МЦОБ: МОДЕЛЬ ДИНАМИЧЕСКОГО ЦЕНООБРАЗОВАНИЯ ДЛЯ ОБЛАЧНОЙ СЕНСОРНОЙ ИНФРАСТРУКТУРЫ

Д. Рэйн, В. Шахов*, А. Шривастава

Индийский институт технологии,
453552, Индаур, Индия
*Институт вычислительной математики и математической геофизики СО РАН,
630090, Новосибирск, Россия

УДК 004.75

Беспроводные сенсорные сети вместе с облачными вычислениями формируют основу для создания широкого спектра новых технологий для Интернета вещей и других инноваций в области инфокоммуникационных систем. Распространена модель, согласно которой инфраструктура сенсорных сетей предоставляется пользователю как услуга, контроль и управление которой осуществляется с помощью облачных инструментов и средств виртуализации. Облачные вычисления способны значительно повысить экономическую эффективность предприятий, позволяя снизить операционные расходы и капитальные вложения, но при этом повысить производительность. Для своевременной и экономически оправданной реакции на критические ситуации, агрегирование и качественный анализ важных данных в реальном времени, требуется мобилизация ресурсов сенсорных сетей, обеспечение их надежного функционирования. Внедрение новых облачных технологий позволяет обеспечить требуемое качество обслуживания в сенсорных сетях, а также оптимизировать стоимость их функционирования. Кроме того, эксплуатационные издержки провайдеров облачных услуг и их вложения в инфраструктуру незначительно коррелируют с количеством обслуживаемых пользователей. По этой причине провайдеры постоянно прилагают усилия для максимального использования имеющихся мощностей, время от времени предлагая привлекательные цены. Для увеличения загрузки инфраструктуры поставщики облачных услуг пользуются услугами облачных брокеров. В данной статье мы предлагаем модель динамического ценообразования для облачных брокеров в схеме „сенсорная сеть в качестве сервиса“ (SNaaS, Sensor Network as a Service). Предлагаемый подход позволяет обеспечить экономически эффективное агрегирование данных, собираемых сенсорными сетями, и их обработку в реальном времени.

Ключевые слова: облачные вычисления, динамическое ценообразование, диапазон ценообразования, анализ ценообразования, модель ценообразования для облачного брокера.

CBPM: A DYNAMIC PRICING MODEL FOR CLOUD-BASED SENSING INFRASTRUCTURE

D. Rane, V. Shakhov*, A. Srivastava

Indian Institute of Technology Indore,
453552, Indore, India
*Institute of Computational Mathematics and Mathematical Geophysics SB RAS,
630090, Novosibirsk, Russia

Wireless sensor networks with cloud computing are drivers to a new stream of technologies like the Internet of Things and innovations in the communications. Cloud computing triumphs with multifaceted benefits to enterprises with cost saving economics, reduced operational, and support costs but higher productivity. The significant functionality of data collected and processed at wireless sensor nodes is rendered fast, uninterrupted and reliably with cloud computing and its optimized implementations. Therefore, sensor network firms are partnering with cloud service providers, which lease computing infrastructure as required. This paper suggests a model for optimizing the computing potential of the wireless sensor network in conjunction with the pricing model of the cloud. Integration of concepts of cloud and sensor networks takes the advantage of the scalable and dynamic aspect of cloud being exploited for sensory data. The results show that the proposed method adapts well with performance expectations of sensor networks and reduces the cost specific overheads for its largely processing based functioning. In order to facilitate the selection of appropriate cloud service provider, with a provision of dynamic pricing and assurance to optimize the final cost, Cloud Broker Pricing Model (CBPM) is proposed.

CBPM mainly offers a pricing band to a consumer, which assures that the charged price at any moment, will not beyond the limits of the band. This way, it offers the benefit of dynamic pricing with as well as the confirmation related to the highest price that can be charged. Moreover, the proposed system gives the freedom to utilize the services newly introduced by some another provider. Further, dynamic pricing on the basis of QoS is transparent for both sensor network cloud provider and consumer, however, if this pricing is decided manually or through pre-defined rules then the pricing scheme will be very complicated. Such pricing needs proper and regular analysis over complete monitored data and weighing of some features to seek importance of one feature over another. Therefore, as future work an advanced algorithm can be developed having the capability to continuously analyze a large amount of data through big data analytics and hence making optimized pricing decisions.

There are few situations in which CBPM may not be useful as expected for wireless sensor networks. In the case of a very frequent change in demand for a computing resource, the system will indulge into the consistent migration of VMs, yielding no work but still paying the cost of migration. As a consequence, the system performance will also downgrade, where the system is greedy and decides to migrate to optimize the total cost. Further, there are issues in migration that needs to be handled. Therefore, as further research in cloud broker pricing model, authors recommend modeling a robust pricing model, capable enough to manage the frequent fluctuations in demand. Further, the behavior of inseparability of computing resources may lead to utility functions producing sub-optimal assignment. Measures should be taken in future work to address this issue as well.

Key words: Cloud computing, dynamic pricing, pricing band, pricing analysis, Cloud Broker Pricing Model.

Introduction. Wireless systems designers are required to provide low-cost, high-performance, easily deploy-able wireless sensors networks which deliver effective means for various operations and are effectively managed and monitored. In wireless sensor networks not only are wireless sensors a key part of the solution but getting the sensor's data processed efficiently and timely is crucial as well. To enable effective processing several works have been proposed [1]. In this paper, the endeavour is to take the concepts proposed a step further by the adoption of cloud computing. Research has recently focused on the development of Cloud-based sensing infrastructures, that integrate large scale sensor networks with sensing applications and Cloud computing infrastructures. The integration of sensors with the Cloud enables users to easily collect, access, process, visualize, archive, share, and search large amounts of sensor data from different applications and support the complete sensor data life cycle from data collection to the back-end decision support system.

Cloud computing is a resource delivery and usage model that facilitates on-demand access to a shared pool of computing resources (e. g., services, application, platform, computing infrastructure, etc.) that are considered to scale infinitely. These computing resources are provided as service or utility and are treated as the commodity that can be traded using pricing model [2]. Further, one among three aspects that prove to be the identity for cloud computing is its metering capability [3]. This capability facilitates measuring the service so that computing resources can be monitored and billed as per usage.

Various factors drive the success of cloud computing such as pay-as-you-go, on-demand virtual resources, elasticity, multi-tenancy pooled resources, and economy of scale. As computing needs are delivered from a distributed infrastructure that can be shared by multiple tenants, economies of scale have considerably reduced the cost as compared to that of owned infrastructure. In support of this, based on a case study which considered a 13-year life cycle, the total cost of establishing and maintaining the cloud environment was only 33 % of that incurred for traditional, non-virtualized infrastructure [4]. Further, this gives freedom to the small enterprises for starting a venture with least capital. Also, for yet another dimension of cloud computing i.e. cloud service broker, where several factors affect the selection of a provider for a resource request, the price is a prime element in the decision [5].

Recently, yet another dimension of cloud computing is emerging, called a *Cloud Service Broker* (CSB), that intermediates the discovery, negotiation, arbitrage, and composition of cloud services between cloud service consumer and cloud service provider [6]. This way, CSB provides service automation to cloud service consumers for requesting, provisioning, and managing a broad range of assisted, pre-configured cloud services across different cloud service providers. The reason that encourages the use of CSB for availing cloud services is that it alleviate the complexity of managing multiple services from multiple vendors, by giving common platform by masking all cloud provider. Also, it allows legitimate comparison of services and prices, across clouds and helps in effective negotiation. Further, CSB supports hybrid cloud strategy and helps in determining the best framework for an organization's need. It also provides commonplace to offer low to high-end capabilities by Service Level Agreement (SLA), security or price. In the case of CSB, where several factors affect the selection of a provider for a resource request, the price is a principal element in the decision [5].

By all this, it is clear that pricing is very crucial in the concept of sensor networks as well as cloud computing. The importance towards pricing is because, the notion of accessing computing needs as and when required, without owning them only by paying for used resources, is the foundation of cloud computing [3]. For sensor networks as there is moderate demand of resources

Table 1

Spot Instances Vs On-Demand Instances Pricing

Region: US East (N. Virginia), OS: Linux/UNIX
Bid Price: 50 % On-Demand, VCPU (min): 1

Instance Type	**vCPU**	**Memory GiB**	**Savings**
t1.micro	1	0.613	84 %
m3.medium	1	3.750	84 %
m3.xlarge	4	15.000	84 %
m3.2xlarge	8	30.000	81 %
m1.small	1	1.700	63 %
m1.xlarge	4	15.000	67 %
m2.xlarge	2	17.100	91 %
m2.4xlarge	8	68.400	89 %

all the time, pricing is very crucial. In addition to this, attractive offerings extended by Cloud Service Providers (CSPs) such as Amazon spot instances may result in up to 90 % reduction in virtual machine instance price. Table 1, lists the statistics of Amazon spot bid advisor, that gives an idea about the savings of spot instances over on-demand instances. Based on the suggestions of spot bid advisor the savings range from 63 % to 91 % for different virtual machine instances. The attempt of cloud computing industry should lie around this notion whether the resources required are for few hours or for a long time. Therefore, to achieve maximum utilization of the computing resources an efficient pricing model should be there.

For an enterprise, pricing models holds the definition of price and cost structure in order to capture maximum customer base, optimize yield from investment, and manage infrastructure deployment more efficiently. In general, profit and net sales act as stimulus that regulates contending providers to an equilibrium price. Price of the service remain static in static pricing model while price respond to supply and demand in real time in dynamic pricing. According to a recent survey conducted by a well-known economic news magazine, 80 % enterprises are observing a change in how their consumers want to access and pay for services and as a result 50 % of these enterprises are changing their pricing models [7]. This survey clearly signifies the need for an evolving pricing model that can suffice the contemporary requirement of the consumers. In this quest, efforts are made to introduce a pricing model for cloud broker, which is dynamic in nature.

Although, there exists, several pricing models [8] in literature viz pay-as-you-go, subscription-based, usage-based dynamic, auction-based pricing, real-time pricing, etc. However, the features that make cloud computing different from another implementation is its volatility where day by day new features are added to existing technology and at the same time new start-ups of the cloud provider is a regular phenomenon. Many dynamic pricing models are there; that tend to take the advantage of this volatility. However, they lack the sense of security for price hike beyond a limit, which is crucial in case of outsourcing. In addition to this, the assurance of optimized cost is also necessary. In cloud computing, where computing resources are outsourced and are charged as per the pricing model a small margin in unit price will create a considerable difference in the overall billed amount.

While many solutions exist to make the wireless sensor network cost effective, there remains possibility to optimize it further. We propose a different approach to define a dynamic pricing model for brokers of cloud-based sensing infrastructure. The idea here is to introduce a pricing scheme in which instead of fixed pricing, the broker will provide a price range to the consumer. This price range will have a minimum price and maximum price, which denotes the lower bound and upper bound of the amount that can be charged to the consumer respectively. So, the charged price will always be within this range. The proposed algorithm for pricing variation makes a consistent effort so that the average price should remain lower than fixed price for the same set of resources.

The contributions of this work are:

— A new dimension of dynamic pricing is proposed that estimates a pricing band to be offered to the consumer. Using this price band, cloud broker will optimize the cost corresponding to desired performance. Also, the consumer will be able to take the advantage of diverse and competitive cloud market while keeping the overhead of interoperability and migration away to cloud broker.

— Estimated pricing band assures the consumer about the upper limit that will be charged, and hence promotes the concept of dynamic pricing.

— Consideration of pricing history, the demand for resources, the supply of resources and Quality of Service (QoS) for the calculation of variable part of pricing, makes the band estimation more precise.

— Adoption of advanced reservation allows cloud service broker to optimize the cost further for the consumer.

This paper is organized as follows. The next section describes the motivation behind proposing the pricing model. In Section 1, the pricing model for cloud brokering architecture is presented. Further, Section 2, put forward an evaluation of proposed pricing model. Next, Section 3 provides the details about related work. Finally, Section 4 provides analysis giving the pros and cons of the proposed pricing model. Here, we also present directions for future research. Section 5 concludes the paper.

1. Cloud Broker Pricing Model.

Cloud computing is said to be a paradigm shift in Information Technology i.e. a change that assures about greater efficiency and scalability at a more economical price. Hence, adoption of cloud computing may prove to be beneficial for a firm in various aspects. This benefit means no further issues about heavy infrastructure configuration, complex server deployments and troubleshooting applications hosted on local infrastructure. However, even by putting moderate attention, it can be revealed that the things are not that easy as it seems in cloud computing, and so, still there are lots of challenges in deploying cloud solutions. Also, the cloud service provider may face the problem of fluctuating demand, because of which at times the resources may be idle or sometimes insufficient to fulfill the demand. Further, new cloud service providers struggle to get the consumers as consumers will mostly prefer established service providers. On the other end, from the perspective of cloud consumer, most of the companies those which are shifting their infrastructure to cloud computing are novice about the field and have trouble in opting the best provider for their needs. Complicated pricing, complex combinations of infrastructure configuration, variation in final billing due to bandwidth usage and other charges, leaves the cloud service consumer with several questions. These questions may be about the best pricing model, suitable configuration, getting expected performance and for many more reasons.

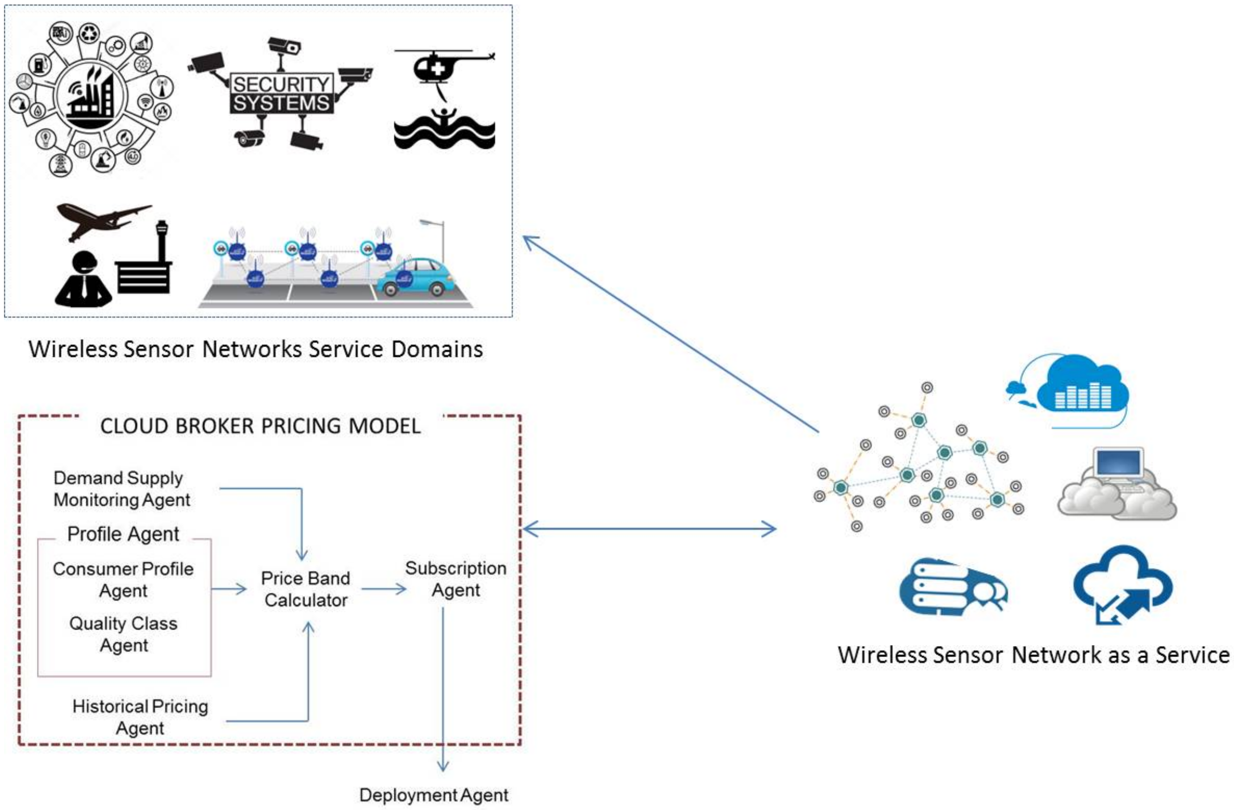

Fig. 1. Pricing Model for SNaaS

In such situations, a cloud broker offering dynamic pricing can prove to be a viable solution. However, the risk of fluctuation in dynamic pricing cannot be ignored. This means if a consumer relies on dynamic pricing to take the benefits of market fluctuation and suddenly the price get hiked due to massive demand then the consumer will have to bear a considerable loss. Some capping is therefore required at both ends i.e. lower bound and upper bound as well. This delimitation will ensure provider about a minimum amount that will be received and at the same time will assure a consumer about the limit beyond which the hired resource will not be charged. Accordingly, we have proposed Cloud Broker Pricing Model (CBPM), a pricing model for cloud broker (Fig. 1). CBPM aims at introducing a pricing band to cloud consumer in order to assure the consumer about the minimum and maximum rates that will be charged corresponding to requested resources. Once cloud consumer agrees to the contract, cloud broker will manage the allocation of computing resources to appropriate cloud provider based on the requirements and constraints placed by cloud consumer. The allocation to the provider will be transparent to the consumer; however, the control will not be there with the consumer to select a particular cloud provider.

Providers are also there as a component of CBPM, so as to publicize their computing resources. A unique id is assigned to the computing resources listed by a provider. Here, the price of resources need to be maintained by the cloud provider, and hence, the provider may increase or reduce the price based on the demand and availability of resources. After this, the resources are ready to be assigned to the cloud consumers if they suffice consumer's resource requirements. CBPM then executes an algorithm to assign the listed resources to the cloud consumers, which as an output gives an allocation matrix having the resources and corresponding cloud consumer. Cloud broker then shares the unique id of the resource with the consumer, using which consumer gets the access to the resource. The CBPM system is compatible with the prominent cloud providers such as Amazon EC2, Google Compute Engine and Microsoft Azure and hence the proposed model can easily be deployed with VMs of these service providers.

Apart from the algorithm that will decide on the allocation of a provider's resource to a consumer, CBPM also provides a user interface (UI) that can be used by the cloud provider and cloud consumer as well. Authentication mechanisms are incorporated to verify the identity of providers and consumers. Cloud providers can enlist their resources with a proper description along with the price. On the other hand, cloud consumers can use the CBPM interface to specify required resources, non-functional requirements, duration and basic Service Level Agreement (SLA) requirements. CBPM logs the allocation details and performance parameters, which will help the providers and consumers to track the allocation history, accounting details, current allocations, request status, SLA compliance and usage statistics. Hence, in CBPM we have tried to find an assignment that fulfills the requirement of the consumer as well as provider in a best possible manner as per the situation.

1.1. *Basic Model.* The goal of CBPM is to facilitate allocation of services offered by the cloud provider to a cloud consumer in a manner, so as to optimize the total cost borne by cloud consumer. For this, a pricing band is offered to cloud consumer having lower and upper limits within which the resource will be charged. Therefore, to get a final optimized price, reallocation should be done as and when required.

This work introduces a pricing model (Fig. 1) composed of modules such as *demand-supply monitoring, consumer profile, quality class, historical pricing, pricing band calculator* and *subscription module.*

As specified, the idea of the pricing model is to propose a pricing band to the cloud consumer corresponding to resources requested. Later, the pricing model will make a consistent effort to optimize the price charged by grabbing the opportunity raised by other providers and then migrating to these provider resources. Therefore, assuming P_{vl} and P_{vh} be the lower limit and upper limit of the variable pricing band offered to consumer c for the resource set R (Fig.). Further, assuming P_{ij} be the price charged from a consumer i by the provider j, where a consumer i utilized the resources of m different providers during the contract period (Fig.). Then the price charged by a consumer i can be given by (1)

$$P_a = \sum_{j=1}^{m} P_{ij} \tag{1}$$

On the other side, let P_f be the fixed price charged by the provider j, if consumer i preferred fixed pricing instead of variable pricing. Provider j is the preferable provider at time t_0 i.e. the time when contract period started. So, under such circumstances the objective of CBPM will be to make consistent effort to achieve the following relation (2):

$$P_a < P_f \tag{2}$$

Therefore, the lower limit and the upper limit defined by CBPM can be assumed as follows:

$$\begin{aligned} P_{vl} &= P_f - c_1 \\ P_{vh} &= P_f + c_2 \end{aligned} \tag{3}$$

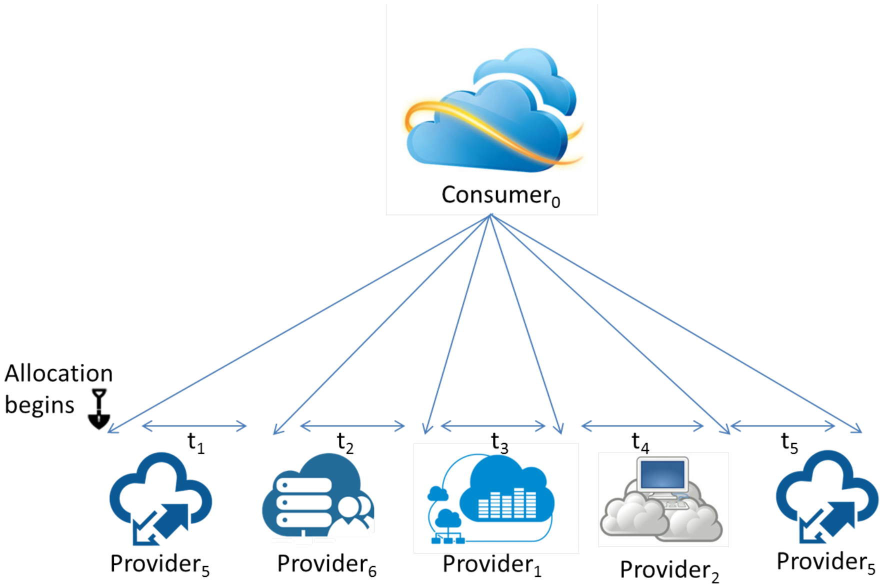

Fig. 2. Dynamic Pricing

Here, c_1, c_2 denotes the marginal cost needed to maintain the limits. In few situations, c_1 can have same value as c_2.

Therefore, the following function will give the outline about the estimation of the limits P_{vl} and P_{vh}:

$$P \leftarrow f(N, T, Q, C, R, H) \tag{4}$$

Here, P is the tuple (P_{vl}, P_{vh}), N *number of resources requested*, T *time of subscription*, Q *expected quality levels*, C *user category*, R *general pricing for required resources* and H is the *pricing history*. The variable N represents the number of resources required by the consumer. The time T helps in reserving resources and is also articulated as vector comprising: t_c as current time, t_s as start time and t_d as duration. The quality desired Q defines the expected QoS levels. Users are also divided into different categories based on the required resources, time of contract, loyalty etc., and is expressed by C. The variable R, denotes the fixed pricing for the required resources. Finally, H portrays an array having the price history of the resources.

Input: Finite sets T_r, N, T, Q, C, R and H of integers
Output: Price band offering from broker to consumer, A tuple P(P_{vl}, P_{vh})
for *all* P_r, $r \in R$ **do**
  resourcePool $\leftarrow$ resourcePool$+P_r$;
end
for *all* PA_k, $k \in$ *[1,l]* **do**
  receive cloud consumer's requirements;
  $P_k \leftarrow$ calcPricingBand(T_r, N, T, Q, C, R, H)
  $P_{k_{vl}} \leftarrow \min(P_k)$
  $P_{k_{vh}} \leftarrow \max(P_k)$
end
PricingBand determines the limits within which price will vary

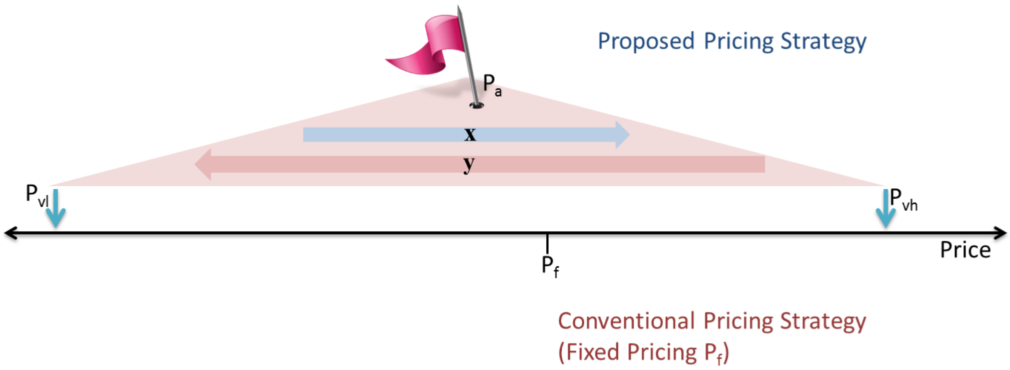

Fig. 3. Pricing Limits

1.2. Pricing Band Estimation. Cloud resources are demanded over time by different cloud consumers through cloud resource broker. Cloud resource broker offers a price band to the consumer for the resources requested. Pricing band ensures that the charged price will be within the limits and not beyond. On acceptance, cloud broker makes continuous efforts to bring the average price below the fixed price. This is done by grabbing new offerings from providers and migrating the VMs to them.

Let, T be the time for which the consumer have requested the resource k and is given by:

$$T \leftarrow \{t_s, t_{s+1}, \ldots\ldots, t_{s+d}\} \tag{5}$$

While offering pricing band, the cloud resource broker emphasizes on dynamic pricing. The dynamism in price offered by cloud service provider will be taken as an advantage to reduce the pricing charged over required duration. According to [9] the relation between price and demand with respect to time using following stochastic demand function:

$$D\left(t, p, \xi\right) \tag{6}$$

In equation [6], ξ is the margin of error. Further, with demand function D it is assumed that this function returns the demand determined by price. This demand is used as the factor to multiply with the price and then to determine the final price.

In case of static pricing, as the price is fixed for the complete duration of the contract, the price should be optimized only once. Corresponding to time t, user category u and quality class q, following optimization problem can be solved to optimize the price for static pricing model:

$$maximize \sum_{t=1}^{T} \sum_{u=1}^{U} \sum_{q=1}^{Q} \left(D\left(t, p, \xi\right)\right) \tag{7}$$

While for dynamic pricing, the price may change even after allocation of the resources. Therefore, apart from the time, there can be several other factors that will affect the price, and hence the demand function needs to be modified. Hence, utilizing the variables of function f described in 4 the demand function can be written as:

Table 2

Values of Demand Factor

Time (Days) (1)	**Demand Factor (D)**	
	Historical Data (Last 60 days) (2)	**Historical Data (Last 30 days) (3)**
Start	1.00	1.00
10	1.47	0.82
20	0.22	1.27
30	1.28	0.76
40	0.75	0.70
50	0.67	1.11
60	0.90	0.62

$$D\left(n, t, q, c, r, h\right) \tag{8}$$

As the demand function is considered to be the factor for obtaining final price, the variation in price at different time intervals can be predicted by utilizing equation [8]. Hence, the limits P_{vl} and P_{vh} can be given as follows:

$$\begin{aligned} P_{vl} &= \min_{\forall t \in T} p * D_t \\ P_{vh} &= \max_{\forall t \in T} p * D_t \end{aligned} \tag{9}$$

Now, cloud resource broker will offer these limits to the consumer and for the whole contract period, the price charged to the consumer will range in between the limits. The broker will gain profit in case some provider offers resources below P_{vl}. On the other side, the consumer will be benefited if the dynamic pricing goes beyond P_{vh}. Here, efforts are made to anticipate the boundary in which the dynamic pricing may fluctuate and not on maximizing the revenue of cloud resource broker.

2. Evaluation. In this section, the experimental setup for the proposed pricing model is described. The experimentation is primarily aimed at evaluating the practicality of the pricing model CBPM. A prototype is developed to support the evaluation process. Primarily, the prototype consists of two important modules: *Price band calculator module* and *VM manager module.* Price band calculator module is responsible for calculating the price band corresponding to the consumer's requirements while VM manager module corresponds to deployment agent. For the simulation of price band calculator module, the time duration for demand analysis is considered to be ten days. Demand factor is calculated using demand function and by utilizing this demand factor the values of P_{vl} and P_{vh} are observed [Table 3]. Different requirements will lead to different values of demand factor at different time instances. For example, only after changing the duration of historical data, the change in demand factor can be seen as described in column 3) of Table 2. The range for the factor of demand analysis is taken from 0.2 to 3.0. The assumption made here is that the demand can be as low as 20 percent of the demand at time t_s i.e. the start time, and it can go up to 300 percent on the other side.

Further, for actual values of price change corresponding to the period for which the values of P_{vl} and P_{vh} are calculated, Amazon EC2 spot pricing is utilized [Fig. 4]. The pricing considered

Table 3
Limits assigned for different demand factor

Demand Factor (Last 60 days)		Demand Factor (Last 30 days)	
P_{vl}	P_{vh}	P_{vl}	P_{vh}
0.0026	0.0200	0.0090	0.0160

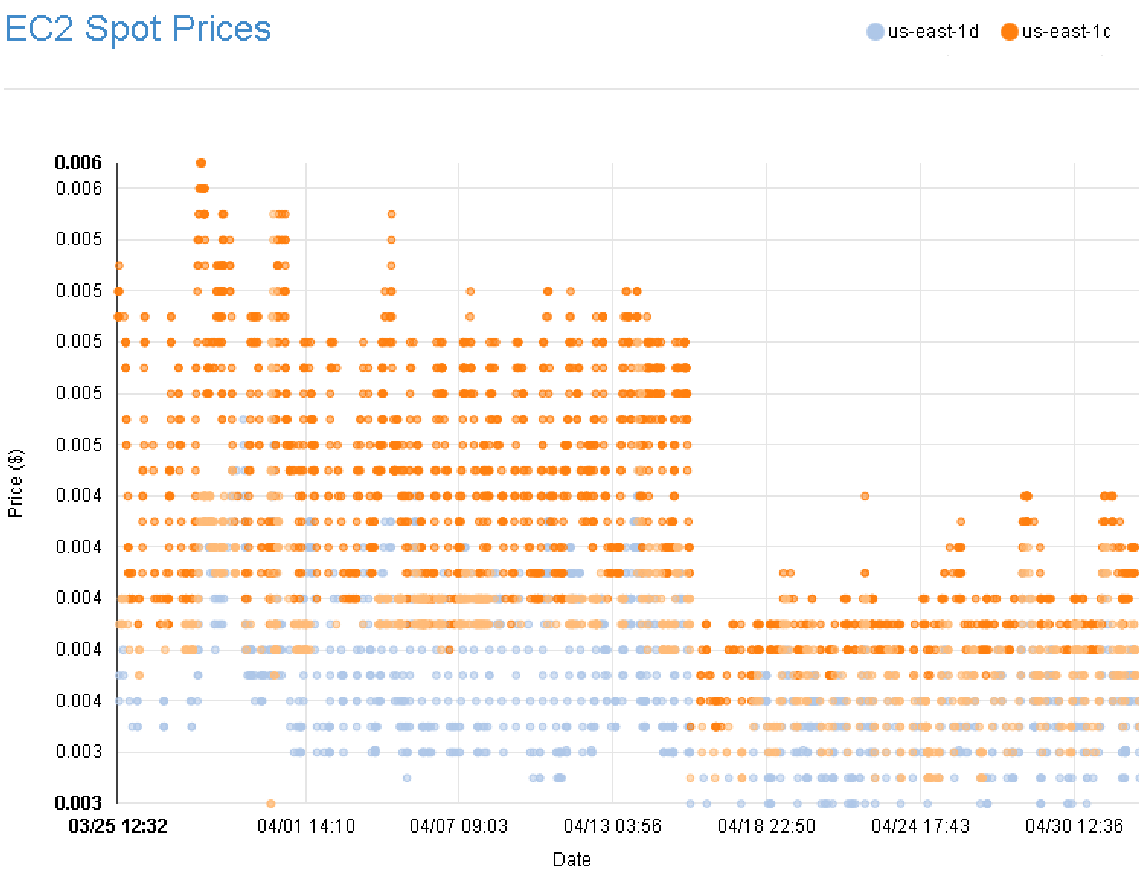

Fig. 4. Amazon EC2 Spot Pricing

is for 60 days on Linux/UNIX machine with t1.micro configuration situated in us-east-1c region. For the whole tenure under consideration, the price ranged from \$0.003/hr to \$0.005/hr.

However, the same instance of Amazon EC2, if considered for fixed price would have cost \$0.013/hr. A comparison of dynamic pricing when limits are offered and that of fixed pricing is given in Fig. 5.

It can be observed that dynamic pricing model CBPM performs extraordinarily well in the scenario considered. Particularly, it proves to be a win-win situation for both providers as well as the consumer. For example, considering the case of demand factor when last 30 days historical data was considered the lower limit came out to be \$0.009. This means that at least \$0.009 will be charged irrespective of the price charged by the provider. As the spot price charged for the observed duration range from \$0.003 to \$0.005, so broker is getting a considerable margin per hour. On the other side, it is assured that the maximum price charged in any circumstances is

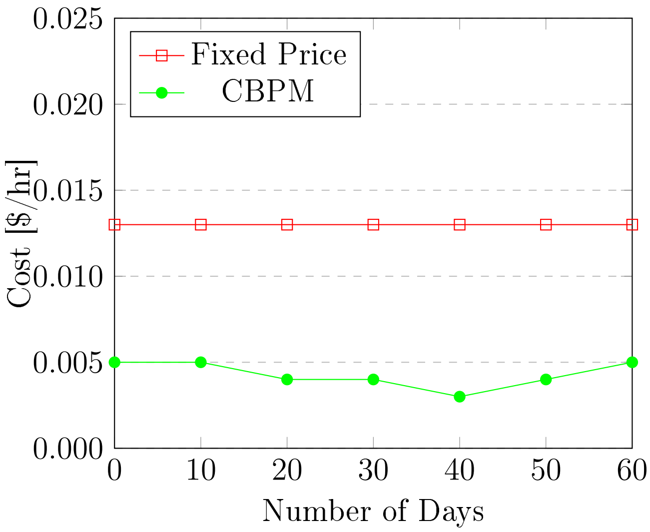

Fig. 5. Effective Pricing at Different Instances

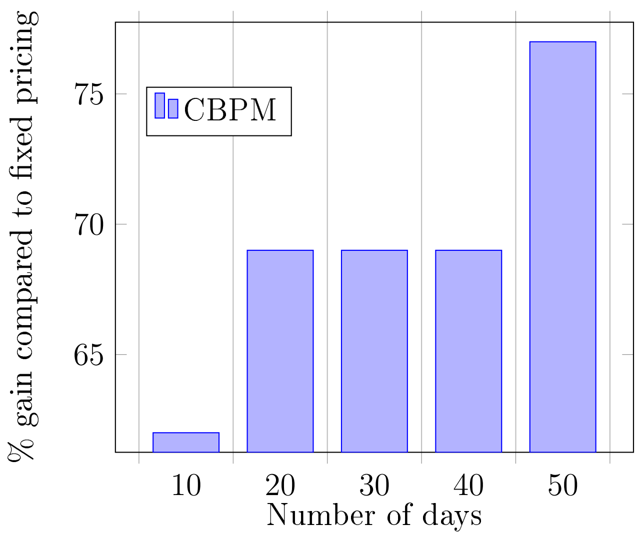

Fig. 6. Percentage Gain by Adoption of CBPM

\$0.016 per hour. This safeguards a consumer against sudden surge such as [10], where Amazon EC2 spot request volatility hits \$1000/hr.

With this elementary evaluation, it can be observed that the idea of proposing a pricing band instead of relying merely on dynamic pricing is favorable for all the stakeholders participating in the cloud market.

3. Related Work. As cloud computing is a promising technology [2] and is still said to be in evolving state [11], so new ventures concerning providers are regularly emerging. Also, because of its competitive environment, existing companies keep on announcing attractive offerings time-to-time. However, sticking to fixed pricing scheme in such evolving and competitive market, will limit the consumer from availing the benefits of these conditions. Hence, use of dynamic pricing will help to conform to the continually changing market. It facilitates maximum revenue generation by properly adjusting price with respect to demand and appropriate utilization of resources. Currently, most of the cloud service providers have adapted fixed pricing scheme [12] except Amazon spot pricing [13]. Providers with fixed pricing scheme promote allocation strategies such as on-demand and reserved instances (see if there are more strategies), while Amazon provides spot instances as well, along with the other two. However, spot instance resources can anytime be interrupted and claimed back by Amazon, resulting in loss of work if the application running is not able to handle the interrupt.

Cloud pricing schemes are mainly classified as fixed pricing scheme, dynamic pricing scheme, and hybrid pricing. Among these, fixed pricing scheme is one adapted by default and is always compared with all other approaches. Therefore, related work on cloud pricing schemes is classified into (i) Dynamic pricing (ii) Hybrid pricing. Again, as cloud computing concept is still evolving, the description is prepared with pricing schemes pertaining to Grid and Web Services. This description is followed by consideration of existing work on cloud pricing schemes.

3.1. *Dynamic Pricing.* Various economic models corresponding to grid computing were compared by Buyya et. al. [14]. This comparison was done between flat fee, usage duration, subscription and demand pricing. In yet another work by the authors [15], they have developed a system for scheduling resources with varying QoS using a resource broker. In this, QoS acts as the decision maker for scheduling the resources. [16] proposed an algorithm for pricing Grid resources using the idea of the commodity market. The proposed approach has improvised Smale's method to identify price equilibrium in grid market. Another study has been carried out by [17], where they have introduced a pricing information service architecture for the grid in which a general pricing scheme denoted as quadruple is used. Dynamic pricing is estimated using this quadruple comprising quantity of resource requested, time, quality class and user profile. Further, the pricing scheme is expressed as XML to link it easily with service level agreements. [18] have presented autonomic variable pricing scheme for utility computing with advanced reservation because of which users can be assured about the required resources in advance while being aware of the exact expenses. As the pricing scheme is autonomic, so it self-adjusts pricing parameters based on demand and supply. Another related work for variable pricing that makes use of financial option theory and Moore's law is proposed by [12]. The primary emphasis for the calculation of variable price is in the age of resource, quality of service and the contract period. [19] had explored variable pricing in cloud computing with a view of the continuous double auction and introduce an ongoing reverse auction. A recent work [20], proposed a dynamic pricing mechanism that provides a complete overview of cloud offerings. The proposed dynamic pricing mechanism is a multi-agent multi-auction based system which helps cloud service consumer to select appropriate provider.

Another aspect of dynamic pricing scheme is pricing decision for multiple resource types which is computationally an NP-complete problem. [21] proposed a pricing scheme that makes use of VCG mechanism for allocating multiple resources in the dynamic environment. This scheme proves to be viable as compared to traditional as well as combinatorial auctions.

Some other works having concern towards dynamic cloud pricing schemes are [22]. Also, [8] provides a comprehensive survey of the various pricing schemes proposed for cloud computing. A review of various research on cloud computing pricing and markets is demonstrated by [23]. Here, after reviewing numerous research papers from different renowned journals, the authors have established a framework that gives an idea about how cloud economics research should proceed.

Further, few other work that deals specifically with cloud pricing but not in dynamic cloud pricing that can be referred are [24–25, 32].

3.2. *Hybrid Pricing.* The hybrid pricing model makes an attempt to provide a diversified model that incorporate advantages of both fixed price model and pay-per-use model. This way, the hybrid pricing model utilizes fixed pricing in normal conditions and maximizes benefits by executing tasks through pay-per-use as and when some good offering arrives. Hybrid pricing model proves best for massive and lengthy projects with unsettled objectives in the beginning. Apart from several benefits for the consumer, it also gives the cloud service provider a more controlled infrastructure with shared liability in financial terms.

For information services, the hybrid pricing model is presented as two-part tariff pricing in [26], that examines the optimality of the pricing scheme that should be adopted by a provider in different conditions. The considerations done for making the decision about a particular pricing is on the basis of consumer behavior, as whether the consumers are homogeneous consumers or heterogeneous consumers. Further, the sensitivity of optimal pricing scheme is analyzed with respect to marginal costs and monitoring costs. Overall, efforts are made to help provider to choose best pricing model on the basis of consumer type (homogeneous or heterogeneous) and the trend between marginal and monitoring cost.

[27] looked hybrid pricing scheme with another aspect where the authors examined the effectiveness of hybrid pricing model for a cloud service provider where fixed pricing scheme is mixed with spot-instance pricing. The difference introduced here is its look-out towards cloud service as damaged perspective, where spot-instances can be claimed any time through an interrupt. The decision support model proposed in this work helps a cloud provider to decide whether the hybrid pricing scheme is suitable or not. Yet another study done in [28] proves that hybrid pricing model is more efficient than subscription pricing and pay-per-use pricing as well.

Other related systems that help cloud service consumer to obtain a comparison of cloud providers on the basis of various factors including pricing model adapted are [29–30].

To the best of our knowledge, the proposed approach does not match with any of the existing work. However, we have utilized the basic concept of dynamic pricing.

4. Discussion and Analysis. One of the main characteristics that drive the competition of CSPs is pricing. Many enterprises including cloud computing are involved in price battle by reducing prices on a regular basis. This reduction in price is not only because of a price cut in the cost of basic infrastructure, but it's also an endeavor for stake acquisition, and to convey the aggression to other CSPs. However, to define an appropriate price based on the present market situation, a suitable mechanism for price selection is required, and can be made precisely using a pricing model. The pricing models are means to maintain the balance between the customer's QoS requirements, price, and the service provider's cost and operational productivity.

Cloud computing started with the pay-per-use pricing model, where the user is charged solely on the basis of actual usage such as $x for an instance/hour. Pay-per-use model is realized in cloud computing by pooled, shared, scalable infrastructure, and multi-tenant services. The main reason for the popularity of this model is because it provides cost-benefit along with agility. After this, many CSPs have shifted to other alternative pricing models such as subscription-based pricing, sustained-use pricing, and spot pricing. All these pricing models can be broadly classified into two categories i.e. static pricing models and dynamic pricing models. One of the examples of dynamic pricing is Amazon EC2 spot instances. Using these instances consumer can bid on idle EC2 instances. Spot instances can be utilized to lower the operational costs for batch-processing tasks and tasks that do not need persistent resource availability. Hence, consumers, as well as providers benefit from this hybrid strategy of using the spot instances when found idle and allotted instances otherwise. Consumers can optimize the price by running their tasks during non-rush hours, and providers can increase their revenue by reducing the price and facilitate improved utilization of resources. However, one serious problem with spot instances is that Amazon EC2 reclaims the resource in between in case the spot price surges above bid price to allocate it to another consumer.

EC2 spot instances deliver the features of an auction through bidding opportunities. However, as EC2 spot instances can be claimed back at any moment, the dynamism offered in pricing is not similar to dynamic pricing offered by the other enterprises such as airlines and stock markets, etc. To the best of our knowledge, apart from Amazon spot instances, till now the concept of dynamic pricing in cloud computing is only in literature and is not offered by any provider. These providers are offering one or the other variant of fixed pricing i.e. subscription-based, pay-as-you-go pricing, etc. Further, the implementation of dynamic pricing of other enterprises, if mapped to cloud computing will not completely solve the purpose. Reason being, in other enterprises such as flight booking, the stock market, and hotel booking the purchase is to be made once and is not recurring. However, in the case of cloud computing after finalizing the provider, the charges will be recurring and will be based on the usage. Therefore, in such case, looking from the perspective of cloud broker who have to maintain a win-win situation for cloud consumer and also for a cloud provider, extreme change in rates will bring loss either to the provider or the consumer. For example, in case the prices slash too much then the provider may not even be able to retrieve the operational cost. On the other side, the consumer may have to pay a very high price in case of the steep price hike. For example, Amazon EC2 spot request volatility hits \$100/hr on contrary to \$0.05/hr which is the lowest price observed for the same instance [10]. Hence, to protect cloud service providers and cloud service consumers from such unexpected loss, the concept to delimit price from both the ends is proposed in this work. The price band offered will ensure balanced revenue to the provider and moderate charges billed to the consumer. Further, in order to compensate the loss of broker, concepts of advanced reservations can be utilized by securing their required resources in advance. To have further insight on advanced reservations the work done by Chaisiri et al. [31] and Yeo et al. [18] can be referred.

Further, with a view of which pricing model is beneficial for which consumer; many consumers choose a fixed pricing model even though this may not be the least costly tariff for them. Few consumers choose a pay-per-use tariff. Consumers biased with a fixed pricing model are not more likely to switch. Further, consumers may derive additional benefits through a fixed pricing, which they would not derive from any other tariff. These benefits make consumers satisfied with their pricing model choice, and consequently, they stick to fixed pricing model. In contrast, we find that low usage results in a switch to the pay-per-use model. Also, there is no indication of specific benefits of pay-per-use model, other than that the consumer has to pay only for what is used. Consumers inclined towards pay-per-use pricing model are more likely to switch tariffs. Therefore, we conclude that they are not satisfied with their choice: If they realize their fault in tariff choice, they are ready to switch to another tariff. Overall, Fig. 8 shows the specific areas favorable for cloud providers while offering fixed pricing, in a plot of demand vs. price. Areas which are marked as provider's loss will prove to be favorable for cloud consumer. Fig. 7 presents a particular case to compare the fixed pricing model and dynamic pricing model. Considering the area under the curve to be divided into three parts, part A depicts the area where demand is high; however the variable price is also higher than the fixed price. While area B characterizes the case where demand is high but the variable price is lower than fixed price. Finally, area C represents the portion where demand is low, and the variable price is also lower than fixed price.

Table 4

Comparison of pricing models

Proposed Model	**Decision Technique**	**Dynamic Assignment**	**Rationality**	**Consideration for multiple cloud providers**	**Price band offering**	**Realization**	**Remark**
Pay-per-use model	Fixed	No	No	No	No	Yes	General pricing approach
Subscription based	Fixed	No	Yes	No	No	Yes	General pricing approach
Spot pricing	Dynamic	No	No	No	No	Yes	Pricing model by Amazon where resource price are driven by demand. Resource terminates once the spot price goes above bid price.
[16]	Dynamic (Commodity based)	No	No	No	No	No	Proposed dynamic pricing approach based on commodity approach where price is determined by demand and supply.
[26]	Hybrid (Flat fee/Usage based)	No	Yes	No	No	No	Comparison of fixed pricing, usage based pricing and two part pricing is performed.
[22]	Dynamic	Yes	Yes	Yes	No	No	A comparative study of fixed and dynamic pricing in federated cloud environment.
[32]	Dynamic	No	Yes	Yes	No	No	A cloud banking model is proposed which contains pricing algorithm in order to maximize the profit of consumer.
[19]	Dynamic (Genetic Model)	No	No	No	No	No	Proposed a genetic algorithmic approach to offer competitive price based on demand.
[33]	Dynamic	No	Yes	No	No	No	Financial option theory is adapted for pricing cloud resources.
[19]	Dynamic (Reverse auction)	No	No	No	No	No	Introduced the concept of open market for IaaS using Continuous Double Auction and proposed Continuous Reverse Auction.
[33]	Hybrid (Pay-per-use/ subscription based)	No	Yes	No	No	No	Theoretical analysis of economic model for cloud computing - especially pay-per-use and subscription pricing
[18]	Dynamic	No	Yes	No	No	No	Use of advance reservation to implement autonomic metered pricing.
[27]	Hybrid (Fixed/Dynamic)	Yes	No	Yes	No	No	Hybrid pricing strategy is proposed which outperforms over spot pricing or fixed pricing.
[34]	Dynamic (Fuzzy logic)	Yes	Yes	No	No	No	Clabacus PJ A cloud compute commodity model is proposed based on fuzzy logic and genetic algorithm, using financial option theory.
[20]	Dynamic	Yes	Yes	Yes	No	No	Proposed dynamic pricing model Cloud Market Maker by utilizing multi-agent system and auction based approach.
[35]	Dynamic (Game theoretic approach)	Yes	Yes	No	No	No	Online system for resource allocation using Mechanism Design a game theoretic approach. In this, users can recommend their price and time for which resources are requested.
CBPM	Dynamic	Yes	Yes	Yes	Yes	No	Dynamic pricing model for cloud broker, driven by demand and offers a price range to consumers in order to assure the maximum price that will be charged.

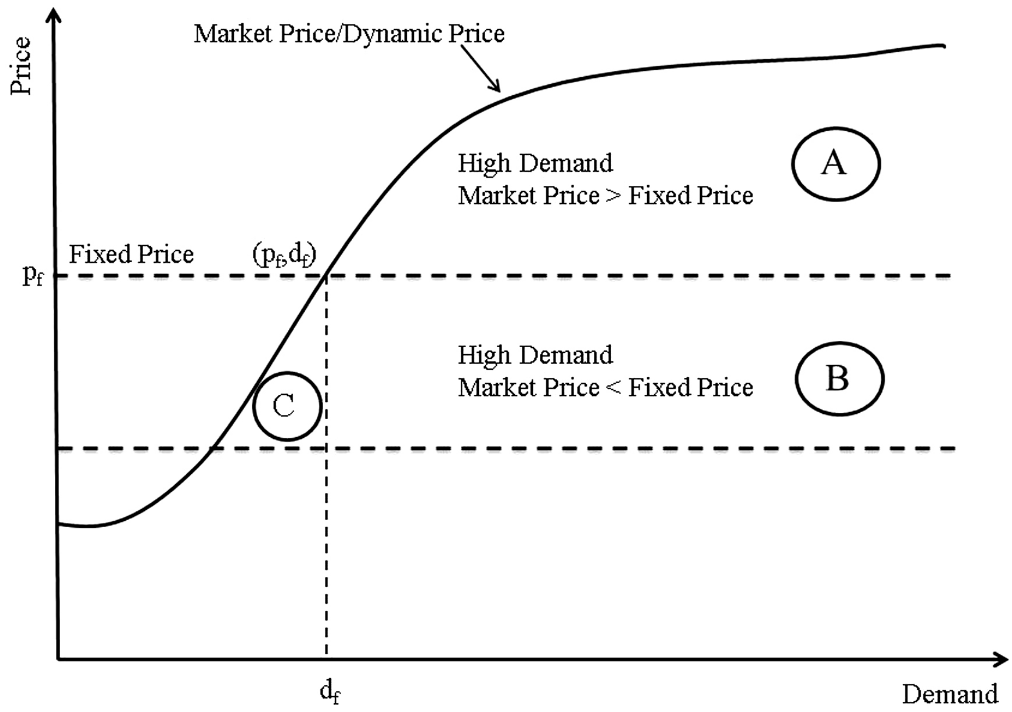

Fig. 7. Fixed vs. Dynamic Pricing

Therefore, brokers should carefully consider decision about the pricing model. Heavy switch between pricing models will lead to dissatisfaction of consumers. Hence, an attempt is made in this work to propose a pricing band that abstracts the core pricing models and presents an environment that exhibits a win-win situation for both cloud provider and cloud consumer. Another concern to decide on the extent of emphasis that should be given to dynamic pricing is to predict its future. The reason for this concern is that in the current scenario, the price is not the only factor for a decision about resource selection. In general, nowadays consumers are concerned more about the overall experience. This experience includes performance, post subscription services, fair billing, and many other factors. So even when the services are same, the overall satisfaction is different from different providers. Therefore, to deliver a comprehensive solution, the pricing scheme should compulsorily incorporate these aspects as well. In this context, as dynamic pricing scheme is the one that can exhibit both the service and the consumers' satisfaction and hence proves its future stability.

A comparison of already proposed and operational pricing models is shown in Table 4 with that of CBPM in terms of decision technique, option for dynamic assignment, rationality for cloud provider as well as consumer, consideration for multiple providers, price band offering and practical exposure of the approach. The comparison considers the pricing approaches proposed in the field of cloud computing as well as fields such as grid and utility computing [16, 18, 26]. Existing systems mainly fall under the fixed, dynamic and hybrid pricing approach category. Also, in dynamic pricing, the main focus of most systems is on proposing appropriate price with respect to a single provider [12, 25]. A few systems [20, 22] have considered the notion of multiple providers. However, in order to seize the prospects created by the competitive environment of multiple providers, a platform for comparison is required. Moreover, the concept of proposing a price band while offering dynamic pricing is also untouched. Cloud Broker Pricing Model utilizes the QoS, historical pricing, consumer rating and hence effective demand to offer a pricing band

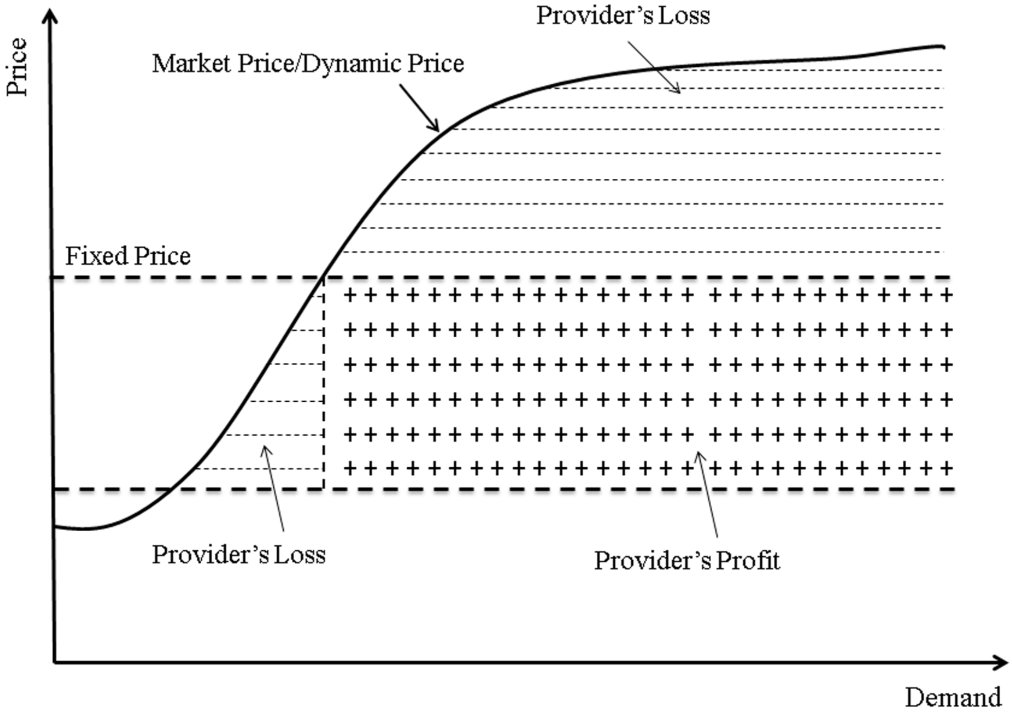

Fig. 8. Provider's Profit and Loss While Offering Fixed Price

to the consumer. Further, consistent efforts are made by CBPM by capturing the appropriate opportunity and migrating to another provider for optimizing the cost charged to consumer.

Conclusion. The significant functionality of data collected and processed at wireless sensor nodes is rendered fast, uninterrupted and reliably with cloud computing and its optimized implementations. Therefore, sensor network firms are partnering with cloud service providers, which lease computing infrastructure as required. This paper suggests a model for optimizing the computing potential of the wireless sensor network in conjunction with the pricing model of the cloud. Integration of concepts of cloud and sensor networks takes the advantage of the scalable and dynamic aspect of cloud being exploited for sensory data. The results show that the proposed method adapts well with performance expectations of sensor networks and reduces the cost specific overheads for its largely processing based functioning. In order to facilitate the selection of appropriate cloud service provider, with a provision of dynamic pricing and assurance to optimize the final cost, Cloud Broker Pricing Model (CBPM) is proposed. CBPM mainly offers a pricing band to a consumer, which assures that the charged price at any moment, will not beyond the limits of the band. This way, it offers the benefit of dynamic pricing with as well as the confirmation related to the highest price that can be charged. Moreover, the proposed system gives the freedom to utilize the services newly introduced by some another provider. Further, dynamic pricing on the basis of QoS is transparent for both sensor network cloud provider and consumer, however, if this pricing is decided manually or through pre-defined rules then the pricing scheme will be very complicated. Such pricing needs proper and regular analysis over complete monitored data and weighing of some features to seek importance of one feature over another. Therefore, as future work an advanced algorithm can be developed having the capability to continuously analyze a large amount of data through big data analytics and hence making optimized pricing decisions. There are few situations in which CBPM may not be useful as expected for wireless sensor networks. In the case of a very frequent change in demand for a computing resource, the system will indulge into the consistent migration of VMs, yielding no work but still paying the cost of migration. As a consequence, the system performance will also downgrade, where the system is greedy and decides to migrate to optimize the total cost. Further, there are issues in migration that needs to be handled. Therefore, as further research in cloud broker pricing model, authors recommend modeling a robust pricing model, capable enough to manage the frequent fluctuations in demand. Further, the behavior of inseparability of computing resources may lead to utility functions producing sub-optimal assignment. Measures should be taken in future work to address this issue as well.

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Дирадж Рэйн является аспирантом факультета информационных технологий и инженерного дела в Индийском технологическом институте (город Индаур). Он занимается исследованиями в такой области облачных вычислений как структуризация и автоматизация соглашений об уровне предоставления услуг. E-mail: `phd11120102@iiti.ac.in`.

Dheeraj Rane is currently a Ph.D. student in the Discipline of Computer Science and Engineering at IIT Indore, India. His area of research lies in Cloud Computing specialising in the domain of structuring and automating Service Level Agreements. E-mail: `phd11120102@iiti.ac.in`.

Абишек Шривастава является доцентом факультета информационных технологий и инженерного дела в Индийском технологическом институте (город Индаур). Он окончил аспирантуру Альбертского университета (Канада). Его научные интересы лежат в области технологий межмашинного взаимодействия (M2M) и машинного обучения, Интернета вещей, облачных вычислений, беспроводных сенсорных сетей, контекстно-зависимых вычислений. E-mail: `asrivastava@iiti.ac.in`.

Dr. Abhishek Srivastava is an Associate Professor in the Discipline of Computer Science & Engineering, IIT Indore, India. He has a Ph.D. degree from the University of Alberta, Canada. His research interests lie in the areas of technology agnostic machine to machine communication, and Machine Learning. More recently, he has been interested in extending these ideas in the realm of Internet of Things, Cloud Computing, Wireless Sensor Networks, and Ubiquitous Computing environments. E-mail: `asrivastava@iiti.ac.in`.

Владимир Шахов — старший научный сотрудник Лаборатории системного моделирования и оптимизации Института вычислительной математики и математической геофизики СО РАН. Окончил Механико-математический факультет Новосибирского государственного университета, получил степень кандидата физико-математических наук. Является вице-председателем Сибирской секции IEEE. Научные интересы включают моделирование и оценку производительности технических систем, технологии Интернета вещей, интеллектуальный анализ данных. E-mail: `shakhov@rav.sscc.ru`.

Dr. Vladimir Shakhov is a Senior Researcher with the Laboratory of system modeling and optimization of Institute of Computational Mathematics and Mathematical Geophysics. He received the B.S. in mechanics and applied mathematics, M.S. degrees in mathematics, and Ph.D. degree in computer science from the Novosibirsk State University, Novosibirsk, Russia. He is the Vice Chair of the IEEE Russian Siberia Section. His research interests include system performance analysis, IoT technology, and data analytics. E-mail: `shakhov@rav.sscc.ru`.

Дата поступления — 22.12.2017