control is not expected to have effects on future customer behavior there is nothing to prevent revenue management from its positive influence on profits. However, as problems of acceptance and dissatisfaction are likely to occur in Cloud Computing due to the importance of permanent availability of IT services [31], [57], a long-term customer-related perspective is suggested in order to avoid negative consequences on existing customer base (primarily loss of valuable relations) in terms of future business and client recommendation behavior. As another characteristic, the structure of the interaction process between customer and provider determines which request- and customer-related indicators can be used for identification of clients [31] (see Fig. 2). If buyers cannot be (timely) identified during booking reservation process, a differentiated treatment on the basis of customer worthiness becomes difficult and can only be estimated by customer segment-specific information (with high forecast uncertainties). Thus, providers seek to offer incentives for clients' identification in their loyalty programs [18] in order to incorporate customized data into booking control – provided information systems' support (see Fig. 2). As a lot of cloud users can be identified by customer ID or login [1], [23], the information systems have to make proper use of the additional customized data [31] for orienting the booking control decisions to establish a long-term profitable customer portfolio. Dealing with merging, analyzing, and acting on disparate information on customers, the information systems and their capability (see Fig. 2) play a significant influencing factor in accounting for both short- and long-term revenue potentials in a Cloud Computing environment, see Fig. 1.

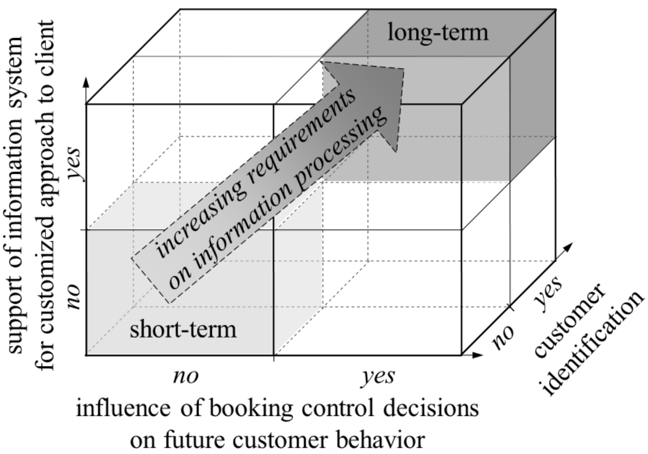

Fig. 2. Characteristics in market environment influencing maximization strategy.

Overall and due to these high requisites, revenue management systems can be considered as intelligent information systems that decisively support analysts regarding a total revenue maximizing resource allocation. Only information systems with a homogeneous data view [37] will allow for

1) the *right information* (required and understood by the analyst),
2) at the *right time* (for taking booking control decisions),
3) in the *right quantity* (as much as necessary, as little as possible),
4) at the *right place* (e.g. for calculations during optimization or transaction control, or evaluations in forecasting or analysis, see section III), and
5) in the *right quality* (sufficiently detailed, valid and directly applicable) [25].

As a result, an integrated revenue management system can enable advantages over competitors and serve as a crucial success factor [32]. Therefore, the information system's decision support function is of considerable importance to establish a profitable customer portfolio. So, facing increased requirements on information processing (up-to-date data availability, relevance, consistency, validity, data transformation, harmonization, matching, analysis and security [42], [44], [59]), the levels of needed integration in the customer-oriented revenue management system have to be clarified next.

III. Integration of Information Systems

Even though the importance of a coherent consideration of information systems and the positive effect of integration efforts have been repeatedly stressed [25], [39], in many firms, revenue management, pricing and customer relationship management are still a chain of separate departments with separate rules and goals measured on separate databases and analytical processes [37]. This hampers a comprehensive view beyond departmental boundaries and their interrelations and hinders that the flow of information becomes a natural image of the business processes in the firm [39]. However, for an integrated design a basic understanding of all individual information systems, their interaction and the decision influencing variables as well are indispensable [13]. As true integration is achieved with a system that integrates data from each department, synchronizes analysis and automatically alerts users when action is needed or conflicts arise [37], we want to develop a framework for integrating information systems in customer value-based revenue management with regard to the specific characteristics in a cloud service environment. Under this integrated framework, all departments have a single view of the data and can coordinate actions with the goal of overall and long-term profit optimization [37].

In general, the integrated information system is caught between repeating activities during the revenue management process (cycling in every booking period [31]) and – with ample planning horizon – the customer life cycle (in terms of customer relationship management [18]) with the goal of establishing a long-term profitable customer base (see axes in Fig. 3). According to the activities in a revenue management for cloud services that built upon one another, the corresponding information systems should be closely examined and statements not only about dimensions of integration (subject of matter, direction, range, degree of automation [25], [39]) but also aspects for decision support should be made.

A. *Database system*

A comprehensive database system is regarded as vital basis for customer value-based revenue management. It comprises current and historical booking data (e.g. acceptance and denial of requests), control data (e.g. cloud service characteristics, cloud resource availabilities) and information about customer base relevant for decision-making [22], [31]. Such a systematic integration of different data sources is an important prerequisite for the analysis of customer preferences and willingness to pay and forecasting of customer behavior – even to the point of individual customer's values [37]. Particular attention has to be paid to a regular and prompt updating of data (risk of obsolete data [55]) and its immediate synchronization via appropriate interfaces [37]. Besides horizontal data integration over all fields of activity, the database system should also provide opportunities of merging and consolidating the data (e.g. data marts [6]) in order to present the analysis reports in diverse levels of detail (vertical integration [25]).

B. *Forecasting system*

Based on identified relations and patterns in booking transactions and cloud service reservations stored in the database, the valuation, segmentation and forecast models are developed [31] that can be used to estimate information needed for optimization and transaction control (process integration [25]), such as provider-related (e.g. amount of capacity), customer-related (e.g. cancellation rate, workload) or competition-related values (e.g. availabilities, prices of substitute services) [31]. Therefore, the used data in the database (data integration [25]) often has to be preprocessed in the first place in order to be ready for forecasting and decision models in adequate format and sufficient quality [22], [58].

The tasks of optimization and transaction control are based on determination of *customer value* during forecasting activities (process integration [25]). By means of determinants (e.g. prospective contribution margin, buying frequency), the (averaged) customer segments' value or even the individual worthiness of cloud users are estimated. Represented as a monetary value or score, customer values serve as a basis for calculating segment-specific contingents or value-related revenues of booking requests [33]. Such a forecast rests upon the assumption that relations of the past (historical transaction data) can be transferred to future booking control decisions [17], [31]. So, high demands are placed on the forecasting system if a growth in customer value (i.e. transition of clients to another customer life cycle phase [7]) should be modeled. This may be the case if a startup's business model reached critical mass and its demand for IT services will explode [3]. On the other hand,

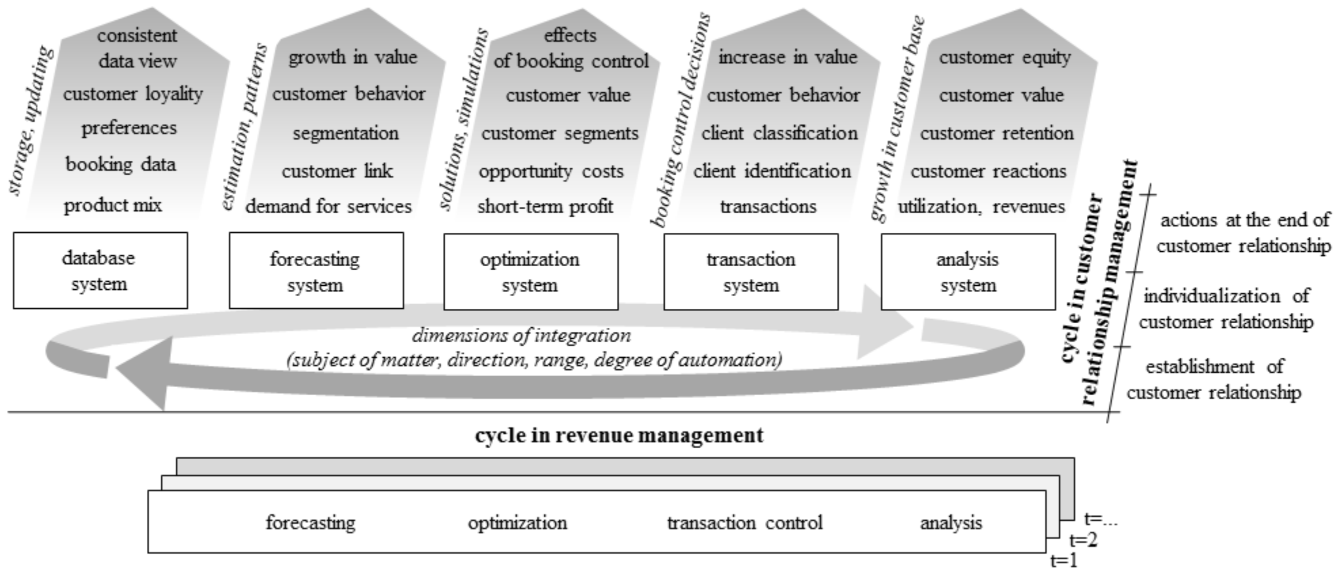

Fig. 3. Framework for integrating information systems in customer-value based revenue management.

some customers may be characterized by high-class historical, but only low-class future determinants [52], i.e. historical transaction and customer data should not be overrated [31]. In addition, the valuation of potential customers during acquisition phase can become a real challenge as transferred characteristic of known costumers to new buyers is often subject to uncertainty regarding information validity.

During prediction of amount of demand it is important not only to store transaction data of successfully served reservations but also to account for denied and cancelled requests for IT-services in order to determine the real demand not manipulated by capacity control [8], [31]. In general, forecasts should be updated throughout the booking process [55], in particular, for such events that have specific characteristics and influence demand for cloud services (e.g. increased website traffic at hosting providers during Christmas [40]). So, the resulting intervention of the revenue management analyst prevents a total process automation.

C. *Optimization system*

The requisites for capability of the optimization system and integrated data processing are very high as the decision problems are of ample complexity, data-intense and to be taken quickly [41], such as for transaction control, the opportunity costs for capacity usage (bid prices) have to be determined [33]. The decision to accept short-term higher-paying customers but not necessarily the most loyal ones [60] should take opportunity costs in terms of lost customer values into account if in return the denied prospective customers will reduce their future purchases or even abort the relationship with the provider [46]. Depending on state of the market and planned marketing actions (e.g. discount for new cloud users), the integrated information system has to allow for a weighting between short- and long-term potential for success [31] (see also parameter α in section IV). The final weighting can be supported by simulations in the optimization system [3]. The target figures of optimization attain particular high informative value regarding long-term growth of customer base if effects of booking control on customer behavior (identified during analysis phase) are incorporated directly into the optimization model. So, Mohaupt and Hilbert (2012) take a decrease of customer loyalty in response to the provider's denial of the booking request into consideration [40].

D. *Transaction system*

By means of transaction system the booking control decisions to either accept or deny incoming requests for cloud services are taken [22]. As target figures from preceded information systems (e.g. bid prices of optimization system, customer segment-based information of forecasting system) are needed for this purpose [31], particular attention has to be paid to their interfaces during (horizontal) process integration [25]. In case the requesting customer could be identified and stored customer history is available, the customized information could be used to estimate future buying frequency and average revenue (*prospective view*), and assist with the decision to invest in that customer relationship (e.g. if the customer is interested in a low-class cloud service at present time, but is predominantly characterized by a high willingness to pay; *retrospective view*) vs. exploiting the short-term revenues only. Thus, besides special booking control rules for new customers (without transaction history), an addressing of customers on an individual, personalized basis is enabled, and where applicable, even a disestablishment of (long-term) unprofitable customers (by denying their requests) could be realized. The analysts can also be notified by the integrated information system that customers are classified as liable to churn due to their past behavior (i.e. anticipation of avoidable costs for reactivation) or have to be treated with priority next time they will request [37].

E. *Analysis system*

On the one hand, the analysis system is used for monitoring the booking process and quality of forecasts during the booking period [55]. On the other hand, it should not only evaluate capacity- and relationship-oriented goals by means of key figures at the end of each booking period (see Fig. 1) but also review the suitability of used application systems and procedures to establish a long-term profitable customer base [31]. The provider can strategically benefit from real-time profitability reports as a faster respond to market change is facilitated. The information generation for supporting such an assessment requires a data integration of all information systems. The analysis of the data base will only develop their full flexibility and lead to meaningful results, if many different topics such as customer, product, transaction and control data are incorporated [19], [31]. So, whereas real revenues are obtained from stored bookings in transaction system, the forecasting system is accessed for estimation of customer values [41]. For evaluating the booking control decisions, current revenues may be compared to potential ones [13], [31]. Hence, the integrated information system should be able to execute runs for evaluation purposes without influencing real-time calculations in present booking period (process integration [25]).

Moreover, the integrated data processing stipulates an adjustment of the information systems' different levels of detail (i.e. vertical integration [25]) as desired analysis should be carried out on varying aggregation levels, i.e. overall worthiness of customer base (customer equity [27]), at customer segment level or even for individual cloud users. So, different customer clusters can be defined with the aid of data mining methods that can then be analyzed regarding their development of buying behavior as a result of varying booking control decisions [40]. Such results can also be enriched with customer surveys on planned IT budget, share-of-wallet and potential reactions of clients, e.g decrease of buying frequency in case of denial, selection behavior after introduction of alternate services, estimation of willingness-to-pay [17], [54], [56]. The integration of (maybe) anonymized, aggregated data of market research (such as customer behavior, consumer habits) with personalized customer data needs increased attention in order to ensure a consistent database [59]. By identifying common structural characteristics and data harmonization, the insights of market research can be transferred into smaller, homogeneous customer groups [19], [52]. Such projection of aggregated data into customized client data facilitates that market data apply with sufficient probability for practical purposes [59]. So, by choosing appropriate decision criteria and at highest level of detail during analysis, customers can be purposefully selected for marketing actions or be identified as preferential. With regard to key figures, degree of capacity utilization, average revenue of customer per booking, ratio of revenue and capacity consumption, prospective buying frequency and duration of customer retention are focus of interest.

IV. Optimization and Booking Control Approach

During optimization the revenue management system conducts the allocation of (still) available capacity on expected demand based on forecasted information [55]. The resulting contingents of capacity resources or bid prices (as opportunity costs of capacity utilization) are then introduced to transaction control in order to decide on acceptance or denial of the requests within the booking period [31]. In dependence of applied revenue element and time horizon (short- vs. long-term), these booking control decisions may vary – with different implications on future demand and profitability of customer base.

The following statements are based on general assumptions in revenue management literature [22], [31], [55] and specific characteristics in cloud computing [3], [4], [14], [40], [41]. A cloud service provider has I resources (like CPU power, memory or storage, each with a total capacity g_i) available and offers H types of cloud services by bundling these resources through a time interval of T consecutive booking periods. In practice, a booking period in the cloud service domain is considerably smaller than in airline revenue management. This contributes to a more spontaneous setting with clients booking IT-services according to the more agile business environment and changing requirements for those services [4]. The element a_{ih} represents the usage of resource i by one unit of service type h (see real Amazon's service parameter [1] in Table 1) offered at a price of e_h. Due to publicly accessible price tables, service prices are fixed over the predefined time interval [1], [10]. But the provider will grant a discount on e_h in dependence of the time of requesting. Thereto each booking period is split into K arrival periods. The earlier the customers detect their own need for IT-services and therefore make a reservation, the greater the discount d_k offered by the provider. In other words, customers willing to book early can save money but have to accept a longer activation time until service utilization in the subsequent booking period. Of course, the provider is interested in selling the more expensive services [48]. When a customer requests an IT-service of low revenue, the provider may accept this request or wait for prospective customers asking for high valued services [4].

Each of the M customers is characterized by a general probability f_m of arrival. In case of arrival the request will arrive at different points in time with certain probability but according to customer's preference, predominantly in a particular arrival period (with correspondent discount $\tilde{d}_m$). As part of forecasting, this demand-pattern is used to establish R customer segments (with averaged revenue $\bar{e}_r$ over all service types). Each segment represents exactly that arrival period where future requests (with correspondent discount $\tilde{d}_r$) are predominantly to be expected. The customized value p_{mrhk} determines the probability that customer m assigned to segment r requests service h in arrival period k. High-class customers (with predominantly late arriving requests and therefore lower discount but identical resource consumption) are thus more profitable.

The provider will base the booking control decisions on value-related revenue [33], [41] representing a combination of *short-term revenue* s_{hk}, i.e. the price e_h of requested service h adjusted to referring discount d_k, see (1), and *long-term value contributions* l_r, that is, the predominantly to be expected revenue $\bar{e}_r$ of the segment (averaged over all service types and with correspondent discount $\tilde{d}_r$) the client is assigned to, see (2):

$$s_{hk} = (1 - d_k) e_h \quad (1)$$

$$l_r = (1 - \tilde{d}_r) \bar{e}_r \quad (2)$$

A weighting factor $\alpha \in [0;1]$ emphasizes either short or long-term value contributions and allows for defining various booking control methods, i.e. *short*-term (α=1), *long*-term (α=0) revenue maximization and a *hybrid* control (α=0.5). The lower α, the greater the extent to which current booking-class revenue is modified by long-term value contributions.

The allocation of the capacity in each booking period can now be formulated as a Linear Programming Model where c_{rhk} represents the contingent assigned to a combination of customer segment r, service h and arrival period k, and b_{rhk} (as an element of B) is the amount of the already reserved service h requested from segment r in arrival period k. The objective-value function Z is obtained by:

$$Z(B) = \max \sum_{r=1}^{R} \sum_{h=1}^{H} \sum_{k=1}^{K} [\alpha s_{hk} + (1-\alpha) l_r] c_{rhk} \quad (3)$$

$$\text{s.t. } \sum_{r=1}^{R} \sum_{h=1}^{H} \sum_{k=1}^{K} a_{ih} (b_{rhk} + c_{rhk}) \leq g_i \quad \forall i \in \{1,.., I\} \quad (4)$$

$$0 \leq c_{rhk} \leq \min\left(0; \sum_{m=1}^{M} f_m p_{mrhk} - b_{rhk}\right) \quad \forall r \in \{1,.., R\}, \forall h \in \{1,.., H\}, \forall k \in \{1,.., K\} \quad (5)$$

The objective function maximizes the sum of short-term and predominantly to be expected future revenue (both adjusted for corresponding discount) over all segments, arrival periods and service types and in dependence of α, see (3). Whereas equation (4) ensures that the capacity used to satisfy present bookings and contingents does not exceed total amount of capacity, equation (5) guarantees that contingents do not exceed demand forecasted from customer base minus present bookings.

In order to achieve the best usage of available IT-resources, capacity should be assigned to an incoming request only if its total revenue is greater than the value of the capacity required to satisfy it. The value of capacity should be measured by its *opportunity cost* which is the expected loss in future revenue from using the capacity now instead of reserving it for future use [55]. Often termed as bid price or hurdle price [36], it can be calculated by comparing the values Z of the remaining capacity for the rest of the booking period both in case of declining and accepting the request [46]. An incoming request (represented by matrix O) is accepted as long as the sum of short-term and predominantly to be expected averaged future revenue $\bar{e}_m$ of the costumer (both adjusted for corresponding discount) outweighs the opportunity costs, see (6).

accept request if:

$$\alpha s_{hk} + (1-\alpha)\left(1-\tilde{d}_m\right)\bar{e}_m \geq Z(B) - Z(B+O) \qquad (6)$$

V. Simulation Results and Evaluation

Even though the application of simulations to analyze relations in complex demand environments is very common [4], [53] and the advantageousness of long-term customer retention is emphasized frequently [57], there is no simulation dealing with the long-term growth of the customer base of a provider with limited resources over several booking periods. Although Martens (2009) does use segment-based customer values as basis for decision-making, the simulation does not account for consecutive booking periods and radically assumes that rejected customer requests are lost instantly and forever [31]. Referring to this, Mohaupt and Hilbert (2012) model a prospective decrease in customer value in case of denial of the customer's request but again forgo a simulation with temporally linked booking periods [40]. Buhl et al. (2011) propose a customer lifetime value-oriented model that explicitly includes the trade-off between short-term value contributions of clients against their long-term potential when allocating capacities, but again only one decision period is considered [9]. The optimization model of Kolb (2012) accounts for multiple periods, but with the simplifying assumption that customers always request the identical service [24]. In the absence of a comprehensive simulation, no conclusions and a revenue comparison between customer value-based and transaction-based booking control at the end of a multi-periodic planning horizon can be drawn. Whereas Pfeifer and Ovchinnikov (2011) optimize over consecutive booking periods, they again only allow for homogeneity in service preference and also assume that denied customers are lost forever [47]. In addition, booking control decisions are not taken for each single client individually but simultaneously for all customer segments. Thus, a detailed evaluation of the long-term effects of a booking control policy is not possible.

By defining the accumulated transaction revenues over all booking periods as a new performance indicator, our paper should close this gap and enable the benchmark of a customer value-based method vs. a transaction-based counterpart maximizing short-term revenues in every single booking period only. The cloud computing environment with long-term customer relationships is suitable for such a consideration [51].

General aim of the simulation implemented in Matlab R2012b [34] is a benchmark of the booking controls *short*, *hybrid* vs. *long* (see section IV) by comparing the accumulated transaction revenues x^{acc} over all T=50 booking periods and the development of the customer portfolio's value [41], see Fig. 4. By choosing a too short T, one should keep in mind that long-term effects of the provider's booking control decisions influencing the development of the customer base cannot be observed. But choosing T too long will hinder the forecast of customized changes in pref-

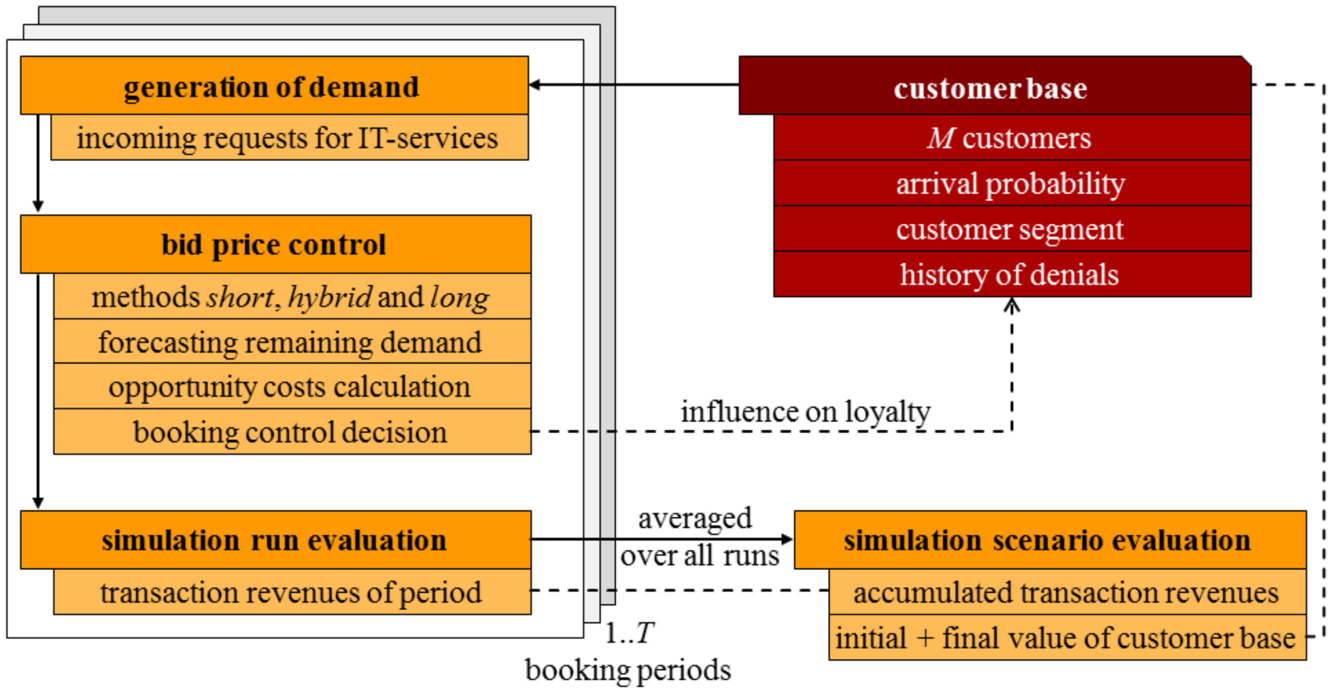

Fig. 4. Process of simulation.

erence and buying frequency (with view to prospective IT-budget).

With initialization of customer base, one third of M=150 customers request with arrival probability f_m=0.5 leaving the rest with a f_m=0.25 (i.e. high vs. low demand for IT-services). A repeated denial of the provider will reduce f_m as a consequence of the negative effect on customer loyalty to the next smaller value or even result in a f_m=0, respectively (see Fig. 4). The exact number of denials until (repeated) decrease in buying frequency varies from customer to customer and is determined by an uniformly distributed random drawing, i.e. $v_m \in \{1, 2, 3\}$. The customized values of $\bar{e}_m$ and $\tilde{d}_m$ comply with the assigned segment r at time of initialization and, for the sake of simplicity, have the values of $\bar{e}_r$ and $\tilde{d}_r$. Please see Table 1 for the configuration of the parameters.

TABLE 1
SIMULATION PARAMETERS

		service type e_1 = 10			
	arrival period	k=1 early	k=2 late	g_i	
a_{ih}	CPU cores	4	4	130	
	RAM (GB)	8	8	270	
	storage (GB)	850	850	28,000	
	discount d_k	0.4	0		
	initial expected demand	25	25	$\bar{e}_r$	$\tilde{d}_r$
p_{mrhk}	r=1 (predominantly early requesting)	0.8	0.2	10	0.4
	r=2 (predominantly late requesting)	0.2	0.8	10	0

Altogether, 1,000 different arrival processes have been simulated resulting in demand fluctuations. Due to the random demand generation the results have been averaged over all runs (see Table 2). Given the simulation design, the tolerance of a short-term loss in revenue (or meaning an investment in a customer relationship) regarding a high-class customer who currently requests a cloud service early and therefore gets a discount, can turn out to be a long-term meaningful decision as this customer will contribute predominantly high revenues with constant buying frequency in future booking periods. So, by the (weighted) incorporation of the predominantly to be expected future revenue, booking control *hybrid* can achieve higher accumulated transaction revenues x^{acc} in contrast to method *short* at the end of the 18th booking period for the first time. In the remaining time interval *hybrid* can extend its lead. Method *long* (entirely without consideration of short-term transaction revenues) is just slightly behind method *hybrid*. At the end of all T booking periods, method *hybrid* realizes 2.3% higher revenues (on average) compared to method *short* and shows a more profitable customer base in the future. Thus, the value of the customer base (determined as the sum of arrival probability times averaged revenue per request for all customers in the next T booking periods) is 7.8% higher for method *hybrid* and *long* in contrast to method *short*. The booking control decisions of *hybrid* and *long* with a long-term component are a determining factor for this result as there are finally 13 more high-class clients in the customer base (compared to method *short*) that actively request (i.e. f_m > 0) the cloud services of the provider.

TABLE 2
SIMULATION RESULTS (AVERAGED OVER 1,000 RUNS)

method / key figure	*short*	*hybrid*	*long*	*hybrid* / *short*
x^{acc}	12,418	12,703	12,499	1.023
x^{acc} / T	248.4	254.1	250	
initial value of customer base	39,970			1
value of customer base after T booking periods	23,908	25,781	25,781	1.078

One should bear in mind that even if the initial excess demand can be stemmed with the help of an increase in capacity and/or prices in the future (but always associated with imminent costs of unutilized capacity due to uncertain demand, see constraints in Fig. 1), the previous booking control decisions could have impaired the customer values already as a consequence of reduced buying frequency. In case of a general decline in demand during the market cycle, the methods *hybrid* and *long* can better absorb this altered revenue situation due to the higher value of the customer portfolio. With view to the prototypical simulation results, a (weighted) incorporation of long-term revenue indicators for a suitable selection of customers to accept vs. to deny seems reasonable, if the booking control decisions of the service provider are likely to have a (negative) effect on future customer behavior (e.g. decrease in buying frequency after denial, see Fig. 2) and customers may have a heterogeneity concerning prospective revenues [41]. It is provided that requests can be classified into customer segments accordingly and a sufficient forecast of customers' worthiness (with the aid of a revenue management system integrating required information sources) is feasible.

VI. Discussion and Limitations

The paper highlights that considerations of long-term oriented revenue maximization might be well justified – provided with specific circumstances and conditions in the market environment of Cloud Computing (see section II.C). Although attested a positive effect [25], a continuous integration (see section III) is often hampered by restrictions of legacy systems [55], [58]. Even though the simulation results in a cloud environment yield first evidence for potential benefits of a booking control with long-term revenue perspective (see section V), the authors strive for further analysis and findings concerning robustness and generation of generic recommendations for action, by means of more evaluations with varying parameters in future work, such as resource, pricing, demand model with forecast errors and acquisition of new customers.

In addition, a further reflection of underlying assumptions (e.g. retrospective observed data as basis for future prediction of customer behavior [43]) seems reasonable. One should keep in mind that the standards on forecasting will increase for providers offering IT-services that are also or primarily used for their own business processes, such as Amazon is seeking for a more even utilization of its IT-resources by providing cloud services to customers [1], [50] but also facing added uncertainty and variability in predicting the resource availability for both internal *and* external users [31], [40].

Furthermore, customers that are expected to request predominantly high-class IT-services in the future (thereby contrary to their current willingness to pay and buying frequency) may also be included in the simulation design (albeit much more difficult to forecast), e.g. promising startups with an initially low amount of bought cloud services. At that point, the weighting factor α introduced in the booking control approach (see section IV) may even be applied on an individual client level in order to dynamically adjust the focus of the planning horizon (short vs. long) to be optimized.

The idea of a more long-term oriented perspective may also be of interest for the recently emerging business segment in auctioning for unused cloud capacity (but of uncertain availability) at spot prices [30], e.g. Amazon EC2 spot instances [1]. The incorporation of buyers' (long-term) worthiness into their bidding (e.g. by a customer value-based weighting of bids or adding a subsidy to bidding base, limited to selected marketing campaigns, if applicable) can allow that valuable customers gain preferential availability, additional demand may be encouraged and customers' loyalty may increase further.

In summary, the integration of revenue management and customer relationship management remains a highly promising research area with significant implications on improving competitiveness not only of cloud service providers.

VII. Conclusions

In practice, cloud service providers face a difficult task to master the complexity of resource allocation and order acceptance decision problem. On the one hand, the efficient utilization of limited and perishable capacity resources is a crucial success factor for those providers. But due to high degree of competition, strengthening of long-term customer relationships is becoming increasingly important as well. However, the desired incorporation of revenue *and* customer relationship management with partly diametric goals causes increased standards of the underlying information systems. As a systematic analysis and examination of their precise design and aspects of integration are still missing, a framework for integrating those information systems with the objective to establish a long-term profitable customer base is developed. Applied to a cloud service environment, promising aspects of the integrated information system for decision support are illustrated. Furthermore, the results of the subsequent simulation in Matlab emphasize the significance of a long-term oriented revenue maximization.

References

[1] M. Aiash, G. Mapp and A. Lasebae, "Security and QoS Integration for Protecting Service Providers in Heterogeneous Environments", *IAENG International Journal of Computer Science*, vol. 38, no. 4, 2011, pp. 384-393.

[2] Amazon. (2013, April). Amazon Elastic Compute Cloud (Amazon EC2). [Online] Available: http://aws.amazon.com/de/ec2/

[3] A. Anandasivam and C. Weinhardt, "Towards an efficient Decision Policy for Cloud Service Providers", in *Proc. of ICIS*, 2010, Paper 40.

[4] A. Anandasivam, S. Buschek and R. Buyya, "A Heuristic Approach for Capacity Control in Clouds", in *Proc. 11th IEEE Conf. on Commerce & Enterprise Computing*, 2009, pp. 90-97.

[5] M. Armbrust, A. Fox, R. Griffith, A. D. Joseph, R. H. Katz, A. Konwinski and G. Lee, "Above the Clouds - A Berkeley View of Cloud Computing", *UC Berkeley Technical Report*, 2009, Paper UCB/EECS-2009-28.

[6] A. Bauer and H. Günzel, "*Data Warehouse Systeme. Architektur, Entwicklung, Anwendung* [*Data Warehouse Systems. Architecture, Development, Application*], 3rd ed., Heidelberg: dpunkt, 2009.

[7] P. D. Berger, N. Eechambadi, M. George, D. R. Lehmann, R. Rizley and R. Venkatesan, "From Customer Lifetime Value to Shareholder Value: Theory, Empirical Evidence, and Issues for Future Research", *Journal of Service Research*, vol. 9, no. 2, 2006, pp. 156-167.

[8] S. V. de Boer, R. Freling and N. Piersma, "Mathematical Programming for Network Revenue Management Revisited", *European Journal of Operational Research*, vol. 137, no. 1, 2002, pp. 72-92.

[9] H. U. Buhl, R. Klein, J. Kolb and A. Landherr, "CR^{2}M - an Approach for Capacity Control Considering Long-term Effects on the Value of a Customer for the Company", *Journal of Management Control*, vol. 22, no. 2, 2011, pp. 187-204.

[10] R. Buyya, C. S. Yeo, S. Venugopal, J. Broberg and I. Brandic, "Cloud Computing and Emerging IT Platforms: Vision, Hype, and Reality for Delivering Computing as the 5th Utility", *Future Generation Computer Systems*, vol. 25, no. 6, 2009, pp. 599-616.

[11] R. G. Cross, J. A. Higbie and D. Q. Cross, "Revenue Management's Renaissance. A Rebirth of the Art and Science of Profitable Revenue Generation", *Cornell Hospitality Quarterly*, vol. 50, no. 1, 2009, pp. 56-81.

[12] H. Deng, Q. Wang, G. K. Leong and S. X. Sun, "The Usage of Opportunity Cost to Maximize Performance in Revenue Management", *Decision Sciences*, vol. 39, no. 4, 2008, pp. 737-758.

[13] K. Donaghy, U. McMahon-Beattie, I. Yeoman and A. Ingold, "The Realism of Yield Management", *Progress in Tourism and Hospitality Research*, vol. 4, no. 3, pp. 187-195, 1998.

[14] P. Dube, Y. Hayel and L. Wynter, "Yield Management for IT Resources on Demand: Analysis and Validation of a New Paradigm for Managing Computing Centres", *Journal of Revenue and Pricing Management*, vol. 4, no. 1, 2005, pp. 24-38.

[15] J. O. Fitó and J. Guitart, "Business-driven Management of Infrastructure-level Risks in Cloud Providers", *Future Generation Computer Systems*, in press, 2012.

[16] S. K. Garg, S. Versteeg and R. Buyya, "A Framework for Ranking of Cloud Computing Services", *Future Generation Computer Systems*, vol. 29, no. 4, 2013, pp. 1012-1023.

[17] S. Gupta, D. Hanssens, B. Hardie, W. Kahn, V. Kumar, N. Lin, N. Ravishanker and S. Sriram, "Modeling Customer Lifetime Value". *Journal of Service Research*, vol. 9, no. 2, 2006, 139-155.

[18] H. Hippner, "Customer Relationship Management", in *Grundlagen des CRM* [Basics of CRM], 2nd ed., H. Hippner and K. D. Wilde, Eds. Wiesbaden: Gabler, 2006, pp. 15-44.

[19] D. Hiestermann, "*Analytisches Customer Relationship Management. Konzeption und Realisierung auf Basis der Business-Intelligence-Instrumente Data Warehouse und Data-Mining* [*Analytic Customer Relationship Management: Conception and Implementation based on Business Intelligence Instruments Data Warehouse and Data-Mining*]", Ph.D. dissertation, Dortmund University of Techology.

[20] E. R. L. Jalao, D. L. Shunk and T. Wu, "Life Cycle Costs and the Analytic Network Process for Software-as-a-Service Migration", *IAENG International Journal of Computer Science*, vol. 39, no. 3, 2012, pp. 269-275.

[21] N. P. Khanyile, J. R. Tapamo and E. Dube, "An Analytic Model for Predicting the Performance of Distributed Applications on Multicore Clusters", *IAENG International Journal of Computer Science*, vol. 39, no. 3, 2012, pp. 312-320.

[22] R. Klein and C. Steinhardt, *Revenue Management*. Berlin: Springer, 2008.

[23] P. Koehler, A. Anandasivam, M. A. Dan and C. Weinhardt, "Customer Heterogeneity and Tariff Biases in Cloud Computing", in *Proc. of ICIS*, 2010, Paper 106.

[24] J. Kolb, "On the Integration of Customer Lifetime Value into Revenue Management", in *Operations Research Proceedings*, D. Klatte, H. J. Lüthi and K. Schmedders, Eds. Berlin: Springer, 2012, pp. 559-564.
[25] H. Krcmar, "Integration in der Wirtschaftsinformatik - Aspekte und Tendenzen [Integration in Computer Science - Aspects and Trends]", in *Integrierte Informationssysteme* [*Integrated Information Systems*], H. Jacob, J. Becker and H. Krcmar, Eds. Wiesbaden: Gabler, 1991, pp. 3-18.
[26] R. Kuhlmann, "Why Is Revenue Management Not Working?", *Journal of Revenue and Pricing Management*, vol. 2, no. 4, 2004, pp. 378-387.
[27] V. Kumar and M. George, "Measuring and Maximizing Customer Equity - A Critical Analysis", *Journal of the Academy of Marketing Science*, vol. 35, no. 2, 2007, pp. 157-171.
[28] P. Lederer and I. Yeoman, "The Natural Extension of Marketing", *Journal of Revenue and Pricing Management*, vol. 2, no. 1, 2003, pp. 81-82.
[29] J. Lindenmeier and D. K. Tscheulin, "The Effects of Inventory Control and Denied Boarding on Customer Satisfaction - The Case of Capacity-based Airline Revenue Management", *Tourism Management*, vol. 29, no. 1, 2008, pp. 32-43.
[30] S. Marston, Z. Li, S. Bandyopadhyay, J. Zhang and A. Ghalsasi, "Cloud Computing - The Business Perspective", *Decision Support Systems*, vol. 51, no. 1, 2011, pp. 176-189.
[31] T. von Martens, *Kundenwertorientiertes Revenue Management im Dienstleistungsbereich* [*Customer Value-based Revenue Management in Services Industry*], Wiesbaden: Gabler, 2009.
[32] T. von Martens and A. Hilbert, "Incorporation of Customer Value into Revenue Management", in *Operations Research Proceedings*, B. Fleischmann, K. H. Borgwardt, R. Klein and A. Tuma, Eds. Berlin: Springer, 2009, pp. 383-388.
[33] T. von Martens and A. Hilbert, "Customer Value-based Revenue Management", *Journal of Revenue and Pricing Management*, vol. 10, no. 1, 2011, pp. 87-98.
[34] MathWorks (2013, April). MATLAB - The Language of Technical Computing. Accelerating the Pace of Engineering and Science. [Online] Available: http://www.mathworks.com/products/matlab/
[35] M. Maurer, I. Brandic and R. Sakellariou, "Adaptive Resource Configuration for Cloud Infrastructure Management", *Future Generation Computer Systems*, vol. 29, no. 2, 2013, pp. 472-487.
[36] J. I. McGill and G. J. van Ryzin, "Revenue Management: Research Overview and Prospects", *Transportation Science*, vol. 33, no. 2, 1999, pp. 233-256.
[37] K. McGuire and S. Pinchuk, "The Future of Revenue Management", in *Proc. of SAS Global Forum*, SAS Institute Inc., Cary, NC, 2009, Paper 342.
[38] U. McMahon-Beattie, I. Yeoman, A. Palmer and P. Mudie, "Customer Perceptions of Pricing and the Maintenance of Trust", *Journal of Revenue and Pricing Management*, vol. 1, no. 1, 2002, pp. 25-34.
[39] P. Mertens, *Integrierte Informationsverarbeitung* [*Integrated Information Processing*]. Wiesbaden: Gabler, 2005.
[40] M. Mohaupt and A. Hilbert, "Ein Revenue-Management-System zur multikriteriellen Kapazitätssteuerung im Umfeld des Cloud Computing [A Revenue Management System for Multi-criteria Booking Control in Cloud Computing]", in *Proc. of Multikonferenz der Wirtschaftsinformatik* [*Proc. of multi-conference in computer science*], Braunschweig, Germany, 2012, pp. 1183-1194.
[41] M. Mohaupt and A. Hilbert, "Integrated Decision Support System for Establishing a Long-term Profitable Customer Base in Cloud Computing", *Lecture Notes in Engineering and Computer Science: Proceedings of The International MultiConference of Engineers and Computer Scientists 2013*, 13-15 March, 2013, Hong Kong, pp. 232-238.
[42] H. Mouratidis, S. Islam, C. Kalloniatis and S. Gritzalis, "A Framework to Support Selection of Cloud Providers Based on Security and Privacy Requirements", *Journal of Systems and Software*, in press, 2013.
[43] N. A. Nechval, K. N. Nechval and M. Purgailis, "Prediction of Future Values of Random Quantities Based on Previously Observed Data", *Engineering Letters*, vol. 19, no. 4, 2011, pp. 346-359.
[44] P. Neckel and B. Knobloch, *Customer Relationship Analytics*, Heidelberg: dpunkt, 2005.
[45] B. M. Noone, S. E. Kimes and L. M. Renaghan, "Integrating Customer Relationship Management and Revenue Management - A Hotel Perspective", *Journal of Revenue and Pricing Management*, vol. 2, no. 1, 2003, pp. 7-21.
[46] K. Pak, *Revenue Management - New Features and Models*, Ph.D. dissertation, Erasmus University Rotterdam, 2005.
[47] P. Pfeifer and A. Ovchinnikov, "A Note on Willingness to Spend and Customer Lifetime Value for Firms with Limited Capacity", *Journal of Interactive Marketing*, vol. 25, 2011, pp. 178-189.
[48] R. L. Phillips, *Pricing and Revenue Optimization*, Standford: University Press.
[49] D. J. Power and R. Sharda, "Model-driven Decision Support Systems: Concepts and Research Directions", *Decision Support Systems*, vol. 43, no. 3, 2007, pp. 1044-1061.
[50] T. Pueschel, A. Anandasivam, S. Buschek and D. Neumann, "Making Money with Clouds - Revenue Optimization through automated Policy Decisions", in *Proc. 17th European Conference on Information Systems*, 2009, pp. 355-367.
[51] F. F. Reichheld and P. Schefter, "E-loyalty - Your Secret Weapon on the Web", *Harvard Business Review*, Jul-Aug 2000, pp. 105-113.
[52] E. Rudolf-Sipötz, *Kundenwert* [*Customer Value*], Ph.D. dissertation, University of St. Gallen.
[53] G. J. van Ryzin, "Models of Demand", *Journal of Revenue and Pricing Management*, vol. 4, no. 2, 2005, pp. 204-210.
[54] G. E. Smith and T. T. Nagle, "How Much Are Customers Willing to Pay?", *Journal of Marketing Research*, vol. 42, no. 4, 2002, pp. 20-25.
[55] K. T. Talluri G. J. van Ryzin, *The Theory and Practice of Revenue Management*. Berlin: Springer, 2004.
[56] I. Uusitalo, K. Karppinen, A. Juhola and R. Savola, "Trust and Cloud Services - An Interview Study", in *Proc. of CLOUDCOM*, 2010, pp. 712-720.
[57] X. L. Wang and D. Bowie, "Revenue Management - The Impact on Business-to-Business Relationships", *Journal of Services Marketing*, vol. 23, no. 1, 2009, pp. 31-41.
[58] K. Weber, J, Sun, Z. Sun, G. Kliewer, S. Grothklags and N. Jung, "Systems Integration for Revenue-creating Control Processes", *Journal of Revenue and Pricing Management*, vol. 2, no. 2, 2003, pp. 120-137.
[59] F. Wimmer and J. Göb, "Customer Intelligence: Marktforschung und Kundenanalyse als Informationsgrundlagen im CRM [Customer Intelligence: Market Research and Customer Analysis as Information Base in CRM]", in *Grundlagen des CRM* [Basics of CRM], 2nd ed., H. Hippner, Ed, Wiesbaden: Gabler, 2006, pp. 400-418.
[60] J. Wirtz, S. E. Kimes, J. H. Pheng Theng and P. Patterson, "Revenue Management - Resolving Potential Customer Conflicts", *Journal of Revenue and Pricing Management*, vol. 2, no. 3, 2003, pp. 216-226.