BSM: A scheduling algorithm for dynamic jobs based on economics theory*

Bo CAO, Yongwei WU, Guangwen YANG, Jia LIU, Jianjin JIANG

Department of Computer Science and Technology; Tsinghua National Laboratory for Information Science and Technology， Tsinghua University Beijing 100084, China
caob04@mails.tsinghua.edu.cn,wuyw@tsinghua.edu.cn, ygw@tsinghua.edu.cn, liu-jia04@mails.tsinghua.edu.cn,jiangjj02@mails.tsinghua.edu.cn

Abstract

In this paper, we propose a new scheduling algorithm with economic theory, called Black Scholes Market (BSM) algorithm for a class of Dynamic Jobs (DJ). BSM is based on the classic option pricing theory in investment- Black Scholes Pricing Model. The algorithm could meet the needs of dynamic flow jobs and select server to provide specific service through simulating an irrational market. Compared with Dynamic Weighted Round Robin (DWRR) and Dynamic Statistical Random (DSR) scheduling algorithms, BSM algorithm achieves a better performance in long time scheduling and the best average delay rate in different maximum job arrival rates. And from view of the stability, BSM is also much better than the other two algorithms.

Key words: Black and Scholes Option Pricing Model, Market Simulation, Scheduling Algorithm, Dynamic Jobs

1. Introduction

A grid is a collection of distributed and heterogeneous computing nodes that has emerged as a powerful platform for computation-intensive applications. Jobs submitted to the grid can be divided as lots of smaller tasks and distributed to a number of servers for execution [1-2]. The jobs mentioned in this paper are complex jobs which consist of multiple tasks and the tasks can be executed individually or cooperatively with others.

With the development of grid, the user will not be just satisfied with Batch Program Grid (BPG) which only can submit a batch program and waiting for the result without any dynamic operations. In the BPG, a job's executive flow is fixed when user submitted. We define such kinds of jobs as Dynamic Jobs (DJ) which executive flow is uncertain and when the job is executed, it can be dynamically launched or paused its tasks under the user control. The main character of DJ is factitious stochastic. The executive process is partly depended on the user interactive operation.

In this paper, we address a kind of scheduler, called Black Scholes Market (BSM) for DJ. The rest of this paper is organized as follow. In Section 2, some grid scheduler algorithms are introduced and a brief introduction of both Black and Scholes Option Pricing Model and irrational market theory is given. In Section 3, we describe BSM algorithm. In section 4, we do simulation and comparison with different parameters and other scheduling algorithms.

2. Relative Works

2.1. Some Grid Scheduling Algorithms

Nimrod-G[4] simulates the model of a market for a single domain with a market mechanism, which designs by modifying Nimrod for operation with GT. The multi-tiered scheduling architecture (TITAN) [5] employs a performance prediction system (PACE) and task brokers to meet user-defined deadlines and improve resource usage efficiency. Genetic Algorithm (GA) [6] approach used in TITAN architecture is able to balance the makespan, idle time and QoS.

Except the algorithms mentioned above there are two universal scheduler algorithms: Dynamic Weighted Round Robin (DWRR) which can dynamically adjusts the weighted value based on the current situation and Dynamic Statistical Random (DSR) which introduces the statistic information to generate the weighted value and random selects one with the weighted value.

** This Work is supported by ChinaGrid project of Ministry of Education of China, Natural Science Foundation of China (60373004, 60373005, 90412006, 90412011, 60573110, 90612016), and National Key Basic Research Project of China (2004CB318000, 2003CB316907)

2.2 Black and Scholes Option Pricing Model

Options are a type of derivative means that their value depends on the value of an underlying investment. European style options are options which can only be exercised by the holder at expiry. European style option's price just stands for the value at a time point instead of a time period. Option price can use the economic method to evaluate the future price of a dynamic changeable security with current price. It can reflect the effect of future dynamic changes.

Black and Scholes Option Pricing Model (BS Model) [2] [3] proposed by Fisher Black and Myron Scholes in 1973 is a classic option pricing model for European style options. There are six assumptions for Black and Scholes Model: 1) the stock pays no dividends during the option's life; 2) European exercise terms are used; 3) Markets are efficient; 4) No commissions are charged; 5) Interest rates remain constant and known; 6) Returns are lognormal distributed. The formula for calculating the option price is:

$$C_0 = S_0 N(d_1) - X e^{-rT} N(d_2) \qquad (1)$$

$$d_1 = \frac{\ln(s_0/X) + (r + \sigma^2/2)T}{\sigma \sqrt{T}} \qquad (2)$$

$$d_2 = d_1 - \sigma \sqrt{T} \qquad (3)$$

A market is a group of sellers that trade products and services for agreed form of remuneration with buyers. Market participants are motivated by self-interests to develop a process of coordination and communication that products the most efficient outcomes. Some of them will take the irrational action in certain situations [7].It is the most effective way to allocate the resource in the man-involved system.

3. Black and Scholes Market Scheduling Algorithm

We can divide the main character of DJ into two factors: one is the dynamically resource exhausting in the future; the other is dynamic flow change. Aim at these two factors, we propose Black Scholes Market Scheduling Algorithm (BSM). BSM scheduler consists of two parts. The first part is to apply Black and Scholes Option Pricing Model to calculate the server "price" which is the transaction object in the market. Here we use the classic option pricing model to evaluate the dynamic resource exhausting and express its value as the option price to map a complex dynamic process into a simple fixed value. The second part is to simulate a market bargain process with some of the participants are irrational who will do the random choice. In that way, we can simulate the user's dynamic choices and select the most suitable server based on the market theory.

3.1 Apply Black and Scholes Model

There are six assumptions in Black and Scholes Model. We prove the system can meet four of six and do two assumptions. First, once the server began to provide service, its totally resource is fixed and there is no extra "dividend"- resource; second the market we simulated is efficient; third there is no commission charged in the simulated market; fourth when job arrives we calculate the "rate" and make it constant; finally, we do two assumptions: 1) task resource requisitions follow the European Style term, 2) resource exhausted is lognormal distributed. And Table 1 illustrates all the map relationships between economic meanings and system meanings of the same parameter.

Table 1. Parameters map relationships between economic meanings and system meanings

Item	Economics Means	System Means
C0	Theoretical Call Premium	The "Price" of server
S0	Current Stock Price	Current available resource on the server
X	Option Striking Price	Recommended resource exhausted
T	Time until option expiration	Job running periods
R	Risk-Free Interest Rate	Margin between the resource available on this server and the average of all the servers
σ	Standard Deviation of Stock Returns	Standard Deviation of Server Resource
N(d)	Cumulative Standard Normal Distribution	Cumulative Standard Normal Distribution
E	Exponential Term(2.7183)	Exponential Term(2.7183)
Ln	Natural Logarithm	Natural Logarithm

Parameter "T" stands for the periods to a fixed time of expiration in European Style Options. In this paper, we introduce a weighted option price $\tilde{C}$ to extend from the time point to time span.

$$T = \{T \mid T_i = i, i < TimeSpan\} \qquad (4)$$

Calculate C_i and the right value W_i as the proportion of each T value in $TimeSpan$ hours which means the system's continuous running time.

[2] Fisher Black and Myron Scholes were awarded the Nobel Economics Prize at 1997 for the contribution in option pricing.

Proceedings of the Fifth International Conference on Grid and Cooperative Computing (GCC'06)
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$$W = \{W_i \mid W_i = \frac{TimeSpan - T_i + 1}{\sum_{T_i \in T} TimeSpan - T_i + 1}, T_i \in T\} \quad (5)$$

In this paper we choose I as the parameters set.

$$I = \{i \mid i = 1, 2, 4\} \quad (6)$$

With the formula 7, we can get the weighted option price $\tilde{C}$.

$$\tilde{C} = \sum_{i=0}^{n} C_i * W_i \quad (7)$$

3.2 Market Simulation

Market simulation is the process to select a server. The whole process can be divided into two main parts: Certification and Option Pricing, Bargain and Irrational Choice. Figure 1 illustrates the flow.

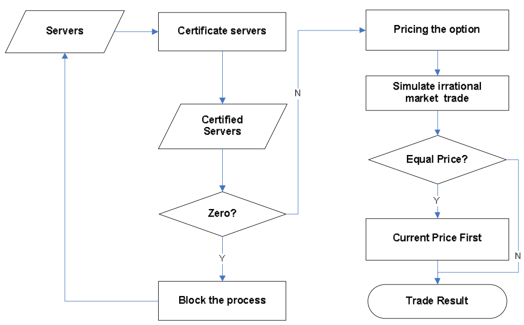

Fig. 1. Market trade flow

We take qualification standards with the resource available is no less than the limited resource to reduce the number of candidate servers. On the other hand, in the Black and Scholes Model, the underlying investment must be valuable, but the server which can not provide resource is valueless.

In marketing simulation, the choice standard in the bargain is Return of Investment (ROI) which defines as "value" divided by "cost".

$$ROI = \frac{ResourceCurrentAvailable}{Option Price} \quad (8)$$

The bargain process includes two sub-processes: rational bargain and irrational choice. In the rational bargain, the simulator chooses the server with highest ROI. In the irrational choice, scheduler generates two random numbers: one is irrational index which is between 0 and 1. We assume that 61.8% traders will do the rational choice. If irrational index is less than 0.618, it is a rational market and the final server is the one in the rational bargain. If irrational index is more than 0.618, it is an irrational market and scheduler generates another random number between 1 and size of certified servers which is the final server number in certified servers. Following is the algorithm description.

```
Algorithm BSM(Task task , Server-Set serverset)
BEGIN
    Calculate the parameters: S0,X,T;
    Calculate the system parameters: σ , r;
    While server in serverset
        For i ∈ I
            C_i (server) = calculateOptionPrice(server, task, S0,X,T_i ,r, );
            W_i (server)=(TimeSpan − T_i +1)/( Σ_{T_i∈T} TimeSpan − T_i +1), T_i ∈ T;
        End For
        C~(server) = Σ_{i=0}^{n} C_i * W_i;
    End While
    While server in serverset
        ROI(server) = C~(server) / X(server);
    End While;
    rationalIndex = genRandom(0,1);
    IF rationalIndex <= 0.618
        serverIndex = min(ROI);
    ELSE
        serverIndex = genRandom(1, serverset.size());
    End IF
    return serverSet(serverIndex);
End.
```

4. Performance Evaluation

In this section, we build a simulation platform to evaluate the performance of BSM. First we compare the performances of BSM in different situations and parameters and we compare the performances in the same situation and parameter with Dynamic Weighted Round Robin (DWRR) using current resource available of each server as weighted value and Dynamic Statistical Random (DSR) using the resource available on the server as the statistic value.

4.1 Simulation Environment

We build the simulation environment to simulate the dynamic job's executive process as follow:

- The job arrivals follow normal distribution;
- The resource exhausted dynamically changes following the lognormal distributed with the Expectation of recommended resource exhausted;
- During the job execution, system random selects some tasks to pause and re-launch;

During the simulation, we change two parameters: time series and job arrival rates. We assume "period" as basic time unit and sample sixteen hits every 168 periods including sequential thirteen short hits from one to thirteen sampling hits (SH) and three long time hits- 26SH, 39SH and 52SH. And we choose the task arrival rate between 0.2 and 0.7 pace 0.1. Job arrival rate means compared with number of servers the max number of jobs will arrive at one time. We evaluate the performance with delay rate which means the quotient between delay periods and the required periods to complete a job series.

4.2 Evaluation in different situations

First, we compared the BSM in different time spans to find out in which time span its performance is the most suitable. Figure 2 illustrates the average delay rate of the 16SH. From experiment we know BSM scheduling algorithm suits the long time job scheduler and the very short time job.

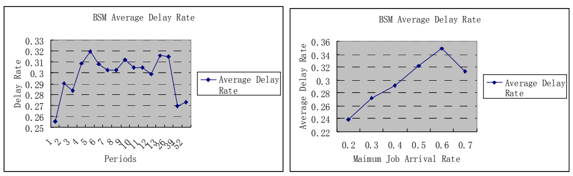

Fig. 2. BSM Average Delay Rate with different parameters

Second, we compared the performances in the different maximum job arrival rate. We choose the six main job arrival rates (AR) to evaluate the performances with average delay rate in 16SH. From Figure 2, we can conclude that job arrival rate 0.6 gets the max average delay rate. But when the job arrival rate more than 0.6, the average delay rate will fall down again, because as the number of jobs arrival in one time increases the required complete periods will increase more than the delay periods.

4.3 Evaluation with other schedulers

The following experiments we compared the performances among BSM, DWRR and DSR with the average delay rate in different parameters to evaluate the performance and the delay rate standard deviations to evaluate the stabilities of these algorithms.

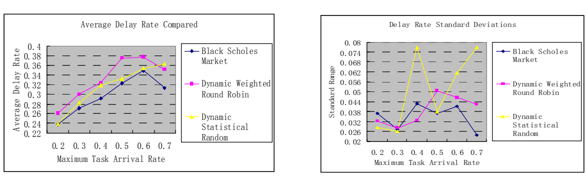

Fig. 3. Compared with DWRR and DSR

In this experiment, we test schedulers with the same time series and calculate the average delay rate of 16SH in certain maximum job arrival rate. After that, we change the maximum job arrival rate. From experiment, we can conclude that BSM achieves the best performance among three scheduling algorithms. Figure 4 also illustrates the delay rate standard deviations among three schedulers with the same time series in different maximum job arrival rates. From experiment, we can conclude that BSM has the best standard deviation. So from the stability's view, BSM is the best scheduling algorithm.

From the experiments above, we can conclude that BSM scheduling algorithm is the best among BSM, DWRR and DSR in stability and performance. For BSM scheduler, performance of long time scheduling is better than the short one and at 0.6 of the max job arrival rate its average delay rate reaches the top.

5. Conclusion

The dynamic job consists of multiple tasks and user can dynamically change the job execution process. The process of jobs will never be fixed during the execution. For meeting the need of dynamic jobs, we propose the Black Scholes Market (BSM) scheduling algorithm based on economic theory. BSM uses option price to reflect the dynamic resource exhausting in the future to a current fixed value, then selects one server in a irrational market bargain process.

To evaluate the performance, we do experiments to compare it with DWRR and DSR. From the experiments, we can conclude that BSM achieves the best performance of average delay rate among the three algorithms and the best stability. BSM itself achieves the best performance in very short and long time period and in AR equals 0.6 the performance is the worst.

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