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Interconnection Contracts between Service and Content Provider with Partial Cloud Migration

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***Abstract*—This paper addresses interconnection contracts in content provisioning scheme with partial cloud migration. Model for traffic workload of such scheme based on content popularity factor is introduced. Monte Carlo simulation for bandwidth demand estimation is used. Cost analysis of content provider's resources utilization regarding average requests' rejection rate is observed. The performance analysis of content provider's incentive for partial cloud migration is applied. Three interconnection contracts are analysed: Revenue Sharing, Cost Sharing and Wholesale Price contract. Obtained results show that partial cloud migration can reduce both content provider's costs and average requests' rejection rate. Under observed constellation, Revenue Sharing contract may represent satisfying solution for both providers.**

***Index Terms*—Clouds; content distribution networks; contracts; interconnection.**

I. INTRODUCTION

The permanent growth of Internet traffic, caused by emerging high bandwidth demanding contents such as video on demand, High Definition Television (HDTV), real time video, online gaming, file sharing and cloud computing, is supported by bandwidth improvement of all participants in content provisioning process. It includes content providers, service providers, Content Delivery Network (CDN) and customers [1]. Participating with 80 %–90 % of overall global Internet traffic, video content distribution is the leading issue of bandwidth requirements [2], [3]. In bandwidth demand estimation video content popularity factor is an important parameter and has to be included in network dimensioning process. Video content popularity factor can be described as frequency of access to certain video content [4]. Several observations on the suitable video content popularity distribution can be found in the literature: Zipf [5], [2], Zipf-Mandelbrot [6], stretched exponential [7], Zipf with exponential cut-off tail [8], etc.

Appropriate bandwidth demand estimation is of great importance for addressing resource investment. Once bandwidth demand is estimated, network resources can be allocated in a way that costs can be minimized. Since peak bandwidth demand changes during the day, provisioning of self-owned resources that satisfy peak bandwidth demand is cost ineffective. These resources would be underutilized in the periods of low or normal traffic load. On the other hand, under-provisioning leads to rejection of requests. In order to minimize costs and improve Quality of Service (QoS) and hence Quality of Experience (QoE) of their customers, content providers need to consider using resources of cloud providers. Cloud providers maintain large-scale data centres to offer storage and computational resources at a relatively low cost [9]−[11]. These providers enable different pricing plans, such as reservation, on-demand and spot market [12]. On-demand pricing plan enables cloud providers' customers to pay only for utilized resources on the hourly basis. In the reservation plan, cloud providers' customers pay an upfront reservation fee in order to reserve cloud resources for a specific period of time. In exchange, they receive a meaningful discount on the hourly resource usage price. The upfront fee of the reservation plan is beneficial for cloud provider, but in the long-term, the total revenue generated is lower than the one obtained by providing equivalent usage hours under an on-demand plan. The spot market pricing plan represents an auction-like mechanism, where cloud providers' customers submit the maximum price they are willing to pay. The access to cloud resources is enabled as long as offered price exceeds cloud provider's last computed market clearing price.

In order to provide content to the customers, interconnection between content provider and service provider is necessary. In this paper, three interconnection contracts with partial cloud migration are analysed: Revenue Sharing, Cost Sharing and Wholesale Price contract. Revenue Sharing contract is characterized with operational simplicity. It defines modality of revenue shares between providers involved [13]−[16]. This contract is widely implemented in cloud systems [17]−[20]. Cost Sharing contract defines cost shares among providers. This contract is analysed in [21]−[24]. Wholesale prices are established under Wholesale Price contracts and analysed in [25]−[27]. Comparison with Revenue Sharing contract is presented in [28], [29].

This paper is organized as follows. After the introductory remarks short literature review is presented in Section I. Problem statement is analysed in Section II. Modelling of traffic workload in content delivery scheme with partial cloud migration and associated interconnection contracts are described. Performance evaluation is given in Section III.

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Section IV contains discussion on obtained results. Finally, concluding remarks are given in Section V.

II. PROBLEM STATEMENT

Let us consider interconnection issues in a cloud assisted content delivery scheme depicted in Fig. 1. Participants in this scheme are: customers, service provider, content provider, cloud provider and cloud CDN.

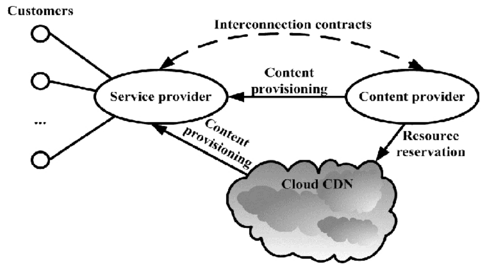

Fig. 1. Content provisioning scheme with cloud assistance.

Service provider enables connection to the customers at a flat rate retail price on a monthly basis. We assume that number of service providers' customers is fixed during observed time interval and denoted by *X*. Content provider stores all original video contents in self-owned servers, servicing major part of the requests to access certain content. Certain part of the content provider's video contents is migrated to the cloud storage. Cloud provider delivers video contents to the cloud CDN, in order to ensure satisfactory QoE. Cloud CDN delivers video contents to the service provider using a global network. Thus, the contents are delivered with the best possible performance. We assumed that cloud storage instances and cloud CDN are owned by the cloud provider. In this paper, we assign video popularity factor from the range $(0,1)$, depicting probability of access for each of video contents using Monte Carlo simulation. In accordance with the introduced content popularity factor, we estimate total bandwidth demand for access to video contents. Without general assumption violation, we perform our analysis into *N* consecutive discrete time slots. Partial migration of content delivery to cloud is being observed. Considering limited bandwidth capacity of content provider's server, we estimate traffic delivered through cloud CDN. According to different cloud pricing schemes, revenues and assessed costs, we evaluate three interconnection pricing contracts between content and service provider.

A. Modelling of Traffic Workload Characteristics

In this paper, modelling of traffic workload is characterized at the level of communication session. A session corresponds to a request for video content provisioning. Such a modelling requires specifying a session's arrival rate and its duration. Internet traffic exhibits similar daily patterns and similar peak values every day. The number of simultaneous requests attains the highest value in the evening hours, whereas the lowest point appears in the early morning hours [10]. Being a discrete distribution, arrival rate of requests for video content provisioning is determined by Poisson distribution [2]. In each time slot requests' arrival rate is determined by Poisson distribution with parameter $\lambda_i, i = 1, \ldots, N$.

Video content duration ranges from a few seconds to several hours. Short video contents mostly consist of advertising items. The distribution of video content duration can be approximated by an exponential distribution [30]. The session duration time is closely related to content's duration. Thus, session duration process can be approximated by an exponential distribution for the average length of the content's range.

Set of all video contents stored in content providers' self-owned servers is denoted as

$$V_{ser} = \{\upsilon_1, \upsilon_2, \cdots, \upsilon_M\}. \tag{1}$$

For video content υ_j, we introduce content popularity factor ϕ_j, which indicates the probability of access to the video content υ_j. It applies

$$\phi_j \in (0,1), \sum_{j=1}^{M} \phi_j = 1. \tag{2}$$

We further assume five quality standards for video streaming minimal required quality, recommended quality, SD quality, HD quality and Ultra HD quality, with corresponding minimal required bandwidth denoted by $w_k, k \in [1, 5]$, respectively. Initiating request for content provisioning, customers randomly choose quality standard, according to a discrete probability distribution. The probability of choosing certain video streaming quality is denoted by p_k and it applies $\sum_{k=1}^{5} p_k = 1$.

Requests for video streaming in each time slot are generated according to average arrival rate. Specification of request for video streaming according to certain video content is obtained applying Monte Carlo simulation in accordance to content popularity factor. Each request corresponds to assigned bandwidth demand (depending on chosen video content quality standard) applying Monte Carlo simulation. The number of simultaneous video streams per time slot and corresponding bandwidth demand per video stream determine total bandwidth demand per time slot, denoted as D_i.

Content provider provides self-owned servers for content delivery. In order to avoid over-provisioning, servers' capacity is constrained by parameter α. This parameter defines the portion of the peak value of total bandwidth demand per time slot. Hence, content provider's capacity can be expressed as

$$CP_{server} = \alpha \times \max_i (D_i), \alpha \in (0,1). \tag{3}$$

Partial migration to the cloud refers to storing a portion of the most popular video contents into the cloud storage with the aim of enabling access to those contents whenever capacity of the self-owned servers is occupied. Parameter defining the replication portion of the most popular contents to the cloud is denoted as $\beta, \beta \in (0,1)$. In order to assure the access to the most popular video contents content provider reserves cloud storage capacity according to appropriate reservation pricing scheme. We assume that cloud storage is limited by chosen virtual machine instance, and the available cloud bandwidth is enough to satisfy all requirements during high traffic load periods. When demand exceeds capacity of the content provider's server, request for content provisioning will be accomplished if that content is being stored into the cloud. Otherwise, the request for content provisioning is rejected. Hence, portion of the contents' replication on cloud has direct impact on request rejection, especially in the periods of high traffic load.

Total number of generated requests for content provisioning per time slot is denoted by n_i. Thus, total number of generated requests can be expressed as follows

$$n_t = \sum_{i=1}^{N} n_i = \sum_{i=1}^{N} \left(n_i^{cp} + n_i^{cl} + n_i^{rej} \right). \tag{4}$$

Number of request served by the content provider's server per time slot in (4) is denoted by n_i^{cp}; number of requests accomplished by the cloud CDN is denoted by n_i^{cl} and number of rejected requests is denoted by n_i^{rej}.

B. Interconnection Contracts

In order to analyse providers' profits, three interconnection contracts are observed: Revenue Sharing, Cost Sharing and Wholesale Price contract. In all contracts, cloud reservation pricing scheme is considered. Thus, content provider's costs can be expressed as:

$$C^{cp} = \sum_{i=1}^{N} C_i^{cp} = \sum_{i=1}^{N} \left(C_i^{cl} + C_i^{ser} \right), \tag{5}$$

$$C_i^{cl} = C_i^{storage} + C_i^{data\ transfer}, \tag{6}$$

where C_i^{cl} includes content provider's costs per time slot for acquiring cloud storage for replication of the most popular video contents and costs for data transfer through cloud CDN to service provider, $C_i^{storage}$ consists of a fixed cost for cloud resource reservation, plus cost per time slot independent of resource usage. Cost for content provisioning from cloud CDN to service provider network is based on the transferred data volume. Total transferred data volume can be expressed as

$$Z = \sum_{i=1}^{N} z_i, \tag{7}$$

where z_i denotes transferred data volume per time slot. In order to obtain this cost, the following staircase function is defined

$$C^{data\ transfer} = \sum_{i=1}^{N} C_i^{data\ transfer} = \begin{cases} A_1 Z, & 0 < Z \le \gamma_1, \\ A_2 Z, & \gamma_1 < Z \le \gamma_2, \\ \ldots \\ A_q Z, & \gamma_{q-1} < Z \le \gamma_q, \end{cases} \tag{8}$$

where $A_1, A_2, \cdots, A_q$ represent fixed prices for q defined thresholds of transferred data volume when Z takes values from the range (γ_0, γ_q). We assume it applies $A_1 > A_2 > \cdots > A_q$.

C_{ser} includes costs for self-owned servers' capacity provisioning. It can be expressed as follows

$$C^{ser} = C_i^{ser} = \sum_{i=1}^{N} c_m^{cp} \times n_i^{cp}. \tag{9}$$

Marginal cost per request provisioned by content provider's self-owned servers in (9) is denoted by c_m^{cp}. Content provider's revenue is obtained as service provider's payment for interconnection establishment. Hence, service provider's cost depending of different interconnection contract- Revenue Sharing, Cost Sharing and Wholesale Price, can be represented as (10)–(12), respectively:

$$C_{sp}^{rs} = \sum_{i=1}^{N} c_m^{sp} \times \left(n_i^{cp} + n_i^{cl} \right) + R_{cp}^{rs}, \tag{10}$$

$$C_{sp}^{cs} = \sum_{i=1}^{N} c_m^{sp} \times \left(n_i^{cp} + n_i^{cl} \right) + R_{cp}^{cs}, \tag{11}$$

$$C_{sp}^{wp} = \sum_{i=1}^{N} c_m^{sp} \times \left(n_i^{cp} + n_i^{cl} \right) + R_{cp}^{wp}, \tag{12}$$

where c_m^{sp} denotes marginal cost per request provisioned to the customers in the service provider's network.

We assume there are L possible retail flat pricing plans offered to the customers by service provider. Each pricing plan has assigned minimal guarantied bandwidth. Higher guarantied bandwidth means higher retail price p^r. Thus, service provider's revenue can be expressed as follows

$$R_{sp} = \sum_{l=1}^{L} p_l^r \times X. \tag{13}$$

Content provider's revenue, depending on the interconnection contract with service provider, can be expressed as follows:

$$R_{cp}^{rs} = \theta \times R_{sp}, \tag{14}$$

$$R_{cp}^{cs} = (1 + \rho + \tau) \times C^{cp}, \tag{15}$$

$$R_{cp}^{wp} = (1 + \rho) \times C^{cp}. \tag{16}$$

Parameter representing revenue share between content provider and service provider in Revenue Sharing contract in (14) is denoted by θ; profit margin in Cost Sharing and Wholesale Price contracts in (15) and (16) is denoted by ρ and parameter representing cost share in Cost Sharing contract in (16) is denoted by τ. Each of these three parameters can take values in the $(0, 1)$ interval.

Providers' profits can be obtained by deducting corresponding costs from revenues. Hence, content provider's profit according to corresponding interconnection contract can be written as:

$$\pi_{cp}^{rs} = R_{cp}^{rs} - C^{cp}, \quad (17)$$

$$\pi_{cp}^{cs} = R_{cp}^{cs} - C^{cp}, \quad (18)$$

$$\pi_{cp}^{wp} = R_{cp}^{wp} - C^{cp}. \quad (19)$$

Likewise, service provider's profits can be written as:

$$\pi_{sp}^{rs} = R_{sp}^{rs} - C_{sp}^{rs}, \quad (20)$$

$$\pi_{sp}^{cs} = R_{sp}^{cs} - C_{sp}^{cs}, \quad (21)$$

$$\pi_{sp}^{wp} = R_{sp}^{wp} - C_{sp}^{wp}. \quad (22)$$

III. PERFORMANCE EVALUATION

In order to evaluate model, simulations in open source programming language Python 2.7 are performed in 50 iterations. Time period of 31 days is simulated. The first day in each simulation represents warm-up period and it is not included in the simulation results. Each day is divided into 24 time slots of 1 hour duration. Total number of customers is 100 000. In order to obtain as realistic as possible traffic workload model, we used 7 different Poisson distribution parameters for arriving requests per time slot for content provisioning. The values of these parameters are: $\lambda_1 = \lambda_{15} = \lambda_{16} = \lambda_{17} = \lambda_{18} = 2.33$; $\lambda_2 = \lambda_{13} = \lambda_{14} = 2$; $\lambda_3 = \lambda_{11} = \lambda_{12} = 1.67$; $\lambda_4 = \lambda_8 = \lambda_9 = \lambda_{10} = 1.33$; $\lambda_5 = \lambda_6 = \lambda_7 = 1$; $\lambda_{19} = \lambda_{20} = \lambda_{24} = 2.67$; $\lambda_{21} = \lambda_{22} = \lambda_{23} = 3$. The average value for Poisson parameter is 2 requests per second, which coincide with average value in [30]. Session duration process is approximated by an exponential distribution with the average value of 30 minutes [30]. Content provider's server stores all M = 500 original video contents. Content popularity factor is randomly assigned to each of video contents and sorted from the largest to the smallest value. Quality standards for video streaming and corresponding minimal required bandwidths are assumed according to [31]. These values are the following: minimal - 0.5 Mb/s, recommended - 1.5 Mb/s, SD quality - 3.0 Mb/s, HD quality - 5.0 Mb/s and Ultra HD quality - 25.0 Mb/s. Customers randomly choose quality standard depending on constraints of access network technology. The assumed values for probability of choosing minimal, recommended, SD, HD and Ultra HD quality are: 0.15, 0.20, 0.30, 0.20 and 0.15, respectively [32]. Average bandwidth demand per time slot is obtained applying Monte Carlo simulation.

Provisioning servers' capacity that satisfies total bandwidth demand is not economically efficient and the system would be in idle state most of the time. The proper bandwidth of content provider's server is from 40 % to 60 % of the peak demand [10]. Hence, parameter α in this analysis takes values: $\alpha = 0.4$, $\alpha = 0.5$ and $\alpha = 0.6$. The less capacity provisioned, less resource is underutilized. Also, costs for maintaining resources are smaller. However, this may lead to greater request for content provisioning rejection, so it must be taken in consideration. A solution for this challenge might be migration to cloud resources. In order to minimize risk of content unavailability, we assume that video content migration to the cloud is occurring in the period of low traffic load, so the content uploading to the cloud would not additionally load the system. Values for the partial cloud replication parameter used in simulation are $\beta = 0.2$, $\beta = 0.4$ and $\beta = 0.6$. This means that 20 %, 40 % and 60 % of the most popular video contents is replicated to the cloud. Figure 2 shows average request rejection rate depending on content provider's server capacity and the amount of content replication to the cloud. In order to assure that cloud resources are available during all observed period, we assume that content provider reserves cloud instances. This implies that content provider pays upfront fee for resource reservation according to reservation pricing scheme for corresponding instance type. Cloud providers offer various instance types and various long-term contracts. In order to obtain content provider's costs at monthly level, reservation pricing scheme and prices for data transfer through cloud CDN from [12] are observed. We assume that reserved instance type is large enough to satisfy storage requirements. Content provider's costs have the lowest value when parameter β equals 0.2, i.e. when migration to the cloud is the lowest, and α equals 0.2, i.e. content provider serves only 40 % of the peak customers' demand. However, requests' rejection rate is higher than 5 % for $\beta = 0.2$ and for all α. Generally, content provider's costs increase with self-owned resources capacity enhancement, which is primary motivation for cloud migration. The appropriate combination of content provider's self-owned resources and cloud migration would be chosen in accordance with the realized profits depending on interconnection contracts with service provider.

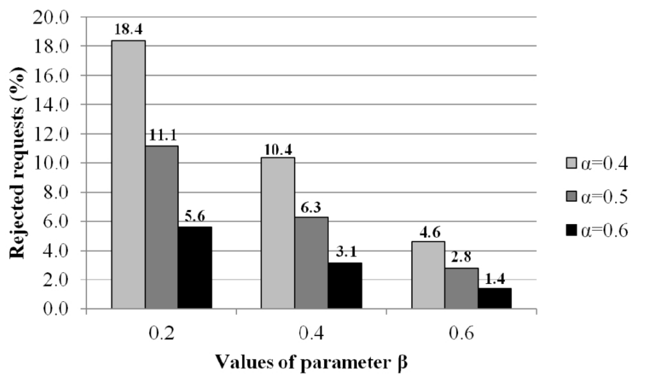

Fig. 2. Average rejection rate of requests for content provisioning.

Content provider's profits according to the Revenue Sharing, Cost Sharing and Wholesale interconnection contracts are shown in Table I, Table II and Table III, respectively. Likewise, service provider's profits obtained applying these interconnection contracts are shown in Table IV, Table V and Table VI, respectively.

TABLE I. CONTENT PROVIDER'S PROFITS – REVENUE SHARING CONTRACT (IN MILLION MONETARY UNITS).

α	β	Revenue share, θ (%)				
		0.3	0.4	0.5	0.6	0.7
0.4	0.2	14.028	31.428	48.828	66.228	83.628
	0.4	10.532	27.932	45.332	62.732	80.132
	0.6	8.022	25.422	42.822	60.222	77.622
0.5	0.2	10.470	27.870	45.270	62.670	80.070
	0.4	8.320	25.720	43.120	60.520	77.920
	0.6	6.772	24.172	41.572	58.972	76.372
0.6	0.2	7.766	25.166	42.566	59.966	77.366
	0.4	6.662	24.062	41.462	58.862	76.262
	0.6	5.867	23.267	40.667	58.067	75.467

TABLE II. CONTENT PROVIDER'S PROFITS – COST SHARING CONTRACT (IN MILLION MONETARY UNITS).

α, β	ρ	Cost share. τ (%)				
		0.1	0.2	0.3	0.4	0.5
α = 0.4 β = 0.2	0.3	15.269	19.086	22.903	26.720	30.537
	0.4	19.086	22.903	26.720	30.537	34.355
	0.5	22.903	26.720	30.537	34.355	38.172
α = 0.4 β = 0.4	0.3	16.667	20.834	25.001	29.168	33.334
	0.4	20.834	25.001	29.168	33.334	37.501
	0.5	25.001	29.168	33.334	37.501	41.668
α = 0.4 β = 0.6	0.3	17.671	22.089	26.507	30.925	35.342
	0.4	22.089	26.507	30.925	35.342	39.760
	0.5	26.507	30.925	35.342	39.760	44.178
α = 0.5 β = 0.2	0.3	16.692	20.865	25.038	29.211	33.384
	0.4	20.865	25.038	29.211	33.384	37.557
	0.5	25.038	29.211	33.384	37.557	41.730
α = 0.5 β = 0.4	0.3	17.552	21.940	26.328	30.716	35.104
	0.4	21.940	26.328	30.716	35.104	39.492
	0.5	26.328	30.716	35.104	39.492	43.880
α = 0.5 β = 0.6	0.3	18.171	22.714	27.257	31.799	36.342
	0.4	22.714	27.257	31.799	36.342	40.885
	0.5	27.257	31.799	36.342	40.885	45.428
α = 0.6 β = 0.2	0.3	17.774	22.217	26.661	31.104	35.547
	0.4	22.217	26.661	31.104	35.547	39.991
	0.5	26.661	31.104	35.547	39.991	44.434
α = 0.6 β = 0.4	0.3	18.215	22.769	27.323	31.876	36.430
	0.4	22.769	27.323	31.876	36.430	40.984
	0.5	27.323	31.876	36.430	40.984	45.538
α = 0.6 β = 0.6	0.3	18.533	23.167	27.800	32.433	37.067
	0.4	23.167	27.800	32.433	37.067	41.700
	0.5	27.800	32.433	37.067	41.700	46.333

TABLE III. CONTENT PROVIDER'S PROFITS – WHOLESALE PRICE CONTRACT (IN MILLION MONETARY UNITS).

α	β	Profit margin. ρ		
		0.3	0.4	0.5
0.4	0.2	11.452	15.269	19.086
	0.4	12.500	16.667	20.834
	0.6	13.253	17.671	22.089
0.5	0.2	12.519	16.692	20.865
	0.4	13.164	17.552	21.940
	0.6	13.628	18.171	22.714
0.6	0.2	13.330	17.774	22.217
	0.4	13.661	18.215	22.769
	0.6	13.900	18.533	23.167

TABLE IV. SERVICE PROVIDER'S PROFITS – REVENUE SHARING CONTRACT (IN MILLION MONETARY UNITS).

α	β	Revenue share. θ (%)				
		0.3	0.4	0.5	0.6	0.7
0.4	0.2	83.720	66.320	48.920	31.520	14.120
	0.4	79.974	62.574	45.174	27.774	10.374
	0.6	77.285	59.885	42.485	25.085	7.685
0.5	0.2	80.345	62.945	45.545	28.145	10.745
	0.4	78.079	60.679	43.279	25.879	8.479
	0.6	76.446	59.046	41.646	24.246	6.846
0.6	0.2	77.745	60.345	42.945	25.545	8.145
	0.4	76.610	59.210	41.810	24.410	7.010
	0.6	75.795	58.395	40.995	23.595	6.195

TABLE V. SERVICE PROVIDER'S PROFITS – COST SHARING CONTRACT (IN MILLION MONETARY UNITS).

α, β	ρ	Cost share. τ (%)				
		0.1	0.2	0.3	0.4	0.5
α = 0.4 β = 0.2	0.3	82.480	78.663	74.846	71.028	67.211
	0.4	78.663	74.846	71.028	67.211	63.394
	0.5	74.846	71.028	67.211	63.394	59.577
α = 0.4 β = 0.4	0.3	73.839	69.672	65.506	61.339	57.172
	0.4	69.672	65.506	61.339	57.172	53.005
	0.5	65.506	61.339	57.172	53.005	48.838
α = 0.4 β = 0.6	0.3	67.636	63.218	58.800	54.382	49.964
	0.4	63.218	58.800	54.382	49.964	45.547
	0.5	58.800	54.382	49.964	45.547	41.129
α = 0.5 β = 0.2	0.3	74.123	69.950	65.777	61.603	57.430
	0.4	69.950	65.777	61.603	57.430	53.257
	0.5	65.777	61.603	57.430	53.257	49.084
α = 0.5 β = 0.4	0.3	68.846	64.458	60.070	55.682	51.294
	0.4	64.458	60.070	55.682	51.294	46.906
	0.5	60.070	55.682	51.294	46.906	42.518
α = 0.5 β = 0.6	0.3	65.047	60.504	55.961	51.419	46.876
	0.4	60.504	55.961	51.419	46.876	42.333
	0.5	55.961	51.419	46.876	42.333	37.790
α = 0.6 β = 0.2	0.3	67.737	63.293	58.850	54.406	49.963
	0.4	63.293	58.850	54.406	49.963	45.520
	0.5	58.850	54.406	49.963	45.520	41.076
α = 0.6 β = 0.4	0.3	65.058	60.504	55.950	51.397	46.843
	0.4	60.504	55.950	51.397	46.843	42.289
	0.5	55.950	51.397	46.843	42.289	37.735
α = 0.6 β = 0.6	0.3	63.128	58.495	53.862	49.228	44.595
	0.4	58.495	53.862	49.228	44.595	39.962
	0.5	53.862	49.228	44.595	39.962	35.328

TABLE VI. SERVICE PROVIDER'S PROFITS – WHOLESALE PRICE CONTRACT (IN MILLION MONETARY UNITS).

α	β	Profit margin. ρ		
		0.3	0.4	0.5
0.4	0.2	86.297	82.480	78.663
	0.4	78.006	73.839	69.672
	0.6	72.053	67.636	63.218
0.5	0.2	78.296	74.123	69.950
	0.4	73.234	68.846	64.458
	0.6	69.590	65.047	60.504
0.6	0.2	72.180	67.737	63.293
	0.4	69.612	65.058	60.504
	0.6	67.762	63.128	58.495

IV. DISCUSSION

Simulation results for providers' profits and possible cloud migration obtained applying all observed interconnection contracts show regularity in profit values for all resource combinations. Analysis of requests' rejection rate and occupied resources indicates that cloud migration is desirable in all observed situations. Costs' analysis confirms this conclusion. In accordance with, for all observed values of parameters α and β, Revenue Sharing contract assures the greatest profits for content provider, with revenue share of 70 %, 60 % and 50 %. The next acceptable solution for content provider is Cost Sharing contract with cost share of 50 % and profit margin 40 % and 50 %, or cost share of 40 % and profit margin of 50 %. Analysing remaining contractual conditions, Revenue sharing with revenue share of 40 % achieves higher profits of all other solutions. It is worth noting that Wholesale Price contract achieves very low profits in comparison with all other contracts. Service provider's position is completely opposite from content provider. The following consideration is valid for all combinations of content provider's self-owned resources and cloud migration. It is evident that all observed contracts assure that service provider never operates with losses. Hence, any contractual form enables costs recovery. Wholesale Price contract achieves high profits in comparison with other contracts. As expected, Revenue Sharing with revenue share of 50 %, 60 % and 70 % provides the lowest profits. If service provider sets its profit margin at, for instance, 30 %, these revenue shares will not meet the requirements. Cost Sharing contracts representing second best solution for content provider also will not be acceptable from service provider's perspective. However, Revenue Sharing contract with revenue share of 40 % satisfies service provider profit margin constraint. Observation of service and content provider's profits infer that Revenue Sharing contract with revenue share of 40 % can be considered as a medium-effective solution for both providers.

V. CONCLUSIONS

This paper presents observation of traffic workload under uncertainty of demand in content provisioning system with partial cloud migration. We analyse bandwidth demand, resource utilization, requests' rejection rate, cost for partial cloud migration and providers' profits obtained under different interconnection contracts. Bandwidth demand is estimated using Monte Carlo simulation with content popularity factor as a relevant parameter. It is notable that provisioning of resources that satisfy peak bandwidth demand leads to low utilization. However, under-provisioning increases average requests' rejection rate. This paper shows that partial cloud migration can be cost-effective solution for that challenge. It also decreases average requests' rejection rate. Analysis of this system for content provisioning with cloud assistance is extended in order to obtain a proper interconnection contract between content and service provider. It approves that Revenue Sharing can assure satisfying profits for both providers.

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