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Modeling Resource Availability in Dynamic Grid Computing

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***Abstract*—Peer-to-Peer network and desktop grids are currently the largest distribution systems for solving data and comput intensive problems. Despite the popularity, such large-scale distributed systems are subject to churn, i.e., continuous arrival, leaving and failure of processes. Such environments define the provider characterization according to provider behavior on particular network systems. Typically, they follow a specific joint algorithm to make efficient use of existing providers and to increase the performance of the system. In this paper, using Grid Economic Simulator (GES), we model provider availability under realistic simulator of concurrent joins and unexpected departures for evaluating the performance of dynamic grid system.**

***Index Terms*—auction market, availability, churn, dynamic grids, grid economics.**

I. Introduction

THE exploitation of desktop grid computing in computational applications such as BOINC [1], [2] and SZTAKI [3], [4] for solving large-scale intensive computing applications has attracted recent research interest. Such environment is classified as volunteer grids where the providers are typically end-users public PCs located at the edge of the Internet. Recent measurements of desktop networks show that providers are connected and disconnected the system by their owners without any prior notification, which degrade the performance of such systems [5]. We believe that the proper evaluation of decentralized dynamic grid system must consider the characteristics of providers joining and departing the system at any time. This leads to determine provider availability, along with, how many jobs completed [6] on it.

In this paper, the provider availability and unavailability are modeled by two kinds of provider-level characteristics. Firstly, the ***uptime*** length distribution that indicates how long the providers stay in the grid system. That's what we called system-based churn model as Classified in [7]. Secondly, the ***downtime*** length, that indicates the interval at which a particular provider left the system. Despite the fact that the characterization of churn has been well addressed in literature, as open issue is still exist an effective mathematical distribution to model the network churn. Various studies, have adopted different mathematical distributions according to datasets used and their observations. Thus there is still no clear answer on how to model the characterization of the churn. Some studies have suggested that ***uptime*** lengths can be modeled using either exponential [8], [9] or Pareto [8], [10] distributions. We adopted both distributions to model churn in our simulation study. Typically, when we modeled the ***uptime*** length using Pareto distribution, we accordingly modeled the provider ***downtime*** using a random period with a uniform distribution. Whilst, when the ***uptime*** length follows an exponential distribution, the provider ***downtime*** is also modeled as an exponential distribution.Also, it is significant from the perspective of the grid user, to consider the number of jobs failing and succeeding without resubmission being required [6]. The simulation results obtained show that the churn in the exponential distribution is more intensive than using Pareto distribution.

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II. An overview of dynamic grid systems

This section presents an overview of a dynamic grid system, that particularly focus on resource management. In other words we present the resource brokering and scheduling systems for computational grids. It is important to characterize how Dynamic Grid Participants (DGPs) interact to collaborate and coordinate resource management activities. Since DGPs are topologically distributed, and have different strategies, objectives, and supply and demand functions. In addition, they are owned by different administrative domains. In this case we deem that the providers in dynamic grids are well managed, and well connected to the Internet. Controlled administration of these providers gives the ability to provide a variety quality of service (QoS). However, such controlled administration of providers gives rise to the matter of provider behavior (outside world) in terms of provider availability.

III. Simulation model

We use a simulation model, namely GES [11] to model churn for evaluating the performance of dynamic grid system. The model we consider consists of a set n_p of geographically distributed dynamic grid providers "resource owners" each committed to deliver a fixed amount of computation power, namely CPU. Using GES, we apply market-based economy principles for resource allocation and job scheduling. All resource owners follow the same pricing strategy for determining the resource winners. The consumers (Grid users) n_u are also quite likely to be topologically distributed and have a queue of jobs to be executed over the dynamic grids. Typically, the job is characterized by CPU-bounded computational tasks. In order to cause a kind of competition in the market between consumers, we have established four groups of consumers. Each group of consumers has a stochastic number of jobs and an independent initial budget. The consumers, however, interact with resource brokers that hide the complexities of grid computing. The consumer u_i sends the job $J_{i,j}$ with its delegated budget $b_{i,j}$ to the broker that is willing to be executed. In accordance to consumer's request, one of the available resource providers p_m will

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TABLE I: Workload and resource notations.

Symbole	Meaning
n_u	Number of resource consumers
n_p	Number of resource providers
n_{np}	Number of non-participated providers
μ_i	CPU speed
c_i	CPU cost
r_m	Resource of node$m$
u_i	The i^{th} consumer in the grid
p_m	The m^{th} provider in the grid
$J_{i,j}$	i^{th} job from j^{th} consumer
$b_{i,j}$	Delegated budget to $J_{i,j}$
$l_{i,j}$	Job length for $J_{i,j}$
$T(J_{i,j,m}, r_m)$	Time required for $J_{i,j,m}$ at resource m
$B(J_{i,j,m}, r_m)$	Cost required for $J_{i,j,m}$ at resource m

receive this request. In other words, the broker plays a complex role of a wide range of tasks between resource provider and the consumer. Significantly, the broker is also needed to gather information about the status of the CPU usage over the dynamic grid. Because when a job failure happen, the broker in this case will send a report to the grid-bank to render appropriate bill that has already prepaid by the account number of u_i to account number p_m. That enables the consumer to resubmit the failed job. In table I, we exhibit the resource notations that are utilized in this paper.

IV. Pricing of resources

In this section we describe how the grid resources are priced in the dynamic grids. Typically we adopt the auctions market for resource pricing. In contrast to the previous work [12], where the motivation was focused on price stability using commodity market, the auction market has been engineered to be more realistic, in which the marketplaces are geographically distributed worldwide. Therefore, a limited number of consumers can bid on which the auctions are opened. In the other ward, the open market is exposed to limited number of bidders. Each consumer is allowed to particpate in one open auction using a uniform random number generator at every time step.

Every consumer, u_i has to show how much he is willing to pay b_i for resource r_m that is ready offered in the auction, and the required processing time for his job number $J_{i,j}$. The resource r_m of provider p_m includes all information about the CPU, such as the CPU speed. In this work we limit the r_m to contain the CPU speed $r_m = (\mu_i)$. When the auction ends, the auctioneer charges the winner c_i per time step of the job $J_{i,j}$ for resource usage. The $J_{i,j}$ consists of the job length, $l_{i,j}$, and the budget $B(J_{i,j,m}, r_m)$. The required time for the $J_{i,j}$ to execute on r_m and the associated cost are computed using the equations (1) and (2) respectively.

$$T(J_{i,j}, r_m) = \frac{l_{i,j}}{\mu_i} \quad (1)$$

$$B(J_{i,j}, r_m) = c_m.T(J_{i,j}, r_m) \quad (2)$$

V. MarketPlace and dynamic grid

Dynamic grid GES applies market-based economy principles for resource allocation and application scheduling. In particular we adopt the auction market model, as shown in figure 1. The auction is a first-price sealed-bid auction with no reserve price, with the high bidder wins the transaction. In this model, every provider represents an auctioneer for selling its available resources. The consumers who represent buyers can directly bid at the auctioneer for the auctioned resources. Each bidder typically, has his own valuation v to bid according to the standard equilibrium bid function from the first-price auction. The bidder with the highest value then wins the auction and pays his bid. The grid-bank, basically, plays a big role in the market because of its benefits to insure a level of agreement among market participants i.e., grid consumers and providers. In principle, the grid-bank can be utilized to establish the credibility of the participants in such grid system. In such case, it is significant that there is certain level of confidence in the marketing to process of determining trustworthiness. So the grid-bank represents a reputation management system that brings confidence, trust, and sales, which are ultimately reflected in revenue growth and profitability.

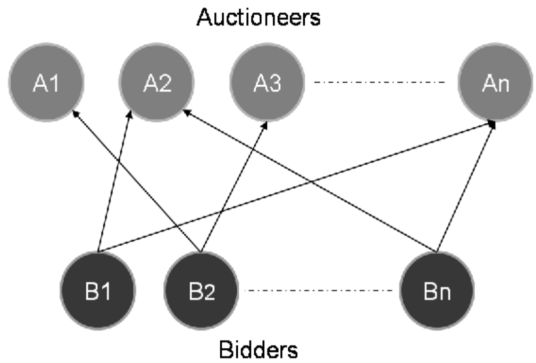

Fig. 1: The decentralised sealed-bid auctions.

VI. Simulation Results

In this section, we present a simulation model of resource availability for evaluating the performance of dynamic grid systems. The model parameters are listed in table II.

TABLE II: Simulation parameters.

parameters	Value
simulation steps	1000_s
Number of grid users	$\{1800, 25000\}$
Number of providers	$\{180, 2500\}$
Number of non-participated provider	0
Job duration in time steps	$\{2, 3, \cdots, 8\}$
Nr. of jobs per user at injection step	$\{1, 2, \cdots, 150\}$
Initial budget	50000
Allowance Group Factor	$\{1, 1.3, 1.6, 1.9\}$
Budget amount replenished	50.000
Number of $CPUs$ per provider	1

A. Modeling resource availability

Resource availability and unavailability in GES is modeled by two kinds of provider-level characterization. Firstly, the ***uptime*** length distribution, which is one of the most basic properties of resource availability, captures how long providers remain in the system each time they appear. Secondly, the ***downtime*** can be defined as the interval between the moment a provider departs and its next arrival.

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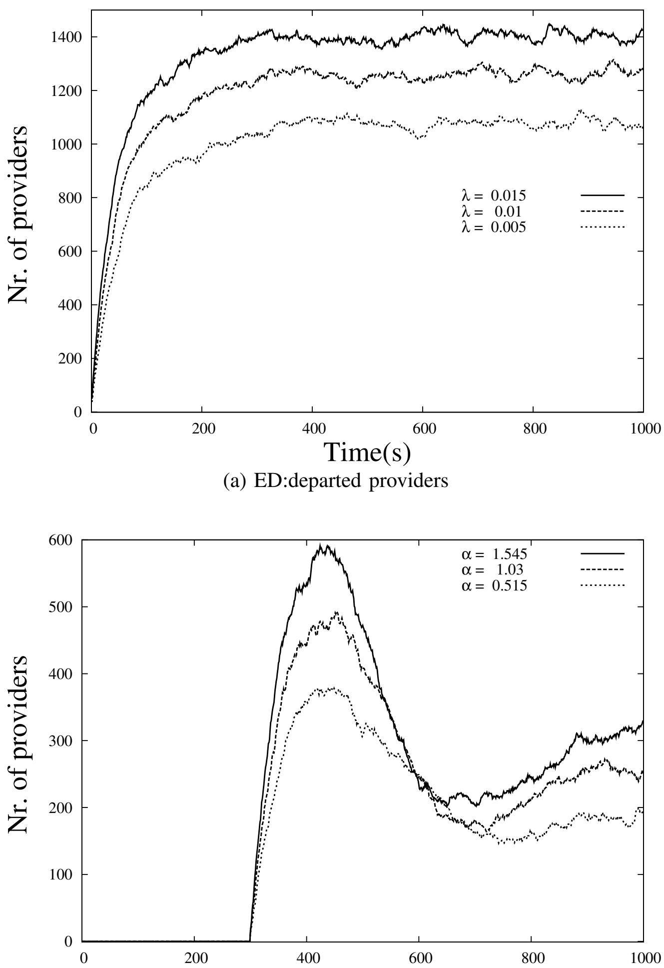
Each provider in the grid is an object with two fields: ***arrivalTime*** learns this provider's arrival time to the market (i.e., the stating ***uptime*** interval), and departTime memorizes its departure time (i.e., the starting ***downtime*** interval). The first action of each arrival event schedules the next departure event in a random number of time steps, generated from *exponential* distribution "ED" with rate λ (i.e., $mean = 1/\lambda$). Then, the normal service can be submitted. In other word, the provider is ready to open a new auction and call interested buyers. On the other hand, when the Departure event occurs, the provider is removed from the current list of participated providers, and schedules the arrivals time step in a random-variate generator using *Pareto* distribution with shape parameter rate α and location parameter β. Here, we should say that the provider is prone to failure, in case of the resource was not free during the departure event. As a consequence, the provider must compensate the consumer for the job failure. For the analysis of the departed providers under exponential distribution "ED"scenario we change the value of the scale parameter $\lambda = \{0.005, 0.01, 0.015\}$ for each simulation respectively. For Pareto distribution "PD" scenario we change the scale paremeter $\alpha = \{0.515, 1.03, 1.545\}$ for each simulation as well. Figure 2 exhibit the effect of scale parameters upon the departed providers. We can see that there is a significant difference among different scale values. The overall trend is that the number of departed providers increases as the scale values (λ and α) increase as indicated in figures (2a) and (2b) respectively. We also notice that the number of departed provider is fairly modest as λ get smaller.

The impact of churn on the job failure is apparent as shown in the graph 3. It indicates the number of jobs that need to be resubmitted because of failure at least once or more. The difference between the different scale values cases is as one would expect: smaller scale values means shorter uptimes and leads to more jobs resubmissions.

B. Measurement of Availability

Some point in time, real systems became unavailable because of desks fails, providers crash, network partition, software miscalculated, administrators misconfigure or users misuse. Consequently, the principle challenge in designing high available systems is to tolerate each failure as it occurs and recover from its effects [13]. This is expected as dynamic resources become unavailable. In previous work, however, we defined the resource unavailability for providers in which the resource usage must complete all the tasks being processed before leaving the system (graceful leaves). Where the provider is unable to sell its available resources. Once all resources become free, then the provider can leave the system. The length of waiting intervals are determined and ascribed to several factors. For instance, tasks characteristics ("the duration of tasks, since these tasks are long running") and the size of resources owned by the provider. These intervals we call it ***"Gaps"***, and do not corresponds to actual provider unavailability, but rather are due to the delay of provider for departure the system. In fact, another sort of *Gaps* occurs exclusively in between the termination of a task and the beginning of a new task on the same provider. We characterize this to the reluctance of the provider's strategy to sell resources due to the market behavior and budgetary



(a) ED:departed providers

(b) PD:Departed providers

Fig. 2: The number of departed providers for exponential and Pareto distributions scenarios.

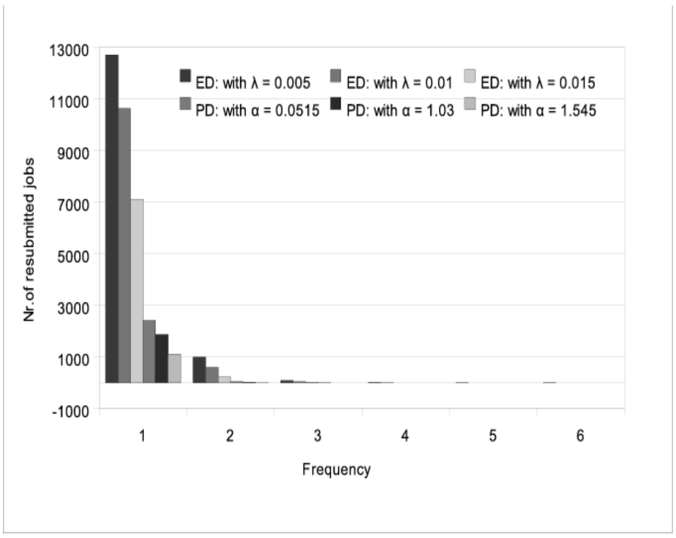


Fig. 3: The number of jobs resubmitted at least once, at least twice, etc. for exponential and Pareto distributions scenarios

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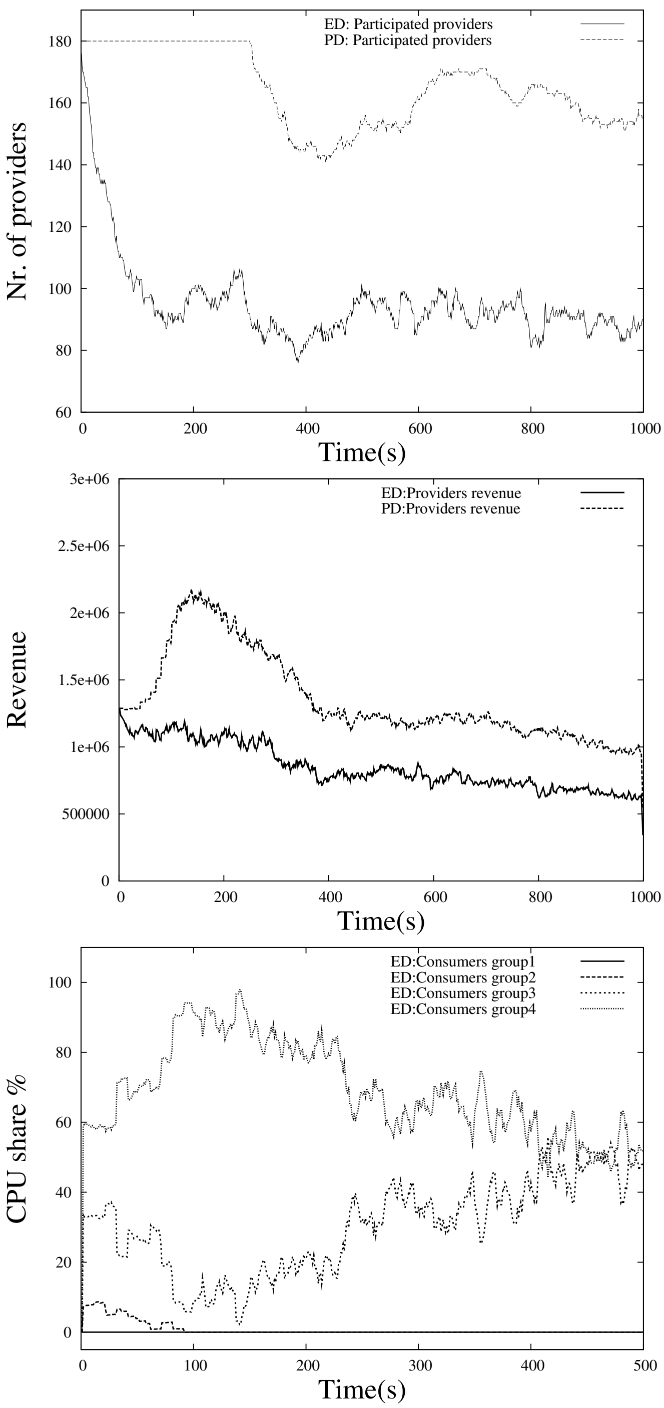

Fig. 4: The participated providers in the grid system, providers'revenues earned and CPU shares per budget group each simulation step for PlantLab traced datasets.

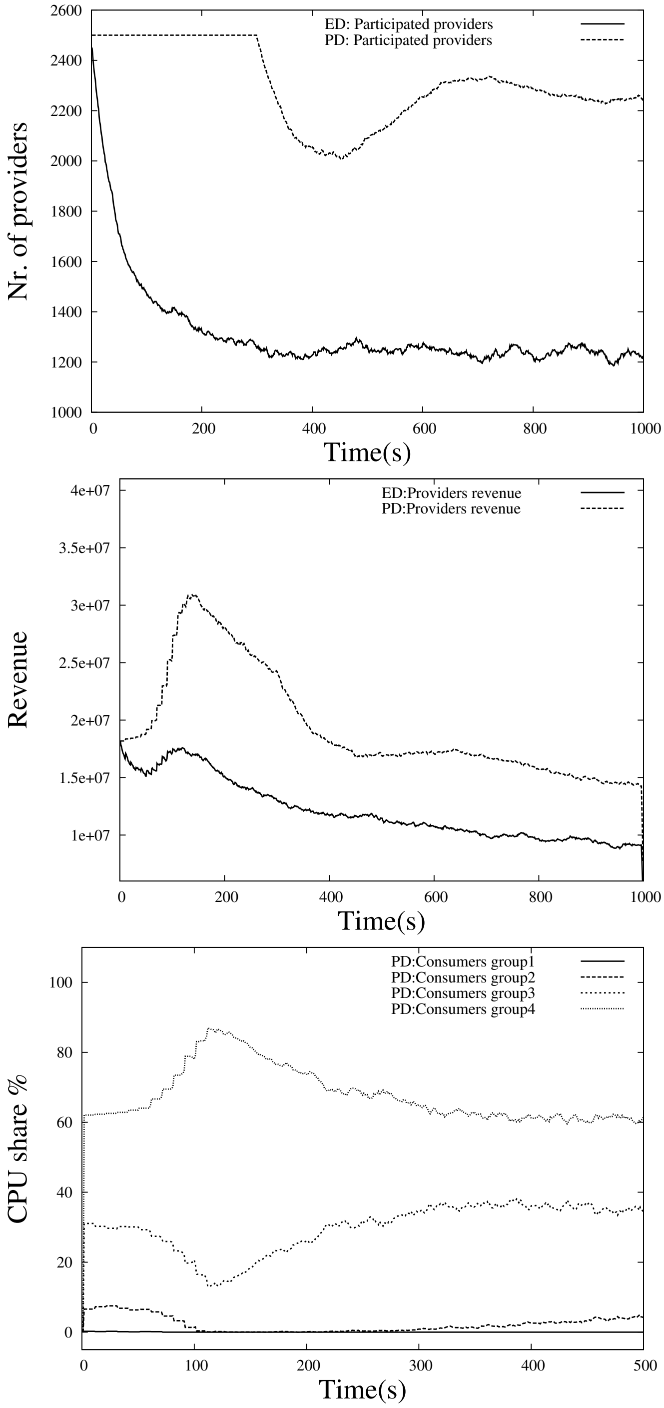

Fig. 5: The participated providers in the grid system, providers'revenues earned and CPU shares per budget group every simulation step for Maredian traced datasets.

constraints. As the basis of our study, we characterize the availability of the large dynamic grid over discrete time step. Actually, we consider two kinds of availability: (I) participants availability, a binary value that indicates whether a provider is reachable, corresponds to the definition of availability in [13], [14], [15]; and (II) resource availability, the number of resources that can exploited by a dynamic grid application, which is not corresponds to the definition in [16], [17], [18]. Of course provider unavailability implies resource unavailability. Accordingly, we measure the size pool of participated providers each time-step.

In this section, typically, we compare the results according to traced datasets: 180 PlanetLab providers [19] and the Meridian (2500 providers) [20]. During the simulation the departed providers may rejoin the market but as new comers. In some cases according to probability distribution the departure of providers can be permanent as the providers may do not rejoin the market again "depart forever". In particular, α and β are the key parameters of Pareto distraction as explained above. We set $\alpha = 1.03$ and $\beta = 300$ as conducted in [10]. When the provider reaches the end of its *uptime* length, it leaves the market and waits for randomly uniform

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distribution time between $0.1 * mean$ and $1.9 * mean$, where the $mean = 100s$, and rejoin the system. In the second approach, the *uptime* and *downtime* lengths for each provider are exponentially characterized. When a provider reaches the end of *uptime* length it leaves the system and calculates the beginning of the following *uptime* length. In this approach, the scale parameter is obtained by:

$$\lambda = \frac{1}{mean}$$

In order to discriminate between both datasets, we capture the number of participated providers and the failed jobs. this corresponds to observation, where at least 80% of total population of providers in the system ramins at any time using Pareto distribution. While on average roughly 52% of available providers that following the exponential distribution. This indicates that the churn in the latter is more intensive than the former.

In figures 4 and 5 we show participated providers, providers' revenue and CPU shares each step of (180) PlanetLab and (2500) Meridian providers respectively. One can observe how providers' CPU shares are affected where the consumer group with higher allowance group factor or higher budget share can only purchase the available resources. As the job queues of those group shrink, the other consumers group are then able to allocate resources. With respect to Pareto distribution the graphs show better performance as the providers remain longer in the system.

VII. Conclusion

We presented two types of churn models (i.e. Exponential and Pareto distributions) in dynamic computational grids for analyzing resource availability and performance.

In the context of the Grid Economic simulator framework we have developed resource allocation scheme based on first-price-sealed-bid auctions.

We analyse experiments in a number of scenarios and arrive at conclusions firstly that the uptime intervals of providers in Pareto distribution have longer uptimes comprered to Exponential distribution. Secondly, the job failures due to churn in such grids are inevitable. There is a need to allevite the impact of these job failures on the quality of service provided by such grids.

VIII. Future work

There are numbers of research issues remaining open for future work. Reducing job failure due to unexpected behavior of providers in such environments is a key issue, and needs to be investigated. One can also model and evaluate other quality of service measures such as the reliability and performance.

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