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Model for Incentivizing Cloud Service Federation

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Model for Incentivizing Cloud Service Federation

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Abstract

Model for Incentivizing Cloud Service Federation

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In cloud computing, big service providers rule the market due to the economies of scale. A cloud federation presents a possible solution that allows small cloud providers to increase their competitiveness by making alliances with one another, thus forming a network with shared resources. Previous research suggests several different variables that may incentivize the participation of a selfish cloud provider, such as cost disparity, big competitors, and an efficient revenue sharing mechanism. It can be assumed that each individual cloud provider aims to maximize its profits and will choose to make alliances that provide it a constant benefit. For deciding on whether to federate or not, cloud providers take into consideration whether the federation-underlying revenue sharing will yield them an increase in profits.

The proposed study models the interactions between selfish heterogeneous agents in a repeated game that aims to maximize individual profits. Each agent starts off as an individual and is allowed to change its strategies and federate with other providers in order to improve its own performance. By looking at the speed of collaboration and overall profit of individuals, we can determine which specific incentives encourage the creation of cloud federations.

Keywords: cloud federation, revenue sharing, business incentives, SME, repeated game

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Chapter 1 Introduction

1.1 Cloud Computing

Cloud computing is commonly defined as "a model for ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources." It is characterized by the provider having a pooled repository of resources that provides a measured service with on-demand access for consumers (Mell & Grance, 2011). Cloud computing is usually divided into three categories, depending on the main focus: software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS).

This new model gathered the attention of the world quickly and became one of the fastest-growing IT markets in the last few years. In fact, 2017 data show that it is a 148 billion dollar industry that is growing at a 25% rate annually, with a shifting tendency from infrastructure towards services (Synergy Research Group, 2017). In recent years, the once emergent cloud computing has become more widely used and deployed in the IT market. Each year an increasing number of users are getting on-demand access to services through the cloud. As the market grows, the provision of on-demand access to software, platforms, and infrastructure resources allows for the achievement of economies of scale (Dikaiakos, Katsaros, Mehra, Pallis, & Vakali, 2009).

1.2 Problem Description

There are two main problems in the current cloud computing market. The first is related to the volatile change in the number of users. In a market where instant on-demand access is required, providers can find it difficult to keep up with the user requirements of computational resources (Mashayekhy, Nejad, & Grosu, 2015). Service providers cannot easily scale their capabilities due to the high initial cost of the infrastructure and the upkeep cost that may ensue after customer overall demand drops.

The second problem lies in the anti-competitive externalities of the economies of scale in the cloud service sector. Recent data show that Amazon controls over 30% of the cloud infrastructure market share, and 50% is owned by 24 other leading companies, leaving less than 20% of market share for medium and small providers (Synergy Research Group, 2016). Due to the highly efficient and cost-effective infrastructure of the big cloud providers (CP), small and medium-sized CPs can be hard pressed to compete against them and their superior resources, service quality, and prices.

Cloud federation has been seen as a possible solution for both issues. A horizontally dynamic cloud federation allows small CPs to collaborate and gain access to economies of scale by increasing the amount of infrastructure resources available to them, and it also helps by ensuring the users' quality of service and minimizes costs (Hassan, Hossain, Sarkar, & Huh, 2014).

1.3 Research Objective

Despite the promises of a cloud federation, it is important to state that there is no functional federation in the open market. Extensive research has been done on optimizing the performance of certain federations and on dealing with challenges, such as interoperability and resource sharing.

The main objective of this study is to understand the variables and environments that would encourage businesses to collaborate with each other and for alliances in the cloud computer sector. Some of the questions addressed in this study are: What variables show promising incentives to businesses that collaborate? What are the effects of such variables and environments on the creation speed and performance of cloud federations? What happens to cloud federations when there are demand changes?

To answer these questions, we need to simulate independent CPs in a market. For this simulation, agent-based modeling (ABM) is considered. ABM is a method for modeling social interactions between agents, each of whom has its own behavior, objectives, characteristics, and/or environment. These models generate heterogeneous interactions that mimic reality and thus allow to study whether observed phenomena can be explained by mechanisms (Helbing, 2012). This type of modeling will allow us to shape each CP with different capabilities and behaviors, which will aid in getting more meaningful results. The model introduces selfish CPs into the Cloud Market and allows them to federate to increase their profits.

This paper makes contributions to the understanding of the formation of Cloud Federations. The results of the simulation in each scenario provide with some insights regarding how the different variables affect the number, size and speed of federations.

The implications of our findings are that the effectiveness of the revenue sharing scheme and other environmental variables, such as cost and capacity disparity, incentivize cloud providers into mutual collaboration, while also affecting the number and shape of the resulting federations.

The subsequent sections of this paper are organized as follows. Chapter 2 features a revision of previous research done on the subject, focusing primarily on determining the variables and environments that other authors have identified as necessary or desirable for a cloud federation. Chapter 3 proposes an agent-based model that simulates a cooperative game mechanism between selfish CPs, which will help simulate and benchmark the variables identified in the literature review. In Chapter 4, the results of the simulations are presented in detail. Chapter 5 concludes with a summary of the main findings and implications of the present study.

Chapter 2 Related Work

After a thorough review of the cloud federation literature, several variables were identified as important for federation incentivizing. Among them, the concept of capacity and revenue sharing is perhaps the most prominent one. Resource and revenue sharing mechanisms are how the CPs in a federation share their computational resources and, more importantly, the profits that result from the collaboration. Having efficient mechanisms is of paramount importance, since they encourage CPs to participate in a federation (El Zant, Amigo, & Gagnaire, 2014). For example, the chicken franchise KFC has a resource and revenue sharing mechanism in which it demands 10% of all stores' revenue, and in exchange they deal with branding, advertisement, and access to ingredients; stores can even collaborate with each other to avoid mutual competition (Yum!, 2017). By choosing to collaborate in this food chain network, business owners can get a steady supply of customers and a stable spot in the market. However, if at any point payment of the 10% revenue is too much for what the franchise provides to the business, then the collaboration would naturally end.

Several studies have been conducted on the matter of revenue and capacity sharing, specific to cloud federation and coalitions. Samaan created a revenue sharing mechanism for the spot market of clouds that features self-enforced capacity regulation (Samaan, 2014). Mashayekhy, Nejad, and Grosu (2015) used a game theory model that profit maximizes the resource allocation of a cloud federation. Niyato, Vasilakos, and Kun (2011) and Lu, Wen, and Sun (2012) developed a revenue sharing mechanism by means of linear stochastic programmed games. Guazzone, Anglano, and Sereno (2014) proposed a framework for the formation of cloud federations in a scenario in which cost minimization of energy resources is essential. Wei, Vasilakos, Zheng, and Xiong (2010) proposed a resource allocation mechanism that uses evolutionary mechanisms and auctioning pricing to obtain optimal allocations.

El Zant, Amigo, and Gagnaire (2014) introduced volatile pricing and changing capacities into a revenue sharing mechanism. Xu, Yu, and Cong (2013) suggested that the Quality of Service (QoS) expectation level of users should be considered in the sharing mechanisms.

Besides revenue sharing, some of the papers suggest that the disparity between the CPs can affect the potential profits of the federation and should also be considered. In some of these cases, the disparity comes in the form of the different computational power and storage capabilities of the CPs. In contrast, others suggest that CPs usually have different cost functions that may influence the difference in their revenues, especially in models that consider different types of service requirements.

Finally, the presence of a big provider will also be considered in the simulation. We can suspect that in the presence of a CP with a higher capacity and cost advantage, smaller competitors may be able to “catch up” by choosing to collaborate. While some of the reviewed studies suggest the occurrence of this scenario, none of them elaborate much on its effect.

In summary, previous studies have highlighted different factors that may influence the creation of “guilds” of CPs, in other words, a cloud federation. However, no study has simulated and measured the impact of such factors. A visual guide of the review papers and the variables mentioned in them is presented in Table 1.

Table 1: Variables mentioned in the literature review

	Revenue sharing	**Capacity disparity**	**Cost disparity**	**“Big” competitor**
(Hassan, Al-Wadud, & Fortino, 2015)	√	√	√	
(El Zant, Amigo, & Gagnaire, 2014)	√	√		√
(Hassan, et al., 2015)	√	√	√	
(Niyato, Vasilakos, & Kun, 2011)	√	√		√
(Guazzone, Anglano, & Sereno, 2014)	√	√		
(Xu, Yu, & Cong, 2013)	√	√	√	
(Wei, Vasilakos, Zheng, & Xiong, 2010)	√			
(Mashayekhy, Nejad, & Grosu, 2015)	√		√	
(Samaan, 2014)	√			
(Lu, Wen, & Sun, 2012)	√			

Chapter 3 Experiment Formulation

In this section, I describe the model and the coalition game that is used for the experiment.

3.1 Model

The model consists of a group of independent CPs and a user demand generator. Each CP has a set amount of computational resources in terms of computing units, memory, and storage. The CPs will offer said resources to the users in the form of virtual machines (VMs), as long as they have the capacity for them.

The user demand generator will play the role of the customers. This entity will generate a variable number of users per day (up to 30 users). In order to represent the flexible demands of users, the model considers three types of VMs: general purpose, storage specialized, and computing specialized. The specifications of the VMs are detailed in Table 2 and are modelled after the Amazon EC2 Web Services instances for Seoul (Amazon, 2017).

Each generated user will request a random CP with variable demands. The model uses the Mersenne-Twister algorithm to generate random numbers with a normal distribution. Each demand is comprised of a certain number of VMs, type of VM and duration in days. This will allow us to simulate the volatile changes in demand and help the model to mimic the cloud services market.

For the sake of simplicity, this model presents some limitations regarding the requirements for cloud federation. In this model, there is the assumption that all CPs can trust one another, that there is no administrative cost to collaboration and that CPs have perfect interoperability. Normally, interoperation between CPs incurs a cost that should be covered by the federation. Also, CPs that do not trust each other would hardly collaborate fully, which would impede alliances. Finally, the model assumes that the prices are fixed.

For the simulation, we propose a federation game that allows CPs to create alliances. The game begins with the CPs in full capacity and with no federations. The demand generator will start to send request to the CPs, who in turn will accept the request if they have the capacity to fulfill it.

Table 2: VM specification

	General	**Storage**	**Computing**
Computing units	14	14	31
GBs of memory	16	30	16
TBs of storage	2	6	2
Price per day	$13.96	$20.26	$18.50

The CPs will have the freedom to collaborate with one another. Since each CP is considered a selfish agent that will strive to increase its revenue, they will only federate, if there is an incentive to do so, in other words, increased utility. In this study, we define a CP's utility as their total revenue, defined by the following function.

$$U_i = \sum_{j=1}^{n} VM_{ij} \times p_j$$

Where U represents the total utility of player i, while VM represents the number of VMs of demand j and p represents their price. [18].

In each game, all CPs will measure their utility and then calculate the expected utility of joining or creating a federation. When a CP concludes that it gets more utility by collaborating rather than by working alone, then it will decide to federate. Similarly, CPs in a federation measure the expected utility that they would receive by working alone and will decide to leave or dissolve the federation if it is higher than its current utility.

3.2 Experiment Setup

We define 4 main scenarios that will be used to compare the effect of each of the variables to be studied. The scenarios will focus on revenue sharing mechanisms, capacity disparity, cost disparity, and big competitor.

For the baseline scenario, a group of ten Cloud Providers is considered that only offer the General VM specified in Table 2. All CPs will start with the same capacity limits and costs. As for the revenue sharing mechanism, CPs will get the full revenue of the VMs assigned by the federation. Detailed information of the Baseline scenario is presented in Table 3.

In addition, in order to account for randomness, the simulation will be run 100 times per scenario. The data obtained will be aggregated into a single result that will represent the overall behavior of the model under each of the tested scenarios.

Table 3: Parameters for baseline scenario

Parameter	Value
Revenue sharing mechanism	Assigned VMs
Number of cloud providers	10
Available VM types	1 (general purpose)
Computing capacity (CUs)	500
Storage capacity (TBs)	100
Cost	N/A

3.2.1 Revenue Sharing

Revenue Sharing mechanisms are important to Cloud Federation due to several factors. First, CPs need an effective revenue sharing method to encourage their participation in a federation; in other words, they will only cooperate if they receive a corresponding benefit (Hassan, Al-Wadud, & Fortino, 2015).

Secondly, revenue sharing mechanisms determine how the allocation of revenue will be done. A fair system is needed that ensures that all CPs are properly recompensed for the amount of work that they invested into the federation (El Zant, Amigo, & Gagnaire, 2014). For this study, fairness is defined as self-centered inequity aversion. This term relates to the behavior where “people resist inequitable outcomes; i.e., they are willing to give up some material payoff to move in the direction of more equitable outcomes" (Ernst & Klaus, 1999).

Finally, revenue sharing mechanisms provide the federation with stability. Even if a federation is successfully created, CPs are still free to leave at any time. Well-designed revenue sharing will ensure that the perceived benefit of participating in the federation will be maintained, and therefore no CP will want to break out of the coalition (El Zant, Amigo, & Gagnaire, 2014).

There are several well-known mechanisms for resource sharing in coalition and game theory models. However, each one provides a different benefit, fairness, or stability values to the collaborations. This may affect how the federations are created, and even how they are dissolved. Therefore, it is important that we compare some of the different revenue sharing mechanisms to further test their impact. The parameters of the proposed scenario are depicted in Table 4.

The revenue sharing mechanisms to be considered are:

Assigned Work

In this mechanism, each CP will obtain a revenue share that is proportional to the amount of work it performed (El Zant, Amigo, & Gagnaire, 2014). This is one of the easier mechanisms to implement, since it only considers the contributions of collaborating CPs to calculate the amount of revenue that each one is due. The proportional revenue sharing mechanism is particularly strong in its fairness. CPs that get the VMs will get all the revenue, whereas CPs that shared them will get a benefit in terms of capacity offloading.

Outsourcing

In some instances, cloud federations are seen as a way for a CP to outsource some of its business to another CP. Following this logic, collaborating CPs can implement a mechanism in which the outsourcing provider will get a percentage of the revenue or a fixed fee. This revenue sharing would allow a CP to keep some of the revenue of the business it secured, even though it would not be able to fulfill it alone. For this mechanism, the variable alpha is defined as the percentage of revenue that will be obtained by the CP. For this experiment, alpha will be set to 0.70, 0.75, and 0.9; this will allow for the observation of changes to the federation formation.

Shapley Value

This mechanism is named after Lloyd Shapley, who proposed a method to calculate the overall gain of all alternatives of a player that participates in a game with a large number of agents. The Shapley value is calculated through the function:

$$\varphi_i(v) = \sum_{S \subset N} \frac{(s-1)!\,(n-s)!}{n!} [v(S) - v(S-i)]$$

Where Φ represents the Shapley value, which is the gain of player *i* in game *v*. *S* represents all the possible coalitions, and *n* represents all the available positions of player *i* (Roth, 1988).

Table 4: Parameters for revenue sharing scenario

Parameter	Value
Revenue sharing mechanism	Assigned VMs/Outsourcing (70%, 75%, 90%)/Shapely value
Number of cloud providers	10
Available VM types	1 (general purpose)
Computing capacity (CUs)	500
Storage capacity (TBs)	100
Cost	N/A

In cloud computing, the Shapley value is used to represent the marginal contributions of any CP to the federation it belongs to. In contrast with other revenue sharing schemes, this scheme allows federations to allocate revenue more fairly. This is because the Shapley value can take into consideration other types of contributions made by the CPs, not just the direct work done by them.

3.2.2 Capacity Disparity

In this scenario, CPs are given different capacities in both storage and computing capacity. Some CPs will have the base capacities used previously, whereas others will be more specialized in storage or computational resources. The supply of different types of VMs is also considered in this scenario in order to accentuate the impact of the capacity disparity. Table 5 details the parameter allocation for the capacity disparity scenario.

Table 5: Parameters for capacity disparity scenario

Parameter	Value
Revenue sharing mechanism	Assigned VMs
Number of cloud providers	10
Available VM types	All
Computing capacity (CUs)	CP 1&2 [500] CP 3&4 [1000] CP 5&6 [250] CP 7&8 [500] CP 9&10 [750]
Storage capacity (TBs)	CP 1&2 [100] CP 3&4 [50] CP 5&6 [200] CP 7&8 [150] CP 9&10 [100]

3.2.3 Cost Disparity

All CPs are given the same resource capabilities. However, each CP will have a different cost depending on the type of VM. This simulates how some CPs can have reduced costs due to increased efficiency in their infrastructure or other factors.

In this scenario, profit will be the main indicator of utility. The supply of different types of VMs is also considered in this scenario in order to accentuate the impact of the cost disparity. The cost percentages and other parameters are presented in Table 6.

Table 6: Parameters for cost disparity scenario

Parameter		Value		
Revenue sharing mechanism		Assigned VMs		
Number of cloud providers		10		
Available VM types		All		
Computing capacity (CUs)		500		
Storage capacity (TBs)		100		
Cost		**VM1**	**VM2**	**VM3**
	CP 1&2	80%	80%	80%
	CP 3&4	**70%**	80%	80%
	CP 5&6	80%	**70%**	80%
	CP 7&8	80%	80%	**70%**
	CP 9&10	**75%**	**75%**	**75%**

3.2.4 Big Competitor

In this scenario, we want to test whether a big competitor will affect the behavior of all the other small providers. We define a "big competitor" as a cloud provider that has lower costs and several times more capacity than normal cloud providers. Thus, we define one special CP that will have five times the capacity limit of the other providers, as well as 10% fewer costs. Table 7 details these parameters.

Table 7: Parameters for big competitor scenario

Parameter	Value
Revenue sharing mechanism	Assigned VMs
Number of cloud providers	10
Available VM types	1 (general purpose)
Computing capacity (CUs)	CP 1~9 [500] CP 10 [2000]
Storage capacity (TBs)	CP 1~9 [100] CP 10 [400]
Cost	CP 1~9 [90%] CP 10 [80%]

3.2.5 Volatile Demand

An additional scenario was set in order to observe the behavior of the CPs when there are quick changes in demand. In this scenario, we define four different demand patterns: quick rise, steady rise, quick drop, steady drop.

These new demand patterns are introduced into some of the main scenarios in order to generate a "shock" effect that may or may not affect the behavior of CPs and the formation of federations.

Chapter 4 Results

The simulation was run 100 times per scenario, and the average was calculated to use as the aggregate behavior that will become the result of each environment. The main indicators of performance to be considered are the number of federations created, the number of steps needed for the model to reach equilibrium, and the total revenue of the population. A higher number of federations created could suggest that the particular environment fosters collaboration. Also, while different scenarios can tend towards the same number of federations and revenue, the number of steps to reach such an equilibrium could be different. Some mechanisms may allow CPs to obtain benefits from collaboration before other mechanisms, in other words, before their capacities are threatened. Finally, the total revenue of the population is an indicator of the overall performance of all CPs; a higher figure would mean that more demand was covered because of collaboration.

4.1 Revenue Sharing Scenario

After analyzing the results obtained in the first scenario, I could detect that the revenue sharing mechanism has a significant impact on the way that the federations are formed.

By comparing the results of each of the mechanisms, it is easy to observe their traits. Table 8 shows the average outcome of the 100 simulations that were done for each mechanism.

While the total revenue of the population did not vary significantly in most mechanisms, the Shapley value mechanism performed poorly in this regard, but it was also the fastest in reaching equilibrium. This means that CPs gave up some of their payoffs in order to get a more equitable balance. This is consistent with our definition of fairness.

Table 8: Revenue sharing results

Scenario	Federations	Equilibrium	Total Revenue
No federation	0	0	$133,021.49
"Assigned work" revenue sharing scenario	2.53	52.15	$137,483.52
"Outsourcing 70%" revenue sharing scenario	0	0	$133,021.49
"Outsourcing 75%" revenue sharing scenario	1.61	50.94	$135,582.31
"Outsourcing 90%" revenue sharing scenario	3.28	54.55	$137,865.75
"Shapely Value" revenue sharing scenario	2.4	36.68	$131,646.12

In contrast, the most efficient mechanism for the formation of Cloud Federations, in both size and revenue, is the Outsourcing mechanism. However, the percentage of revenue to be shared is highly significant. If the percentage is not good enough, the CPs will choose to always work by themselves, which is the case if alpha is 70% or below. By comparing the Outsourcing scenarios, we can conclude that if the value of alpha is not considered fair by collaborating CPs, then federation will not happen.

4.2 Capacity Disparity Scenario

In the capacity scenario, the results show a considerable fall in performance in contrast to the other scenarios, yet it still has an increase in comparison with a scenario with no federations and multiple types of VMs. Results are summarized in Table 9. This is consistent with previous studies. CPs with different capabilities and pools of resources have a harder time managing the volatile demand of customers; this is particularly true if there are different types of services and different requirements. In this case, the presence of different VMs causes this effect.

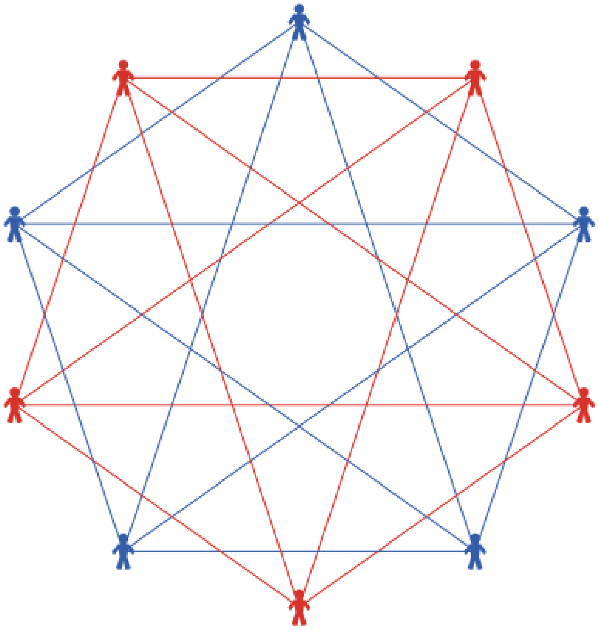
Nonetheless, the simulation showed a very particular behavior in this scenario. In most cases, the CPs that formed federations included members with completely different capabilities, resulting in very heterogeneous federations. Figure 1 shows a very common result in this scenario, which is also the archetype of a perfectly heterogeneous federation, in which no CP has the same capabilities in terms of storage and computing power. This behavior shows that CPs had better performances in federations with different capabilities. The heterogeneous agents allow federations to allocate VMs with a set demand of resources to the CP that would be able to fulfill it more effectively, which in turn helps their allies by saving resources.

Table 9: Capacity and cost disparity results

Scenario	Federations	Equilibrium	Total Revenue
No federation	0	0	$103,223.61
Capacity disparity scenario	2.9	34.62	$114,773.53
Cost disparity scenario	2.49	37.11	$121,276.47[1]

[1] The result of the cost scenario is in profits, instead of revenue. This figure was fixed to the proportionate revenue value. The raw figure is $27,893.59.

Figure 1: Perfectly heterogeneous federations



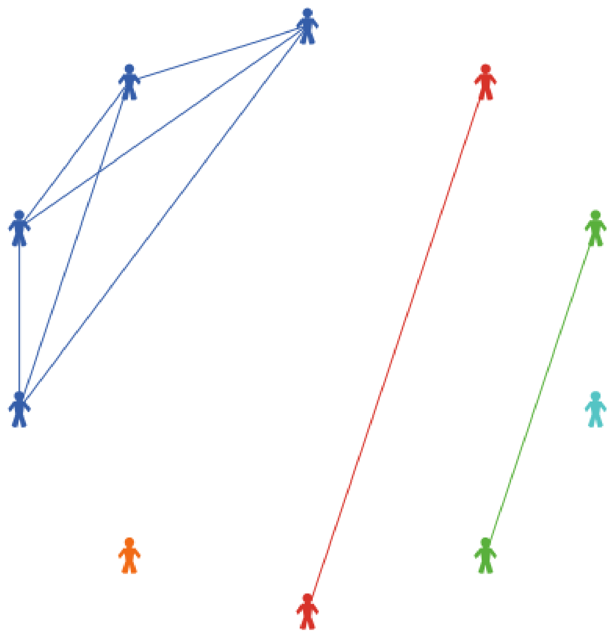
4.3 Cost Disparity Scenario

Contrary to expectations, the results of cost disparity are quite different than the capacity disparity. In terms of number and formation speed of the federations, both models yielded similar results, as can be seen in Table 9. However, the resulting federations were quite different than the previous scenario.

Normally, CPs would strive to assign their resources in the most cost-effective allocation. We would expect CPs to collaborate with one another to gain the strategic advantage that others can provide in terms of cost-effectiveness. This would lead to heterogeneous federations formed by CPs of different capabilities. However, results show that such occurrence is rare in this scenario. Figure 2 shows a typical formation with cost disparity.

From this behavior, we can conclude that gaining an advantage in cost-effectiveness is less important than taking advantage of their unused resources. In other words, CPs will tend to federate towards CPs that let them use as much of their resources as possible, rather than gaining more profit per VM.

Figure 2: Sample federation in cost disparity scenario



4.4 Big Competitor Scenario

Data obtained from this scenario show that the presence of a big competitor boosts the speed of equilibrium in the model. Additional simulations with different revenue sharing mechanisms were conducted to confirm this conclusion. Table 10 presents a summary of these results. Data show that the number of steps required to reach equilibrium is always lower in the presence of a big competitor. From this we can conclude that small and medium-sized CPs may cooperate with one another in order to improve competition against a bigger CP; therefore, it can be considered as an incentive to cloud federation.

Table 10: Big competitor results

Scenario	Federations	Equilibrium	Total Revenue
No federation	0	0	$133,021.49
"Assigned work" scenario	2.53	52.15	$137,483.52
"Big CP" scenario	2.3	43	$129,029.92[2]

4.5 Federation Behavior in Demand Peaks

The simulations also provided a good opportunity to study the behaviors of CPs and federations when there are significant changes in demand. Since the demand generator simulates the demand peaks that are commonly seen in the cloud service market, we can obtain some insight from the results.

First, after observing the behavior of agents in instances where the federations were not very stable, data suggest that CPs usually stop collaborating (leave the federation) when the demand is low. This was particularly strong in simulations that used the outsourcing revenue sharing scheme. From this behavior, we can conclude that CPs will tend to stay collaborating when demand is high, and in cases where they do not need help with resource

[2] This figure was fixed to account for the increase of computational resources to the environment brought by the big CP. The raw figure is $167,738.89.

offloading and could get the whole revenue for themselves, the CPs are better off by stopping collaboration.

Secondly, the model also detected a trend in the formation of federations according to the demand behavior. In cases in which the demand was kept high in the steps where the federations formed, data show that CPs tended to generate more small federations. In contrast, the bigger federations were created when demand rose slowly. This behavior suggests that CPs will quickly form small alliances to deal with a sudden increase in demand, whereas more stable federations require time and stability to form. These observations were commonly seen yet do not represent all cases, so more research should be conducted on the matter.

Chapter 5 Conclusions

5.1 Summary

This paper proposed a model that simulates the interactions of CPs in different environments. Each of these scenarios is used to test and study different variables, identified in previous studies, as incentives to cloud federation. The simulated variables were revenue sharing mechanisms, capacity disparity, cost disparity, and the presence of a “big competitor.” The results of the simulations offer insights regarding the effects of these variables and demand changes on the creation of cloud federations.

5.2 Discussion and Implications

The results obtained in each simulation show the potential effect of such variables in the creation of cloud federations, as well as some implications regarding the future of businesses in the sector. Revenue sharing mechanisms are vital to the federations since they define the distribution of the benefits provided by collaboration. The Shapely value mechanism proved to be the fastest in reaching equilibrium but also had lower performance than the others. In contrast, the outsourcing mechanism was the most efficient in terms of number and performance of federations. However, it is necessary to have a sufficient percentage to share; otherwise the CPs will not have enough incentives and the performance of this mechanism drops significantly, even to the point where no federations are created. The implications of these findings are that a cloud federation must have a fair revenue sharing mechanism that also provides sufficient benefits; otherwise businesses will not have any incentive to collaborate.

Results also showed that capacity disparity is a better incentive than cost disparity. By comparing the resulting federations and behaviors, we can conclude that CPs will benefit more by using all their available resources, rather than obtaining a cost advantage for a fraction of said resources. This coincides with the IT sector, where the technologies can be easily replaced and updated. In other words, although both are inherent characteristics of businesses, the disparity in resources and capabilities is much more important than cost competitiveness.

The presence of a “big competitor” was also identified as an incentive to cloud federation. Its impact is more focused towards speed rather than performance. This brings the implication that businesses will choose to collaborate more often with each other if they must compete against a bigger company.

Finally, there is some evidence to the effect of demand changes on the formation of cloud federations. Quick rises in demand tend to yield more numerous yet smaller federations, whereas steadier demand will slowly form bigger and more stable federations. More research is needed on this matter.

5.3 Limitations and Future Work

The limitations of this paper are as follows. The model assumes that there are no impediments to federations, as long as CPs decide to collaborate. Obstacles such as interoperability, trust between CPs and QoS are not considered in the model.

Secondly, we assume that the prices are fixed and that CPs do not have enough power to affect them.

The study also has the normal limitations of Agent-based modeling. The simulations done were simplified to some extent, in order to easily observe the effect of variables, which also limits its similarity to reality.

For future work, we would recommend testing more variables such as quality of service constraints and trust between CPs. In addition, simulations that test several of these incentives at the same time would also yield considerable insight on cloud federations. Additional research is needed on the effects of demand changes to the behavior of federations. Finally, a similar study could be done where the prices are variable and the creation of federations may yield monopolies or oligopolies.

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초 록

클라우드 서비스 연합 장려 모델

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클라우드 컴퓨팅에서 대규모 서비스 제공 업체는 규모의 경제로 인해 시장을 지배합니다. 클라우드 연합은 소규모 클라우드 제공 업체가 서로 제휴하여 경쟁력을 높여 공유 리소스가 있는 네트워크를 형성 할 수 있는 가능한 솔루션을 제시합니다. 이전 연구는 비용 차이, 큰 경쟁자 또는 효율적인 수익 공유 계획과 같이 이기적 클라우드 제공자의 참여를 장려 할 수 있는 여러 가지 변수를 제안합니다. 각각의 개별 클라우드 제공 업체는 수익을 극대화하고 지속적인 이익을 제공하는 제휴를 선택한다고 가정 할 수 있습니다. 연합 여부를 선택할 때 클라우드 제공 업체는 수익 공유를 통해 이익이 증가하는지 고려합니다.

제안 된 연구는 개인 이익을 극대화하고 자하는 반복 게임에서 이기적이고 이질적인 에이전트 간의 상호 작용을 모델링합니다. 각 에이전트는 개인으로 시작하여 전략을 변경하고 다른 제공자와 연합하여 자신의 성과를 향상시킬 수 있습니다. 공동 작업의 속도와 개인의 전반적인 이익을 살펴봄으로써 특정 인센티브가 클라우드 연합의 창출을 장려 할 수 있는지 판단 할 수 있습니다.

주요어: 클라우드 연합, 수익 공유, 비즈니스 인센티브, SME, 반복 된 게임

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