Cloud Resellers on Bazaar-based Cloud Markets

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***Abstract*—Today, Cloud services such as virtual machines are purchased from provider platforms such as Amazon EC2. Thereby, consumers can choose between pre-configured virtual machines (aka instance types) without negotiating price and SLA terms. More dynamic approaches for trading Cloud services are emerging see e.g. Virtustream where consumers are charged based on so called μVMs or Amazon EC2 spot market where consumers can bid for single virtual machines as well as for fleets of virtual machines. Hence, autonomous bilateral multi-round negotiations (Bazaar-negotiations) are a promising approach for trading services on future Cloud markets. The notion of such a Cloud market is not a simple buyer-seller relationship, there are numerous other intermediaries involved in it. In this paper we elaborate the role of resellers (as an example of an intermediary) from an economical point of view and developed negotiation strategies for them. The introduced concepts are evaluated by simulating Cloud markets with resellers using a CloudSim-based simulation environment which we developed.**

***Keywords*-Cloud Market; SLA Negotiation; Simulation; Cloud Reseller;**

I. Introduction

A Cloud market (also known as Cloud service market) is the culmination point of stakeholders providing and requiring services. Recently, Gartner predicted a growth of 18% for the Software as a Service (SaaS) market and 28% for the Infrastructure as a Service (IaaS) market in 2018 [1]. SaaS providers such as Salesforce or Mircosoft use subscription models where consumers have to pay an annual or a monthly fee [2]. Infrastructure services such as virtual machines are mainly traded on provider platforms whereby Amazon Web Services (AWS) with the EC2 platform is the market leader [3]. Amazon EC2 supports four different marketspaces for trading virtual machines: (i) On the *reservation marketspace* consumers and providers have a long-term contract with a fixed, predefined price. (ii) A *consumer-to-consumer marketspace* exists where consumers can resell virtual machines with a long-term contract - which were purchased on the reservation market - to other consumers. (iii) Consumers on the *on-demand marketspace* pay per hour for a virtual machine whereby the prices are higher than the prices on the reservation marketspace. (iv) The *spot marketspace* is more dynamic: here consumers can bid for virtual machines. The higher the bid, the higher is the chance of getting the virtual machine.

The recent development of Amazons spot marketspace - with spot blocks and spot fleet management - shows that dynamic Cloud markets are gaining popularity. Nevertheless, consumers usually purchase Cloud services directly from providers via web portals. On the contrary, we envision a whole network of market participants which negotiate autonomously with each other against end-user requirements resulting into binding SLAs and consequently to a temporary value network. During negotiation the participants exchange offers and counteroffers - such negotiations are called Bazaar-negotiations - see e.g. [4], [5] for our previous work on this topic. Specifications such as the WS-Agreement Negotiation protocol [6] support the development of such Bazaar-based Cloud markets. The notion of such a dynamic Cloud market is not a simple buyer-seller relationship, there are numerous other intermediaries involved in it. So in industry related literature such as in [7] it is described that *multiple global Cloud providers*, *local players*, and *private Cloud capacity*, underpinned with *different contract types* foster the economic model of a Cloud broker. But also scientific literature such as the papers of Weinmann [8] or Foster [9] consider intermediaries as important players on future Cloud markets - see also [10], [16], [11]. The roles of intermediaries in such value chains is manifold: they could e.g. act as *usual* resellers but they could also act as trust managers or service compositors. Business strategies for as well as a detailed analysis of the impact of such intermediaries are missing.

Following the vision of [12] not only big providers such as Amazon but also SMEs should be able to sell their unused computational resources. For finding appropriate providers we could either assume that consumers know all providers (which is unrealistic and unfavourable for non-prominent providers) or that they are able to discover all providers using a central directory. Hence, such a directory is the main pillar for ensuring sufficient liquidity on markets [13]. In the last decade the vision of such central directories for Cloud services and web services was lost: So the UDDI has never been widely adapted [14] and comparable directories for the Cloud market are not existing. E.g. the *Deutsche Boerse Cloud Exchange* [15] - a Cloud trading platform for finding and comparing IaaS providers - closed in 2016. The absence of a central directory on the current emerging Cloud markets reveals the need for intermediaries such as resellers which act as directory for consumers and providers. Contrary to directories, resellers are active profit-oriented participants of value chains. Helping the provider in expanding business and reselling services of Cloud providers are the main roles of a Cloud reseller [16]. Their economical effect is analyzed in this paper and validated using a CloudSim-based simulation environment which we developed. We see this paper as a first step towards an analysis of Cloud intermediaries and so we focus on Cloud resellers first. In [12] we introduced our basic vision of a Cloud market without analyzing intermediaries such as resellers. In this paper we use IaaS as an example. However, the approach is considered to be appropriate for other service types as well. The introduced Bazaar-based approach implies an exchange of offers and counteroffers which leads to an overhead compared to transactions on non-dynamic Cloud markets: consumers purchase services directly - without any delay. Therefore, we envision the co-existence of different cloud marketspaces such as described in [17].

The remainder of the paper is structured as follows: In the following section we present related work. An economic analysis of the Cloud reseller is introduced in section III. The use cases which we executed for evaluating our theory are described in section IV. The paper ends with the conclusion and further research in section V.

II. Related Work

We structure this section into two parts. In the first part we summarize current research on Cloud markets. Relevant negotiation strategies used for the negotiation of SLAs on Bazaar-based Cloud markets are analyzed in the second part.

Today, providers and consumers trade services in a supermarket fashion [18], [6]: Providers offer their resources in form of services to consumers at fixed prices. Consumers can neither negotiate the price nor the characteristics of the services. Hence, the approach is also known as the *take-it-or-leave-it approach*. According to Dastjerdi and Buyya the dominance of the supermarket approach is underpinned by the limited automatization of the negotiation step in the SLA lifecycle, which encompasses the following steps: Service Discovery, SLA-Negotiation, Monitoring, Scaling and Decommissioning [19]. Amazon's EC2 spot market shows that Cloud providers are already adapting more dynamic market forms: At the EC2 spot market consumers can bid for virtual machines (VMs). If the current spot market price is lower than the bid, consumers can use the required virtual machine. On the contrary, if the current spot market price is higher than the bid, the virtual machine can not be used. Consumers benefit from this market as the spot market price is usually significantly lower than buying the virtual machine at a fixed price from Amazon [20]. At the same time Amazon is able to increase profit by selling unsold resources [18]. The Cloud provider Virtustream goes one step further by charging consumers based on used μVMs, which are intended as unit for measuring computational resources[1]. A generic model for managing Cloud services is described in [21]. The paper of Buyya et. al. is probably the most popular paper which envisions a Cloud market [22]. Thereby the authors describe a typical consumer-provider market where consumers and providers trade services. Negotiation is considered as one form of trading services. With a focus on Cloud market capabilities the paper neither describes technical insights nor conceptual market structures. Such a simplified consumer-provider Cloud market was also envisioned in [23], [24] as well as by the authors of [25]. A detailed description of concepts or technical architectures is missing in these publications. The authors of [26] and [18] consider a simplified consumer-provider market too. Both envision a Cloud market where consumers buy resources of a provider via auctions. Also in [27] the authors envision an auction based approach for trading Cloud services. The authors of [28] emphasize an auction based consumer-provider market. In more detail, the authors envision that consumers can buy resources by participating in auctions or on a commodity market.

Negotiation strategies for negotiation between consumers and providers on Bazaar-based markets are already existing even if they do not consider economical principles [29]. Thereby, consumer and provider exchange offers until a binding SLA is formed. In this paper we use the terms offer and counteroffer synonymously. During our related work analyses we identified two different groups in the scientific community which are designing bilateral negotiation strategies: The first group tries to apply game theoretical approaches, while the second group considers game theoretical approaches as inappropriate for negotiations. The main motivation of the second group for rejecting game theoretical approaches is the assumption that a negotiation strategy usually has to consider unknown preferences and strategies of negotiation partners [30], [31]. In the paper at hand we build upon the assumption of incomplete information and therefore we focus in this section on approaches belonging to the second group. Buyya and Dastjerdi propose a consumer and provider negotiation strategy which is mainly time-dependent [19]. The authors assume that consumers and providers have a deadline at which they stop negotiation. The more time passes the higher is the willingness of a provider and consumer to form a compromise. A highly cited paper in the community is [30]. Thereby the authors introduce negotiation strategies for participants in consumer-provider markets. These generic negotiation strategies consider a deadline as well as estimated preferences of the negotiation partner. Similarly, the authors of [31] use a time-dependent negotiation strategy and estimate the preferences of the negotiation partner using particle swarm optimization. Bilateral negotiation strategies are summarized in the surveys [32] (including re-negotiation strategies) and [29].

Our related work analysis shows that the scientific com-

[1]See http://www.virtustream.com/software/micro-vms for more information

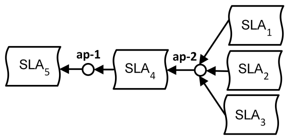
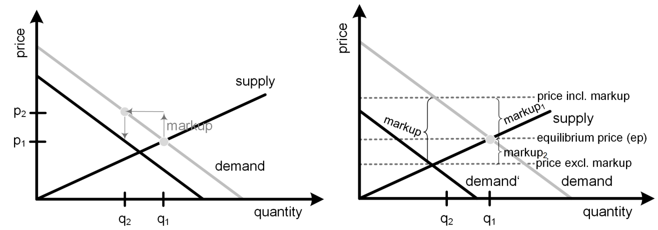


Figure 1: Service chain on Cloud markets



(a) Shift of demand curve due to the introduction of the markup

(b) Division of the markup between consumer and provider

Figure 2: Impact of reseller markups on demand and supply

munity developed visions, concepts and strategies for Cloud markets. A common shortcoming found in all publications is their limitation to the classical consumer-provider market. We have not found any publication envisioning a complex negotiation network or corresponding negotiation strategies.

III. Cloud Resellers

Cloud markets are underpinned by service chains. Service chains are defined by [33] as a set of services provided by businesses which are interconnected with binding SLAs. On Bazaar-based markets Cloud service chains are self organizing structures that emerge as result of successful negotiations among various service providers. In our previous work [12] we formally described such service chains. Thereby consumers, providers as well as intermediaries are represented by so called aggregation points (ap). Aggregation points can be formally described as a tuple ap=$< aggsla, KB >$ where KB represents the knowledge base of the aggregation point which contains inter alia a negotiation strategy and $aggsla$ represents a set of aggregated SLAs which the aggregation point established with other aggregation points, so $aggsla = \{SLA_m, ...SLA_{m+n}\}$. An example is visualized in figure 1. Here ap_2 provides the service described in SLA_4 by composing the services described in $SLA_{1,2,3}$. Aggregation point ap_1 provides the service described in SLA_4. The services which the aggregation points offer depend on the services which they use from other aggregation points. If e.g. SLA_1 guarantees a reliability of 50% then the composed service described in SLA_4 has at maximum a reliability of 50%.

We envision a Bazaar-based market where such service chains are established by autonomous Bazaar-negotiations. In this section we make an economical analysis of the resellers followed by an evaluation using the simulation environment developed by us. On Cloud markets, resellers are represented by separate aggregation points. A reseller usually sells the services bought from the provider at a higher price in order to make profit. The offers exchanged during negotiation e.g. between the two aggregation points a and b are defined as follows: $o_{a \to b}(t) = \{< SLA, p, m >\}$. Each offer is represented as a tuple where SLA represents the description of the service, p represents the price, m represents the type of offer and t is the time when the offer is sent from a to b. The type of offer is described in protocols such as WS-Agreement Negotiation [6]. Recently, in [34] the WS-Agreement Negotiation specification was extended by introducing the *binding* state representing a binding SLA. The difference between the price paid to the provider and the price charged by the consumer is called markup. So an offer i received from the provider, $i \in o_{provider \to reseller}(t)$, which is forwarded to the consumer, $j \in o_{reseller \to consumer}(t + \epsilon)$, fulfills the following condition $i.p < j.p$. The effect of such a markup is illustrated in figure 2a. It shows a typical market with a supply curve and a demand curve (for now, we ignore the black demand curve). The demand curve represents the consumers willingness to pay. The left part of the demand curve represents consumers which are willing to pay a high price for the traded good on this market. At a certain price only consumers which have a higher willingness to pay buy the good which is reflected by the low demand at high prices. If the price on the market decreases, more consumers are willing to buy the traded good as their willingness to pay exceeds the price. Similarly, the supply curve represents the cost of providers for supplying the traded good. The left side of the supply curve represents providers which have low costs and would supply the traded good on the market at a low price reflected by the low quantity. The intersection of the demand curve and the supply curve forms the market equilibrium. At this price the provider's supply matches the consumer's demand and so the price is called market clearing price or equilibrium price.

In the next step we introduce resellers on the market model which buy the traded good from the provider and sell it to the consumers. Consumers and providers are not trading goods directly anymore. Assume that the market price before the reseller enters the market is p_1 as shown in figure 2a. The reseller charges a markup of e.g. 1$ which has to be transferred by the consumer. So the consumer has to pay at the end the price p_1 plus the markup of 1$. From the consumers point of view it does not matter if the reseller or the provider takes the money. For the consumer it seems like it has to pay price p_2 which contains price p_1 and the markup. In other words, the consumers demand at price p_1 (including the markup) as much as if the price would be p_2. Hence, due to the markup the gray demand curve shifts inwards represented by the black demand curve. The shifted demand curve and the supply curve form a new market equilibrium. Compared to the initial market equilibrium the new market equilibrium has a lower price and a lower quantity.

The market participant which has to transfer the markup (which is the consumer in our example) has not necessarily to pay the markup. This phenomenon is illustrated by figure 2b. Due to the new market equilibrium the price the consumer pays to the provider is lower than initially. Additionally, the consumer has to transfer the markup. So in total the consumer has to pay more as in the scenario without a markup: it pays the *price incl. markup* instead of the *equilibrium price*. The provider receives in the initial scenario a higher price than in the scenario with the markup: it receives the *price excl. markup* instead of the *equilibrium price*. So it looses money too. The shares of the consumers and providers on the markup are denoted with $markup_1$ and $markup_2$ in figure 2b. At the end, the elasticity of the demand and supply curve determines who pays the markup (consumer or provider). The elasticity is represented by the amount of the slope. It is calculated as shown in the following: $elasticity_{price} = |\frac{dQ/Q}{dP/P}|$. The higher the elasticity of the demand or supply the smaller is the share of the markup the consumer and the provider have to pay. This is because the elasticity can be interpreted as the flexibility of consumer and provider. For example a consumer with a high elasticity is price sensitive because it has alternatives making it easy for it to leave the market. A consumer with a low elasticity is not very price sensitive. This is because the consumer needs the good traded on the market and has no alternatives so that the consumer has to accept a higher price. Indeed the described effects are comparable to the one of taxes described in literature such as [13].

Before analyzing the reseller from a market efficiency's point of view we describe how market efficiency is measured in basic economic literature such as [13]. On an usual consumer-provider market, market efficiency is the sum of the following components. **Consumer Surplus:** The consumer surplus is the difference between price paid and the willingness to pay of all consumers buying the good traded on the market. **Provider Surplus:** The provider surplus is the difference between price received and the cost for each provider selling a good on the market. Figure 3a shows a market scenario without resellers. The market efficiency (consumer surplus and provider surplus) is represented by the triangle which is highlighted on the left side of the market equilibrium. With the introduction of the reseller a further component occurs: **Resellers Surplus:** The reseller surplus is the markup the reseller charges. These three components are illustrated in the example shown in figure 3b. Compared to the example illustrated in figure 3a the consumer surplus decreases because of two effects: 1) Consumers have to transfer the markup and so the difference between price paid (incl. the markup) and willingness to pay decreases. 2) Some consumers do not buy the good any more: Consumers which have a willingness to pay which is higher than the initial market price (before the intermediary was introduced - see *equilibrium price* in figure 3b) but a lower willingness to pay the new market price including the markup (see *price consumers have to pay* in figure 3b) do not buy the good any more. As no transaction occurs no further consumer surplus can be gained.

Also the provider surplus decreases compared to provider surplus shown in figure 3b. The effects leading to the reduction are similar to the previously described effects. The reseller surplus is represented by the rectangle between the consumer surplus and the provider surplus. It compensates the loss of consumer surplus and the provider surplus caused by effect 1. This is because each dollar the consumers and providers pay to the reseller is equal to the markup of the reseller. However the introduction of the reseller surplus can not compensate the loss of the consumer surplus and provider surplus caused by effect 2. This is visualized by the black triangle in figure 3b: Due to the reduced number of transactions neither consumer and provider nor the reseller gain surplus. These examples illustrate that the total market efficiency with the introduction of the resellers is lower than without the resellers. The higher the markup the resellers charges, the lower is the market efficiency. In other words, resellers lead to a reduction of market efficiency. With a focus on improving market efficiency, it would be better if consumers buy services directly from providers. Therefore consumers and providers need a central directory where market participants are listed. As the examples of the UDDI [14] and the Deutsche Boerse Cloud Exchange [15] show, the introduction of such central directories is not trivial. Indeed, to the best of the authors' knowledge, such a directory is neither existing nor planned for Cloud markets. Hence, resellers play a vital role of future Bazaar-based Cloud markets. They are profit oriented market participants which can play the role of central directories. The core contribution of resellers is their knowledge of the existence of market participants. There are three scenarios in which resellers can make profit: (i) **Attractive Price.** For example a consumer can use resellers to buy services from providers which the consumer itself does not know. The unknown provider is e.g. attractive for the consumer if it offers low prices so that the markup can be compensated. In other words, the price the provider charges including the markup has to be lower than the prices of the providers from which the consumer can buy directly. **Example:** A SME provider loses a significant consumer and tries to minimize its loss by selling the unsold resources temporary at attractive prices. (ii) **Resource Availability.** Resellers expand the number of potential providers which consumers can use. So the reseller offers additional services to the consumer in cases in which all providers which the consumer knows are overbooked. **Example:** In high-demand periods prominent providers will not be able to host additional consumers. Here, other providers might be able to sell resources. (iii) **SLA compliance.** The reseller may know providers which comply to strict SLA criteria such as availability zones. **Example:** Changes of laws (e.g. enforcement of domestic data processing or sanctions) might prohibit the usage of currently used providers so that local providers have to be used. In all other situations resellers are not providing additional value and are squeezed out of the market. We identified the following three basic strategies for resellers whereby the type of offer *binding* indicates that a binding SLA is formed based on the SLA described in an offer $o =< SLA, p, m >$.

Neutral Strategy. According to this strategy, the reseller forms binding SLAs with a provider and a consumer at the same time. Hence, it can avoid buying services for which no consumer exists or selling services for which no provider exists. R represents the set of all transactions of a reseller whereby each transaction is represented as a vector (i, j):[2]

$$\begin{aligned}&(i,j) \in R, i \in \{o_{provider \to reseller}(t) \cup o_{reseller \to provider}(t)\}\\ &|m = binding \Leftrightarrow j \in \{o_{reseller \to consumer}(t) \cup \\ &o_{consumer \to reseller}(t)\}|m = binding \wedge j.SLA \subseteq i.SLA\end{aligned} \tag{1}$$

For each binding SLA with the consumer a corresponding binding SLA with the provider is necessary and vice versa so that $\forall (i, j) \in R : \nexists (m, n) \in R/\{(i, j)\}, m = i \vee n = j$.

Buy First Strategy. According to this strategy, the reseller purchases services even if it has not found a consumer yet. This gives the reseller the opportunity to purchase services at temporary low prices.

$$\begin{aligned}&\forall i \in \{o_{provider \to reseller}(t) \cup o_{reseller \to provider}(t)\}|m = \\ &binding \implies \nexists j \in \{o_{reseller \to consumer}(t) \cup \\ &o_{consumer \to reseller}(t)\}|m = binding \wedge j.SLA \subseteq i.SLA\end{aligned} \tag{2}$$

Resellers using this strategy have transactions $(i, j) \in R$ where j is *null* - until a consumers buys the service at time $t + \Delta_j$. In such a case the following condition holds:

$$\begin{aligned}&i \in \{o_{provider \to reseller}(t) \cup o_{reseller \to provider}(t)\}|m = binding \\ &\implies \exists j \in \{o_{reseller \to consumer}(t + \Delta_j) \cup \\ &o_{consumer \to reseller}(t + \Delta_j)\}|m = binding \wedge j.SLA \subseteq i.SLA\end{aligned} \tag{3}$$

Sell First Strategy. The sell first strategy is contrary to the buy first strategy. Here, the reseller sells services to a consumer for which it has not found a provider yet. The reseller tries to avoid losing a consumer because of the (temporary) absence of a fitting provider for serving the consumer as the following equation shows:

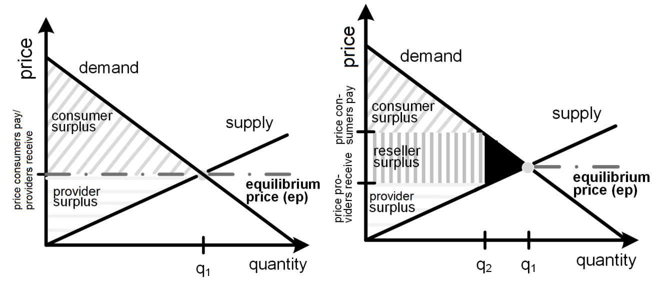
$$\begin{aligned}&\forall j \in \{o_{reseller \to consumer}(t) \cup o_{consumer \to reseller}(t)\}|m = \\ &binding \implies \nexists i \in \{o_{provider \to reseller}(t) \cup \\ &o_{reseller \to provider}(t)\}|m = binding \wedge j.SLA \subseteq i.SLA\end{aligned} \tag{4}$$

Resellers using this strategy have transactions $(i, j) \in R$ where i is null - until a provider sells a fitting service at time $t + \Delta_i$. In such a case the following condition holds true:

$$\begin{aligned}&j \in \{o_{reseller \to consumer}(t) \cup o_{consumer \to reseller}(t)\}|m = \\ &binding \implies \exists i \in \{o_{provider \to reseller}(t + \Delta_i) \cup \\ &o_{reseller \to provider}(t + \Delta_i)\}|m = binding \wedge j.SLA \subseteq i.SLA\end{aligned} \tag{5}$$

The theory which we introduced here is evaluated with the scenarios introduced in section IV - whereby we focus on the Neutral Strategy and use virtual machines as an example of a service. The evaluation of the other strategies is out of the scope of this paper and part of our further research.

[2]We use $j.SLA \subseteq i.SLA$ to ensure that for all SLA parameters such as storage or reliability - which are guaranteed in $j.SLA$ - are equal or smaller than in $i.SLA$. This conditions makes sure that the reseller is able to deliver the appropriate service which it sold to its consumer.



(a) Measuring market efficiency before introducing a reseller (consumer surplus and provider surplus)

(b) Measuring market efficiency with reseller (consumer surplus, provider surplus and reseller surplus)

Figure 3: Effect of markup on the market

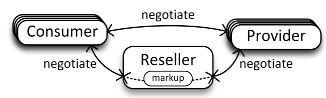


Figure 4: Simulated market structure

IV. Evaluation

To analyze our Cloud market scenarios with resellers we extended the CloudSim-based simulation environment. Therefore, we used the CloudSim plugin introduced in [5] which we extended to simulate intermediaries such as resellers. The steps to create a simulation are the following: first, the market participants which should attend the market have to be defined. Second, a negotiation strategy has to be assigned to them. Finally the simulation can be executed. After the simulation was executed the final resource allocation can be analyzed. The subject of negotiation in our simulation environment are virtual machines (as an example of an infrastructure service). For the measurements of the market efficiency we used the Bazaar-Score developed in [35]. It is a specific metric developed for Bazaar-based markets. The Bazaar-Score is a sum of the consumer Bazaar-Score, the provider Bazaar-Score and the reseller Bazaar-Score. The consumer Bazaar-Score is basically the difference between price paid and willingness to pay, the provider Bazaar-Score represents the difference between price received and cost while the reseller Bazaar-Score is identical to its markup. For more information about the Bazaar-Score see [35]. In the use case explained in the next section the Bazaar-Score is used as key metric for comparing the different scenarios.

With the use cases presented in this section we evaluate the resellers in market situations with complete information (all consumers know all providers) as well as in situations with incomplete information (consumers know some but not all providers). In all scenarios we use virtual machines as an example of a service. The market structure which we simulate is depicted in figure 4. There are three different types of market participants: consumers, providers and resellers. Resellers modify received negotiation messages by adding

Table I: Simulation parameters

Parameter	Value	Parameter	Value
Consumer			
w_{RAM}	0.01	$w_{ProcessingPower}$	0.01
$w_{Storage}$	0.01	w_{Price}	0.97
min_{RAM}	1024 MB	max_{RAM}	7168 MB
$min_{\text{Processing Power}}$	10000 MIPS	$max_{\text{Processing Power}}$	30000 MIPS
$min_{Storage}$	102400 MB	$max_{Storage}$	1024000 MB
min_{Price}	3$	max_{Price}	420$
Provider			
A_{RAM}	0.8	$A_{ProcessingPower}$	0.8
$A_{Storage}$	0.8	w_{RAM}	0.5
$w_{Storage}$	0.25	$w_{\text{Processing Power}}$	0.25
MinRP_i	rand(0.5,1)	MaxRP_i	rand(100,140)

their markup and forward them to other market participants. If two participants agree on the price and on the virtual machine characteristics, they form a binding SLA. A virtual machine is characterized using the following descriptors (see [36]): (i) processing power, (ii) storage, (iii) RAM, and (iv) price. These characteristics are negotiated. Therefore consumers, providers and resellers use negotiation strategies. We implemented the time-dependent negotiation strategies introduced in [19] which was refined in [37]. Thereby, consumers as well as providers have a strict negotiation deadline. This means that the negotiation is stopped after the deadline is reached. An intuitive example of the time-dependent strategies is given in the following: The provider starts with offers which have a high utility for it. These offers are located on the lower right corner in the utility-utility plot. The consumer (broker) starts with offers which are located on the upper left corner of the utility-utility plot. These offers have a high utility for the broker. Over time, the consumer as well as the provider make offers which have also value for the negotiation partner. So the offers of the consumer and the provider move to the center of the utility-utility plot. In the shown example consumer and provider do not form a binding SLA as the utility values of their offers are not overlapping.

In the following we describe the reseller strategy only. The consumer as well as the provider strategy are published online[3]. We used classical markup strategies as reseller strategies in order to validate our theoretical concepts. In our further research we will develop more advanced strategies e.g. time-dependent strategies.

During negotiation the reseller forwards negotiation messages from providers to the consumers and vice versa. Each negotiation message is modified: the price is increased/decreased representing the markup of the reseller. For the consumers resellers appear like providers, and for the providers resellers appear like consumers.

For evaluating the impact of resellers on Cloud markets we executed several scenarios with 50 consumers and 50 providers. The consumers are created with increasing minimum price and maximum price (min_{Price}, max_{Price}). The providers where created with an increasing minimum resource price and maximum resource price ($\text{MinRP}_i, \text{MaxRP}_i$). The initial prices which we used are shown in table I. For each further consumer/provider we incremented both values (min_{Price}, max_{Price}/$\text{MinRP}_i, \text{MaxRP}_i$) by 5$. This was done to simulate demand and supply curves as shown in figure 2a. Further, to approximate the idealized example shown in figure 2a, all consumers have identical preferences. In efficient markets consumers with the highest willingness to pay buy from providers with the lowest cost [13]. So not all consumers and providers will find a matching partner.

Scenario Results. Table II summarizes the scenarios which we executed with our simulation environment. The first nine scenarios are visualized in figure 5. For each scenario the total Bazaar-Score, the Bazaar-Score of the datacenters (providers), the Bazaar-Score of the brokers (consumers) and the Bazaar-Score of the resellers are shown. In the scenarios we changed the resellers markup strategy as well as the knowledge of the consumers and providers: In scenario 1 consumers know all providers while e.g. in scenario 2 the consumers know only every second provider.

The executed scenarios are grouped into four classes:

Reseller charges 5% markup. In the first three scenarios the reseller charges 5% of the price as markup. In scenario 1 the reseller does not make profit. All the consumers buy the services directly from the providers to avoid paying the 5% markup. Hence, the reseller is squeezed out of the market. In the second scenario the consumers know only 50% of all providers. The reseller still knows all providers. Some consumers prefer to buy virtual machines from the reseller as it can offer the VMs at a lower price than the already known providers. This leads to a decrease in the consumer and provider Bazaar-Score but increases the reseller Bazaar-Score. However, some consumers and providers do not trade the virtual machine any more: because of the markup the reseller charges the price consumers have to pay (incl. the markup) is higher (exceeds willingness to pay) and the price providers receive is lower (under costs). These are the consumers and providers which are close to the market equilibrium shown in figure 3b (black triangle). Hence, the total Bazaar-Score decreases. In scenario 3 the effect is stronger: Here, all transactions (traded VMs) are sold by the reseller.

Reseller charges 50% markup. In scenario 4 we get the identical result as in scenario 1: Consumers buy directly from the providers. In scenario 5 and 6 the effect observed in scenario 2 and 3 is reinforced: Due to the high markup the number of transactions which the reseller charges is reduced leading to a low total Bazaar-Score. The reseller profits from the high markup. Even if e.g. the number of transactions drop in scenario from 6 to 17 (compared to 37 in scenario 3) the total Bazaar-Score is higher than in scenario 3. So the resellers profit-maximizing strategy leads to a reduced total Bazaar-Score. The previous described theoretical effect shows up that a higher markup leads to a lower Bazaar-Score.

[3]http://homepage.univie.ac.at/a1347629/appendixcloud.pdf

Reseller charges 30$ markup. In the scenarios 7-9 the reseller used a fixed markup. Scenario 7 is identical to scenario 1 and 4. Scenario 8 and 9 lead to similar total Bazaar-Scores like in the scenarios 2 and 3: the effects of the markup remain the same: the number of transaction is reduced because the higher prices for consumers/the lower prices for providers prevent consumers and providers from forming binding agreements.

No Reseller. In the scenarios 10-12 (not shown in figure 5 to save space) no reseller was attending the market. These scenarios lead to the lowest total Bazaar-Score: Consumers can only form binding SLAs with the providers which they know. Unknown providers which would offer a cheaper (even after the markup is added) do not participate on the market.

Our simulation results show that the resellers have an important position in the market where a central directory is missing. In the absence of the reseller, the Bazaar-Score is dropping significantly. Indeed, the scenarios 5 and 6 show that resellers have a great market power. Hence, the government has to ensure that there is enough competition between resellers in order to avoid monopoly situations. We want to emphasize that the shown scenarios do not consider e.g. that the Cloud market is dominated by several big providers. Further simulation for a complete evaluation of these resellers is part of our further research.

V. Conclusion and Future Work

In this paper we elaborated the role of the Cloud reseller on Bazaar-based Cloud markets. Due to the absence of a central directory on Cloud markets consumers face the problem that they do not know all providers and vice versa. This reveals the need for intermediaries such as Cloud resellers which are active market participants which act as a directory: They buy services from providers and resell them to the consumers. Thereby they charge a markup. Our simulation results show, that resellers have a significant impact on market efficiency.

In our further research we will use our developed simulation environment to analyze and identify business strategies for resellers. Thereby, we envision more dynamic markup strategies (e.g. time-dependent strategies). A further field of research which needs more investigation is the competition between resellers as well as smart contracts which is a promising technique for maintaining binding SLAs.

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Table II: Simulation results

Scenario	Reseller Markup	Total Bazaar-Score	Reseller Bazaar-Score	# binding SLAs (Reseller)
Scenario 1: Consumers know all providers	5%	35426	0	0
Scenario 2: Consumers know 50% of the providers	5%	34509	463	18
Scenario 3: Consumers know no provider	5%	33591	962	37
Scenario 4: Consumers know all providers	50%	35426	0	0
Scenario 5: Consumers know 50% of the providers	50%	25340	1662	8
Scenario 6: Consumers know no provider	50%	15324	3946	17
Scenario 7: Consumers know all providers	30$	35426	0	0
Scenario 8: Consumers know 50% of the providers	30$	34511	720	18
Scenario 9: Consumers know no provider	30$	33595	1478	37
Scenario 10: Consumers know all providers	–	35426	0	0
Scenario 11: Consumers know 50% of the providers	–	18056	0	0
Scenario 12: Consumers know no provider	–	0	0	0

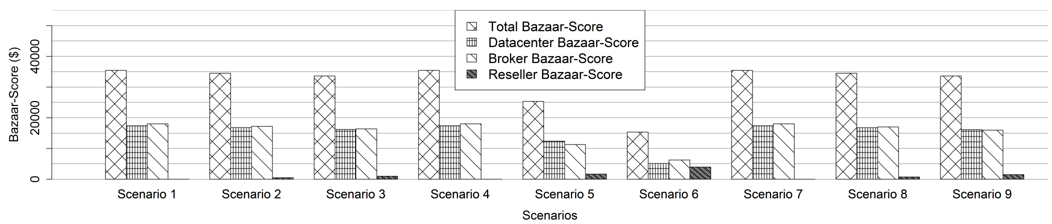

Figure 5: Simulation results for scenarios 1-9

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