Intelligence Integration in Distributed Knowledge Management

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Chapter XIX
Survey on the Application of Economic and Market Theory for Grid Computing

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ABSTRACT

In this chapter, we present a survey on some of the commercial players in the Grid industry, existing research done in the area of market-based Grid technology and some of the concepts of dynamic pricing model that we have investigated. In recent years, it has been observed that commercial companies are slowly shifting from owning their own IT assets in the form of computers, software and so forth, to *purchasing services from utility providers. Technological advances, especially in the area of Grid computing, have been the main catalyst for this trend. The utility model may not be the most effective model and the price still needs to be determined at the point of usage. In general, market-based approaches are more efficient in resource allocations, as it depends on price adjustment to accommodate fluctuations in the supply and demand. Therefore, determining the price is vital to the overall success of the market.*

INTRODUCTION

The term Grid computing was introduced for describing a new model for distributed computing. The basic concept refers to the sharing of distributed heterogeneous compute resources virtualized as a single resource pool (Foster & Kesselman, 1999; Foster, Kesselman, Nick & Tuecke, 2002). Typically, as grids are often used for running computational intensive applications, the common type of grid resource usually means compute cycle. However, the concept does not place any restrictions, as it can be all kinds of computing resources like network bandwidth, data storage, application licenses and even scientific devices.

Today, the practice of Grid computing is based on voluntary sharing of compute resources, which is sufficient for establishing small-scale private grid dedicated to a specific purpose. However, to build a global level generic grid, this is simply not sustainable. Organizations, especially from the industry, will find very little reason to share their resources for free, and will expect some gains from their participation. Therefore, in order for grid to be the mainstream computing model, an efficient supporting platform and mechanism should be designed for encouraging resource owners to offer their idle resources and customers to satisfy their resource needs. Therefore, the idea of using markets in Grid computing as a means for organizations to commercialize their grid resources was revitalized by many researchers.

A market is, as defined in economics, a social arrangement that allows buyers and sellers to discover information and carry out a voluntary exchange. Our definition of the Grid Market refers to a software platform with the business mechanisms to support trading between grid users. Its principle is similar to the conventional marketplace and the goods that are traded on are generic grid resources, including concrete computing/storage/network physical resources, grid services and complex workflows. The Grid Market provides the required business functions to support the business process to allow any customers to participate in the trading. Such functions have to cover the all the possible activities in a typical market such as registration of new customers, advertising the trade goods, searching and browsing the market, bartering, monitoring the prices and making or receiving payment.

An emergence of such a marketplace for grid brings the following advantages:

- Encourages more users to adopt Grid technology, especially in enterprises.
- Provides incentives for resource owners to provide their idle resources, which is helpful for establishing large-scale, mature grid systems.
- Enforces efficient utilization of grid resources in which buyers who value a resource most highly will buy from sellers most willing to sell. Provide access for even small businesses to temporary grid resources which may be too expensive to acquire on their own, or just to meet their short term peak demand.
- Customers, including both buyer and seller, can easily design their trading policies based on their current status so as to maximize resources' utilization and their benefits.

Currently, many works have been done on applying market-based economic paradigm to Grid computing. The objective of this chapter is to provide a review of the past and current efforts in commercialization of Grid computing, as well as some of the business and pricing models that have been considered for e-commerce and e-business which can be apply to the Grid Market.

OVERVIEW OF GRID COMMERCIALIZATION

Economic systems in human society can be broadly classified into two models: Central Planning Model and Free Market Model (Shetty, Padala, & Frank, 2003). In central planning model, a single institution has total authority and decides what to produce, how to produce and to whom. In a free market model, producers and consumers make these decisions suiting their benefits. Our Grid Market is a typical free market model.

Change in technology also brings change in our economic environment. The advent of computers and Internet brings new dimension to market trading. Online auctioning services like e-bay and Yahoo Auctions have major impact on how we buy various commodities (Shetty et al., 2003). Many works have been done to introduce market concept into grid systems. In this part, we will give a survey and detailed discussion on these research and application, including work done by the industry, standard organization and academia.

Grid from the Industry

Today, the industry has taken the first step in commercializing grid computing, such as the major Grid offerings like the Sun Grid Compute Utility, IBM's On-demand Computing (ODC), Platform Enterprise Grid Orchestrator (EGO) and HP Adaptive Enterprise.

Sun is changing the very nature of computing by delivering access to enterprise compute power over the Internet with its Sun Grid Compute Utility (http://www.sun.com/service/sungrid/). Sun Grid provides an easy and affordable access to an enormous computing resource for the predictable and all-inclusive price of $1/CPU-hr. Firstly, Sun Grid utility computing can provide zero barriers to entry and exit. Users can access the computing power they need, when they need it, with no hidden costs, without a long-term contractual obligation, and increase or decrease their usages as their demands require. Users only pay for what they use. And secondly, Sun Grid utility computing radically simplifies the way you select, acquire, and use next generation IT infrastructure. This utility model enables users to react quickly to business needs without investing in expensive infrastructure. In short, Sun Grid Compute Utility helps users reduce complexity, better utilize overbuilt infrastructures, and optimize IT resources.

Similar with Sun, in October 2002, IBM releases its "On-demand Computing" policy, which can provide IT resources dynamically based on user requirements (http://www-128.ibm.com/developerworks/ondemand/). ODC is a computing and communications infrastructure that facilitates flexible business service delivery and provides the basis for: (1) autonomic computing, (2) fast response to external business-affecting changes, (3) adaptive business processes to protect revenues and contain costs, (4) complex interactions inside and outside of organizational boundaries and (5) resilience against external threats such as viruses, intrusions, and power outages. IBM sees its ODC as being a way to help customers meet the market challenges of continuous changes, rigorous competition, unrelenting financial pressure, and unpredictable threats (e.g., to security and market dominance). All of this is happening in a market where customers need to become very responsive, able to focus on their business, avoid fixed costs where possible (to support that flexibility), and be resilient instead of vulnerable. In conjunction with Grid computing, it can be seen that ODC is conceptually similar to the global outsourcing phenomenon (Kourpas, 2006).

For the computing utility model in Sun and IBM, it is a kind of method to buy computing resource, software and management. Companies provide powerful, robust and security computing service, and users can buy the resources they need and pay money based on their usages with lower risks. The business models of user purchase are more fixed such as pay-per-use model.

Enterprise agility is the key to increasing competitive advantage and delivering customers with timely products and services. In order to support IT technology challenges faced by enterprise, Platform Enterprise Grid Orchestrator and HP Adaptive Enterprise projects give an efficient resolution.

Platform Enterprise Grid Orchestrator is a Grid platform that introduced by Platform Computing Inc., and delivers virtualization, automation and sharing of all IT resources to any enterprise application (http://www.platform.com/Products/Platform.Enterprise.Grid.Orchestrator). Businesses can improve performance, organizational efficiency and achieve accelerated results by using it. Platform EGO uses a single common agent on each server to orchestrate the sharing of resources specific to business and technical challenges that enterprise IT organizations face. The introduction of Platform EGO represents a paradigm shift in the Grid computing market, with enterprises now able to build a unified framework for Grid-enabled applications that allocates resources and responds to business needs in real time, allowing them to fully realize the benefits of utility, adaptive, and on-demand computing environments. So, Platform EGO offers the strength and reliability of grid computing to the enterprise. It provides the required infrastructure for deploying on-demand, scalable and utility computing solutions required for enterprise businesses ("Aligning IT", 2005).

For enterprise users, HP releases "Adaptive Enterprise" policy. With HP's Adaptive Enterprise strategy, companies are synchronizing business and IT to gain a competitive advantage (http://www.hp.com/go/adaptive). The main idea of adaptive Enterprise is to improve the agility of business so that IT environment can be suitable for dynamic business need (Hewlett-Packard, 2005).

In brief summary, the projects described so far are designed to share special resources and face IT technology challenges with simple, flexible, reliable and economic resolution for enterprise users. Enterprise only needs to pay relative acceptable expense to use resources or technologies freely without worrying about expensive infrastructure and relative IT technology construction and updating. EGO and HP provide a very good platform for enterprise.

All of the above can be regarded as successful applications for transactions between IT resources, technologies and services. Compared with our Grid Market concept, they just provide a kind of transaction model but not a platform. That is, resources, technologies and services are provided by special providers for trading, and clients can buy something based on their requirements.

Efforts by the Research Community

Along with the development of market-based grid research, several important standard organizations have done some related work. There is a group in OASIS (Organization for the Advancement of Structured Information Standards) working on concrete examples of business requirements for service-oriented architecture (SOA) implementations. Others are the Distributed Management Task Force, Inc., (DMTF) Utility Computing Working Group and Grid Economic Services Architecture Working Group (GESA-WG) under the Global Grid Forum (GGF).

OASIS SOA standardization effort focuses on workflows, translation coordination, orchestration, collaboration, loose coupling, business process modeling, and other concepts that support agile computing. As a result of the maturation of these standards, the on-demand computing model can enable a modular approach to infrastructure, including software design, development and execution (see http://www-128.ibm.com/developerworks/ibm/library/i-odoe2/). At present, some concrete examples of business requirements for SOA implementations have been identified, and because the on-demand computing model is based on industry standards, it can be used to define the business, applications and systems at various levels: within a department, across an entire enterprise or throughout an industry ecosystem. It enables true end-to-end business process integration.

DMTF Utility Computing Working Group aims to create interoperable and common object models for utility computing services within the DMTF's Common Information Model (CIM). The DMTF Utility Computing Working Group (http://xml.coverpages.org/DMTF-Utility.html) focuses on commercial enterprise Grid application use cases and requirements and defines how to assemble complete service definitions. This includes work focusing on the composition of the models in CIM, as well as business- and domain-specific functional interfaces. This working group also renders the utility computing classes of CIM in Unified Modeling Language.

The next related effort is the work of GESA-WG under GGF (https://forge.gridforum.org/projects/gesa-wg). The goal of this working group is to provide the supporting infrastructure to enable Computational and Data Grids operated by different organizations to "trade" services between each other. The main work of GESA-WG is to define the protocols and service interfaces needed to extensibility support a variety of economic models for the charging of grid services in the OGSA. The Grid economic services architecture (Newhouse, MacLaren, & Keahey, 2004) defined a Chargeable Grid Service (CGS), which wraps the grid service that is to be sold, that interacts with the Grid Banking Service (GBS) and the Resource Usage Service (RUS). Note that the GESA-WG is now officially closed and no further documents are planned.

For projects in the academic community, we have conducted a survey on such systems as GridBus, Compute Power Market, Computational Markets and Business Grid Computing. GridBus project (http://www.gridbus.org/intro.html) aimed at applying some economic rules for better Grid resource management. This project is a technically-oriented development project of fundamental, next-generation cluster and Grid technologies that support a true utility-driven service-oriented computing. The project consists of the following parts: GRid Architecture for Computational Economy (GRACE), Grid Resource Broker (GRB), GridBank and Grid Accounting Service Architecture (GASA). The GRACE-infrastructure (Buyya, Abramson, & Giddy, 2000b) supports generic interfaces (protocols and APIs) that can be used by the grid tools and applications programmers to develop software supporting the computational economy. Nimrod/G (Buyya, Abramson, & Giddy, 2000a) as a GRB is a grid application scheduler and it is responsible for resource discovery, selection, scheduling, and deployment of computations over them. Nimrod/G supports both deadline (soft real-time) based scheduling by keeping the cost of computation as low as possible and budget (computational economy) constraints in scheduling, and at the same time it can optimize execution time or budget expenses (Buyya, Murshed, & Abramson, 2002). The GRACE infrastructure will enable Nimrod/G to dynamically trade for grid resources in the open market environment and select resources that meet user requirements (deadline and cost). The GridBus project processes successfully task scheduling and resource allocation with user's constraints. It tries to optimize each kind of criteria to provide a more economical resource usage model, but the project does not touch how to setup resource market and trading.

The Business Grid Computing project was started to address the requirements of systems providing essential social services as part of the Focus 21 project of the Japanese government. The project is developing Business Grid technologies for building and operating business-oriented IT systems flexibly and inexpensively with high reliability. This project is developing the Business Grid middleware (Savva, Suzuki, & Kishimoto, 2004) based on the Open Grid Services Architecture (OGSA) and the features of it include: (1) all information relating to a business application can be described and retained in a defined format, (2) the IT resources used by business applications are virtualized as hosting environments, and (3) business applications can be deployed automatically on distributed IT resources.

The Compute Power Market (CPM) project (http://www.computepower.com) is a market-based resource management and job scheduling system for Grid computing. It allows application users to access computing power with ease and simplicity, and to choose computing power/resource providers that offer cost-effective service on demand. Thus, it aims at creating a competitive market approach to service-oriented Grid computing. The CPM project seeks to address complexities involved in developing a technology infrastructure that lets the users and resource providers operate under a computational economy over the Internet. The design of CPM comprises of three types of components: the Market, the Market Agent and the Market Broker. It supports three major economy models, Commodity Market, Tender/Contract-Net and Auction models (Buyya & Vazhkudai, 2001; Ling et al., 2003).

Another important research project is the Computational Markets project (http://www.lesc.ic.ac.uk/markets). It is funded under the DTI e-Science Core Technology program and is concerned with the development of mechanisms to support the trading of grid services. The project aims at designing and implementing facilities for pricing, accounting and charging for all types of grid resources (software, hardware, data and network capacity). These trading mechanisms are implemented as extensions to the OGSA and its reference implementation Globus Toolkit 3, and provide inputs to the standardization process through the GGF.

Building Blocks of the Grid Market

So far, the projects described are mainly focusing on expending grid system framework based on OGSA in existence, as well as providing middleware or framework for grid resource transaction. However, to build a Grid Market requires more than these. An independent, complete market platform with all the necessary mechanisms to support the entire trading process is required. In addition, it should be able to support different business and pricing models for different consumers and providers.

We have identified several fields that are vital to building the Grid Market.

- **Business model:** The business model refers to the method used for trading in market. It has been defined and categorized in many different ways. Any business model is hard to tackle all special requirements for different customers independently. A different business model has different application characters and use background. It provides various trading methods for customers (including buyers and sellers) in market with their particular requirements.
- **Pricing model:** The pricing model is the price formation model used for trading in market. Dynamic pricing is an important feature for trading in market (Narahari, Raju, Ravikumar, & Shah, 2005). Pricing model includes simple fixed price model, commodity market model, bargaining

model, tender/contract-net model and auction model. As buyers and sellers interact in grid market, the resulting dynamic prices more closely reflect the true market value of the products and services being traded.

- **Contract management:** All trade in the grid market will generate a contract between the consumer and the provider as the result of mutually accepted agreements on the terms of the grid service/resource purchase contract. The contract should include the detail information of the trade and the commitment conditions. Furthermore, the contract management system will save the contracts and track the status of the contract negotiation and execution thereof (Czajkowski, Foster, & Kesselman, 2005; Guth, Simon, & Zdun, 2003; Paschke, Dietrich & Kuhla, 2005; Paschke, Bichler & Dietrich, 2005). It provides the mechanisms to generate contracts, query the contract details for involved parties as well as tracking changes of the contract options.
- **Accounting and banking:** In market framework, accounting and banking systems are necessary (Frogner, Mandt, & Wethal, 2004). Accounting systems will enable resource owners to monitor the usage and utilization of their grid resources. There will be no restriction on the "types" of resource utilization that can be recorded and accounted for by the associated management tools. Banking systems will be implemented to provide a secure charging and payment mechanism for resource usage. The existing commercial electronic payment methods and their compatibility with Grid market for secure payment will be investigated.
- **Reputation management:** Credit problems exist in any market. Reputation management involves recording a person or agent's actions and the opinions of others about those actions (Resnick & Zeckhauser, 2001). Reputation management that is efficient and adapts market characters will provide the support on keeping markets safe and efficiently running and ensure customers' trading activities.
- Others: The other aspects of running and managing the grid market include marketplace security, propaganda and advertisement and property rights protection. The investigations of these problems will help to build the perfect function grid market.

Compared with the common market, the grid market has its own characteristics. We not only research commercial transaction platform in existence, but also consider the distributed and dynamic features of grid resources as trading contents and objects. In the process of designing and realizing market service mechanism, these features of grid resources should be supported by grid market. For customers in markets, a different business model and a pricing model can be combined flexibly for their requirements and benefits.

BUSINESS AND PRICING MODELS

In this section, we discuss some of the common business models that are applicable to the Grid context. The term business model is commonly used, but there is no single dominant definition. Here, what we are concerned with is how the buyers and sellers conduct business and operate in the Grid Market. Or, more specifically, the activities and interaction of the buyers and sellers for establishing the trade, as well as the pricing and charging model of the sellers. We expect that different businesses have different requirements, goals, policies and strategies, and therefore there is no single business model that can fit all.

To get a clearer understanding, we will first look at the possible interactions and activities of the buyers and sellers in the Grid Market. The group led by Dr. Rajkumar Buyya has done extensive research on different models for the Grid economy. In Buyya, Abramson, Giddy and Stockinger (2002), several models are proposed for adaptation to the Grid context:

- **Commodity market model:** In the commodity market model, resource owners specify their service price and charge users according to the amount of resource they consume. The pricing policy can be derived from various parameters and can be flat or variable depending on the resource supply and demand. In general, services are priced in such a way that supply and demand equilibrium is maintained. In the flat price model, once pricing is fixed for a certain period, it remains the same irrespective of service quality. It is not significantly influenced by the demand, whereas in a supply and demand model prices change very often based on supply and demand changes. In principle, when the demand increases or supply decreases, prices are increased until there exists equilibrium between supply and demand. Pricing schemes in a commodity market model can be based on flat fee, usage duration (time), subscription or supply and demand-based (McKnight & Boroumand, 2000). In the commodity market model, the consumer only considers the resource price specified by the provider as selection reference, and cannot negotiate with the resource owner for use price.
- **Posted price model:** The posted price model is similar to the commodity market model, except that it advertises special offers in order to attract consumers to establish market share or motivate users to consider using cheaper resources. In this case, consumers need not negotiate directly with providers for price, but use posted prices as they are generally cheaper compared to regular prices. The posted-price offers will have usage conditions, but they might be attractive for some users. By using the posted price model, the provider can formulate the flexible price strategies in terms of the utilization of resources, and make full use of the resources' capabilities. For example, during holiday periods, demand for resources is likely to be limited and providers can post tempting offers or prices aiming to attract users to increase resource utilization.
- **Bargaining model:** In the bargaining model, consumers bargain with resource providers for lower access price and higher usage duration. Both buyers and sellers have their own objective functions and they negotiate with each other as long as their objectives are met. The buyers might start with a very low price and sellers with a higher price. They both negotiate until they reach a mutually agreeable price or one of them is not willing to negotiate any further. This negotiation is guided by user requirements and buyers can take risk and negotiate for cheaper prices as much as possible and can discard expensive machines. This might lead to lower utilization of resources, so sellers might be willing to reduce the price instead of wasting resource capability. Buyers and sellers generally employ this model when market supply-and-demand and service prices are not clearly established. The users can negotiate for a lower price with promise of some kind favour or even using the provider's services in the future. It should be pointed out that the negotiation process will consume some resource and time, and if both sides cannot reach an agreement, the consumption of negotiation will not bring any profits.
- **Tendering model:** The tendering model is one of the most widely used models for service negotiation in a distributed problem-solving environment (Smith & Davis, 1980). It is modeled on the contracting mechanism used by businesses to govern the exchange

of goods and services. It helps in finding an appropriate service provider to work on a given task. The advantage of this model is that if the seller is unable to provide a satisfactory service or deliver a solution, the buyer can seek other sellers for the service. The tender model allows directed contracts to be issued without negotiation. The selected resource provider responds with an acceptance or refusal of award. This capability can simplify the protocol and improve the efficiency of certain services.

- **Auction model:** The auction model supports one-to-many negotiation, between a seller and many buyers, and reduces negotiation to a single value (i.e., price). The auctioneer sets the rules of auction, acceptable for the buyers and the sellers. Auctions basically use market forces to negotiate a clearing price for the service. In the real world, auctions are used extensively, particularly for selling goods/items within a set duration. The three key players involved in auctions are resource owners, auctioneers (mediators), and buyers. Many e-commerce portals such as Amazon.com and eBay.com are serving as mediators (auctioneers). Both buyers' and sellers' roles can also be automated. Depending on various parameters, auction models can be classified into several types (Sandholm, 2000), such as English auction, First-price sealed-bid auction, Vickrey auction (Vickrey, 1961) or Dutch auction.

Business models have been defined and categorized in many different ways. Internet business models continue to evolve. New and interesting variations can be expected in the future. The basic categories of business models discussed as follows.

According to the type of resource, business model can be classified into three classes: Service Model, Leasing Model, and Bartering Model. An agile trading activity can be provided for both business parties by using different models.

- **Service model:** Service model is the most popular resource providing and consuming model in OGSA currently. Seller or provider offers the available resources; and buyer or consumer purchases and uses the resources in terms of his requirements with paying the corresponding fees. In service model, the buyer will never own the resource. A provider offers a defined service for which the consumer pays a regular service fee. The service models differ regarding their clearing: (1) fix service model, in which the consumer pays a regular service fee for a specified service, and (2) consumption dependent service model, in which the fee is rated per unit and the consumer has to pay an amount calculated according to his consumption. Service model tries to provide resources for consumer in simple and agile way. Consumer can take into account the price wave sufficiently and grasp the ideal trading opportunity. To buy according to needs and to pay according to usage are the main features of the service model.
- **Leasing model:** The owner of the resource (the leaser) allows the customer (the leasee) to use the resource for a specified time in return for payment. The obvious difference between leasing model and service model is ownership may be transferred to the customer after the leasing period. In the leasing period, the lessee can use the leasing object freely. If permitted in the contract, the leasee even can resell or re-lease it. Leasing contract is used to formulate the detailed leasing matters, such as leasing period, leasing fee and payment mode and responsibility of resource maintenance in the leasing period. Comparing with service model, leasing model is often suitable for the case that the resource needs to be used for a long time or several times. And then, because in the leasing model what to purchase is the use of resource in specific period of time,

the consumer suffers little from the price wave.

- **Bartering model:** In the bartering model, several customers in the market form a resource sharing community. Once customers join this community, they need to contribute their resources to this shared resource pool, which can be used by other customers in this community. After the customers' resources are used by others, they also can use the resources from other customers in resource pool. The system may provide a virtual grid currency to measure the contribution and the capability of employing resource of each customer. The bartering model is suitable for the customers who are not only resource providers, but also resource consumers sometimes.

According to the time of resource providing and consuming, trading mode in grid market can be classified into three classes: Instant Mode, Subscription Mode and Agreement Mode. Different trading modes bring the convenience for providing or consuming resources.

- **Instant mode:** Instant mode is the most popular e-business trading mode. The customers can buy or sell the resources that are available currently. Sellers can publish their idle resources in market and buyers can purchase these resources and use them instantly. Instant mode is simple and suitable for requirements of the resources that need to be used right now. But the problem of this mode is that the wishes of both business sides are influenced by price wave in large measure. When the resource price is higher, sellers like to complete business quickly, but the buyers tend to find other sellers with lower price.
- **Subscription mode:** Grid resources as trading objects in grid market are capacity-type resources, or in the language of commodity markets, they are nonstorable commodities. Capacity not used yesterday is worthless today. It is necessary to reasonably foresee and arrange the use of resources in future. Subscription mode provides a mechanism that prearranges the use of resource in future periods. Sellers can publish resource information in the market, which can be used in the future. Buyers are able to subscribe the use of resources in a future period. "Buy now use later" is a characteristic of subscription mode. Subscription mode is more flexible than instant mode because both business sides not only arrange the use of resource ahead of time, but also have enough time to negotiate and try to satisfy both sides.
- **Agreement mode:** There is a great difference between agreement mode and the above two modes. Both business sides agree to put up business in a special time confirmed before through a certain way. Here, an agreement between two sides is made outside of the market. They just use the market platform to execute business, and the seller transacts with the specified buyer and buyer does likewise. The system does not need to search and choose trading objects for them, and just provides the basic functions for the execution of the trade, such as monitoring, accounting and banking. Agreement mode brings more convenience to over-the-counter business and transaction between long-term companions.

Besides the business models mentioned above, in Grid market customers have many ways to choose trading objects. Generally speaking, sellers and buyers can use three ways, including Commission Proxy, Confirmation Proxy and Non-Proxy, to search and match the trading objects.

- **Commission proxy:** The commission proxy way is used when customers provide business requirements and policies to the system and entrusts to proxy to deal with trading instead of oneself. The proxy chooses the proper objects according to the customer's demands. After determining the trading object, the proxy returns back the result to the customer. During the matchmaking process, proxy fully follows customer's requirements and policies, and maximizes his benefits. Using commission proxy, customer attaches itself littler to the matchmaking and the operation is relatively simple. But customer has to define requirements and policies in advance, which cannot be changed during the matchmaking process. So commission proxy way is a lack of agility.

- **Confirmation proxy:** Confirmation proxy is mainly used by the seller or resource provider. Compared with commission proxy, confirmation proxy needs a confirmation from customers after the system has selected a trading object according to the requirements. For sellers, business is successful if they have confirmed, and then customers can use the resource. Otherwise, the system will continue matching other trading objects. Moreover, customers can modify the original requirements and policies in the course of confirming and then carrying out the new search. This shows that confirmation proxy is more flexible than commission proxy for the customer's confirmation. However, the enhancement of the degree of customer's participant will increase the customer's overhead accordingly.
- **Non-proxy:** The non-proxy way is simpler and mainly regards the buyer or resource consumer. Customers only ask the system to provide a matching trading object list in which the proper object is chosen by oneself. For customers, it is easy to use this way to change trade requirements and policies in a flexible way according to the present dynamic change of the market during the process of choosing trading objects so as to ensure the best profits. However, this way needs customers to participate directly, and is unfavorable for a long time and requires large-scale resources matchmaking and negotiation.

It should be pointed out that no single model is suitable for all trade because the customer's demands and goals are varied. Both providers and consumers in the market need to select the proper business model according to their own demands and interests, and maximize their commercial profits.

Dynamic Pricing

The one most important thing of a market is price is the terms on which the trading objects (products or services) are exchanged. In an ideal market, the price is a reflection of the current state of the market, and therefore should be dynamic, that is, it varies when the market demand changes.

Dynamic pricing is the dynamic adjustment of prices to consumers depending upon the value these customers attribute to a product or service (Reinartz, 2001). Dynamic pricing includes two aspects as follows (Narahari et al., 2005).

Price dispersion—Price dispersion can be spatial or temporal. In spatial price dispersion, several sellers offer a given item at different prices. In temporal price dispersion, a given store varies its price for a given good over time, based on the time of sale and the supply-demand situation.

Price discrimination—Price discrimination describes the case that different prices are charged to different consumers for the same product. Varian (1996) describes three types:

- **First degree price differentiation:** This is also called perfect differentiation. A producer sells different units of output for different prices and these prices can differ from person to person. Here, each unit of the good is sold to the individual who values it most highly, at the maximum price that this individual is willing to pay for the item.

- **Second degree price differentiation:** This is also called nonlinear pricing and means that the producer sells different units of output for different prices, but every individual who buys the same amount of the product pays the same amount. Thus, prices depend on the amount of the product purchased, but not on who does the purchasing.
- **Third degree price differentiation:** This occurs when the producer sells products to different people for different prices, but every unit of the product sold to a given person sells for the same price. Price differentiation is achieved by exploiting differences in consumer valuations.

Elmaghraby and Keskinocak (2003) categorize dynamic pricing methods into two broad categories: posted price mechanisms and price discovery mechanisms. Under the first category, a product or service is sold at a take-it-or-leave-it price determined by the seller. The posted prices could be dynamic in the sense that the seller changes prices dynamically over time depending on the time of sale, demand information, and supply availability. In price discovery mechanisms, prices are determined through a bidding process. Auctions provide an immediate example.

Cost is perhaps the greatest factor precluding the widespread use of dynamic pricing, because in traditional markets, it is expensive to continuously re-price goods. But in digital markets, the costs associated with making frequent, instantaneous price changes are greatly diminished (Smith, Bailey, & Brynjolfsson, 2000).

A variety of mathematical models have been used in e-business dynamic pricing. Most of these models formulate the dynamic pricing problem as an optimization problem. Depending on the specific mathematical tool used and emphasized, dynamic pricing mainly includes five categories of models.

- **Inventory-based models:** These are models where pricing decisions are primarily based on inventory levels and customer service levels. Dynamic pricing in retail markets based on inventory considerations has been researched quite extensively. Elmaghraby and Keskinocak (2003) discuss three main characteristics of a market environment that influence the type of dynamic pricing problem a retailer faces: replenishment vs. nonreplenishment of inventory (R/NR), dependent vs. independent demand over time (D/I), and myopic vs. strategic customers (M/S). According to the authors, most existing markets can be classified under three categories: NR-I-M, NR-I-S, and R-I-M. Gallego and van Ryzin (1999) consider optimal dynamic pricing of inventories with stochastic demand over finite horizon. Federgruen and Heching (1999) consider the optimal inventory and pricing policy of a seller who faces an uncertain demand where prices are changed periodically over time. Bernstein and Federgruen (2003, 2005) consider inventory-based pricing in a two echelon supply chain with random demands. The approach used is based on game theory. Biller, Cha, Simchi-Levi, and Swann (2005) propose a strategy that incorporates dynamic pricing, direct-to-customer model, production scheduling, and inventory control under production capacity limits in a multiperiod horizon to improve the revenue and supply chain performance in automotive industry. Besides, a comprehensive review of models of traditional retail markets, where inventories are used as the main consideration for determining optimal prices, can be found in Elmaghraby and Keskinocak (2003), Swann (1999), and Chan, Shen, Simchi-Levi and Swann (2005).

- **Data-driven models:** These models use statistical or similar techniques for utilizing data available about customer preferences and buying patterns to compute optimal dynamic prices. Availability of customer data through e-business Web sites has opened up enormous opportunities for revenue enhancing measures. Some companies accumulate huge amounts of data about customers which they can leverage to improve their revenues and profits. In the real world, there are some examples of a data-driven approach for dynamic pricing. Boyd and Bilegan (2003) survey revenue management techniques to illustrate a successful e-commerce model of dynamic, automated sales enabled by central reservation and revenue optimization systems. Morris, Ree, and Maes (2000) examine the dynamic pricing strategies in the airlines industry by discovering patterns in customer preferences. By identifying product features for which consumers are willing to pay a premium, the Ford motor company has developed a pricing strategy that encourages consumers to purchase more expensive vehicles, resulting in a marked increase in revenue and profits (Coy, 2000). Rusmevichientong, Van Roy, and Glynn (2005) have developed a nonparametric, data-driven approach to determining optimal dynamic prices that uses online data on consumer preferences collected through a Auto Choice Adviser Web site developed by General Motors. Using the data available from the Web site, the authors formulate a revenue optimization problem. Once customer data becomes available through Web sites and customer relationship management software, a variety of techniques can be used for analyzing and using this data for determining better ways of pricing.
- **Auction-based models:** Auctions constitute a natural model for dynamic pricing. The outcome of an auction is determined by supply-demand characteristics and therefore the prices as determined by an auction can truly be based on market conditions, provided the bidders reveal their true valuations. Auction mechanisms can be designed to have truth revelation properties and the theory of auctions has a great deal to offer to the area of dynamic pricing. Auctions are now possibly the most popular mechanism for implementing price negotiations in B2B and B2C situations. Auctions can take several forms and each type of auction mechanism would implement a particular type of pricing outcome. Bichler et al. (2002) have described in detail the role of auctions in dynamic pricing, in the context of e-procurement, e-selling, bid preparation and reverse logistics. Narahari and Dayama (2005) discuss the combinatorial auctions, which represent an important class of auction mechanisms being employed in e-business situations. The paper by Elmaghraby (2005) is a focused survey on auctions and pricing in e-marketplaces. More surveys on general auctions can be found in the literature (McAfee & McMillan, 1987; Milgrom, 1989; Klemperer, 1999; Kagel, 1995; Kalagnanam & Parkes, 2005; Wolfstetter, 1996).
- **Game theory models:** Game theory models provide a natural tool to be used in modeling situations of conflict and cooperation arising in the interaction of rational and selfish agents. In a multiseller scenario, the sellers may compete for the same pool of customers and this induces a dynamic pricing game among the sellers. Game theory models lead to interesting ways of computing optimal dynamic prices in such situations. There are a few studies of using a game theoretic approach for dynamic pricing in e-business markets. Bernstein and Federgruen (2003, 2005) consider the dynamic pricing problem in a two echelon supply chain with one supplier servicing a network of competing

retailers under demand uncertainty. Game theory models have recently been used in the area of pricing of network/Internet resources (Cao, Shen, Milito, & Wirth, 2002). In network settings, dynamic pricing can be used as an effective means to recover cost, to increase competition among different service providers, to reduce congestion, and to control the traffic intensity. Game theory models which have been used in the context of Internet pricing (He & Walrand, 2005) and network pricing (La & Anantharam, 1999; Yaiche, Mazumdar, & Rosenberg, 2000) can be applied to e-business contexts in a fairly straightforward way.

- **Machine learning models:** Machine learning has recently emerged as a popular modeling tool for dynamic pricing in e-business. An e-business market provides a rich playground for online learning by buyers and sellers. Sellers can potentially learn buyer preferences and buying patterns and use algorithms to dynamically price their offerings so as to maximize revenues or profits. With learning-based models, one can put all available data into perspective and change the pricing strategy to adapt best to the environment. Machine learning models can be logically classified into single learning agent models and multiple learning agent models. A few studies of using single learning agent models are described in the papers by Brooks et al. (1999), Gupta, Ravikumar, and Kumar (2002), Carvalho and Puttman (2003), Leloup and Deveaux (2001), and Raju, Narahari, and Ravikumar (2003, 2006b). A few representative models that employ two or more learning agents can be found in the papers by Ravikumar, Batra, and Saluja (2002), Hu and Zhang (2002), Greenwald, Kephart, and Tesuaro (1999), Kephart and Tesauro (2000), Dasgupta and Das (2000), and Raju, Narahari, and Ravikumar (2006a).

The above way of categorizing dynamic pricing models is in no way a conclusive way. The categorization is neither mutually exclusive nor jointly exhaustive. A certain dynamic pricing scheme may include two or more of the above types. A given type of a model may use another type. For example, inventory-based models could be data-driven. Machine learning models may be data-driven. Machine learning models may use inventory levels in their learning algorithms.

FUTURE TRENDS

At present, a prime issue that is not yet resolved is how to organize and make efficient use of Grid infrastructure in a commercial context where several customers compete for the same Grid resources to support their computational tasks or the services they offer to their customers and business partners. The emergence of Grid market will solve these problems. It will support compute resource trading by enabling grid services to be registered, discovered, negotiated and paid for the usage.

By applying economic theories, we can gain insights to the problem by analyzing the characteristics of the Grid market. For example, the grid services, as the trading objects, are capacity-type resources and so are completely nonstorable commodities and unused capacity from yesterday is worthless today. These characteristics are expected to have a major impact on the business models. Prices are generally the combined result of supply and demand, so a price formation mechanism for matching these is required. A large body of research in auctions for a wide variety of goods is available, but for every new market a new mechanism is needed or an older one must be adapted to fit the idiosyncrasy of this market.

Another important issue is security, or more specifically, privacy. In order to convince commercial companies to participate in the Grid Market, they must be able to trust the system to protect their Intelligent Properties. For example, an animation company running rendering jobs for their new movie certainly would not want the movie to leak out to the public before it is released. Using encryption and some form of virtualization can alleviate the problem somewhat, but for stricter security requirements, especially from financial or medical institutes, would require innovation at the system or hardware level.

In the early part of the chapter, we also mentioned that the establishment and operation of the Grid Market, as a special market environment, also needs to support the basic functions that are considered in the conventional markets. So, a series of problems, such as arrangement, fulfillment and management of the contracts, monitoring of the transaction, payment and banking service, management of reputation of participants and security of market, need to be taken into consideration. Individually, each of these fields is well-researched, but to put them together into a real world system is not a trivial task. Already, we have seen many new projects taking on this challenge and we expect to see more in the future.

CONCLUSION

Today, many enterprises are working toward building agile businesses, where the buzzword in IT services are total cost of ownership and return of investment. It has already been observed that the trend in cost-cutting in the IT department is to outsource the management of their IT resources. However, now we are starting to see that companies are outsourcing their IT, that is, purchase compute services from external providers. Although this trend has been around for a long time (the term application service provider (ASP) refers to a company that offers application services over the Internet), the idea never really took off. However, with recent advances in Grid technology, we have observed that many big industry vendors have recognized this trend, the latest being Sun Microsystems, which has launched their Sun Grid Compute Utility.

Grids are often envisioned as a transfer of the deregulated electricity grid paradigm to high performance computing, but oddly enough, one distinct feature of electrical power has been mostly neglected. The term "utility" is rooted not only in the shared transportation network of electrical power, and in the plug-and-play user experience, but additionally in the fact that electrical power is a traded commodity. Commercial prices are set by markets, not policies.

On the other hand, Grid computing is recognized as a potential major platform for scientific computing as well as commercial computation in the future. However, despite the existing technical advances and commercial needs, up until now, almost all research efforts were focused on using Grids within the academic community. The adoption of Grid technology by commercial companies are still comparatively slower. We note that if there is a means for commercial companies to sell or buy extra resources using Grid technology, it will definitely speed up the adoption of Grid.

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