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A selection algorithm of voluntary server in the hybrid video grid

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ABSTRACT

To solve the problems such as how to choose the clients with high performance as voluntary servers to provide video services to other users and how to ensure the stability of voluntary servers in the hybrid video grid, we propose a new algorithm for selecting voluntary server based on stability degree. Selection process of voluntary sever was simulated and emulated by using simulation software AnyLogic at micro level. The results indicated that the voluntary servers selected by the algorithm have better stability compared with them that selected by the random selection algorithm; therefore, the system stability and service capacity is improved after using the voluntary server selection algorithm. This study provides a theoretical basis for the practical application system.

KEYWORDS

Video grid, Voluntary server, Selection algorithm, Stability degree, AnyLogic.

INTRODUCTION

The processing capacity of single server systems is limited. Therefore, the quality of service (QoS) of the video service will drop constantly[1] with the increasing number of users when a single server provides streaming media[2] for multiple clients. Video grid[3] can provide effective solution to the aforementioned problem.

Video grid is the combination of grid and multimedia techniques. The content delivery networks (CDN) technique[4, 5] is to distribute video files that video service process needs in the local servers on user assembly sites. Users will receive the video service in the principle of “the first the nearest and payload balance”, i.e., the server nearest to a user will be selected to provide video service and the payload of these servers will be balanced. Video grids provide short paths of video data stream and optimized use of network bandwidth of backbone. Therefore, the service capacity is enhanced greatly. Due to the fact that the distribution of service requests coming from users is random[6], it is very difficult to decide the local server’s appropriate performance, quantity, sites to place, and so on. Although the video coding and decoding technology ceaselessly improves and a single video file incessantly becomes smaller[7], it is still difficult due to the operating expense to satisfy the video service requests while the demand of paroxysmal event is bursting.

A method was proposed in[8] that some clients with high performance become temporary servers (voluntary servers) to provide services to other users while they are enjoying their videos. As a result, the payloads of local servers are reduced, and the expansibility and service capacity of video grid system are enhanced. The video grid of two levels architecture is introduced into the video services, so the voluntary servers effectively relieve the pressure of the central server and local servers. However, there is no discussion about how to choose voluntary servers as resource nodes to provide video service for other users. In this paper, we present the working mechanism and an algorithm for selecting voluntary servers. The selection process of voluntary server computers was simulated and emulated by using simulation software AnyLogic.

THE SCALABLE ARCHITECTURE OF VIDEO GRID

The traditional video grid is the video grid of two-layer architecture, as shown in Figure 1. The central server has huge storage capacity and stores all video files. However, the local servers lack the same storage capacity to store all duplicated video files and only keep the ones with hot degree in their space[9]. When a local server does not store the video files that user needs or it cannot receive new service requests duo to the full workload, the service would be provided by other local servers or the central server. And if other local servers or the central server has reached its maximum load, the user's service requests would be denied.

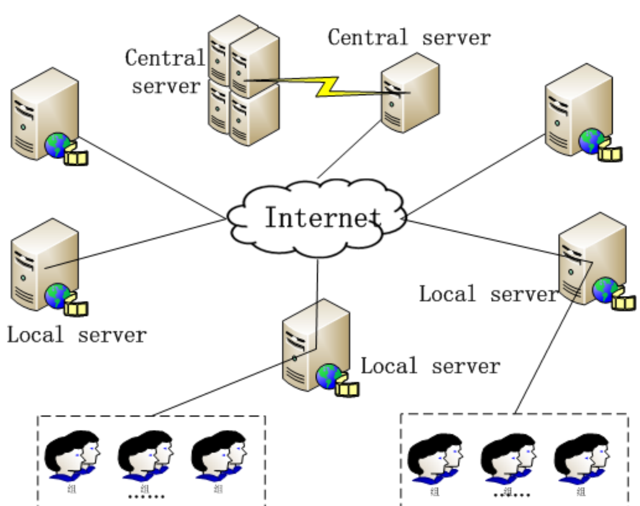

Figure 1 : The video grid of two-layer architecture

On the basis of video grid of two-layer architecture, clients with high performance are selected to serve as the voluntary servers, and the data traffic of service on-demand will be confined to a legion as far as possible in order to reduce the pressure on local servers and the data traffic of trunk or branch network . A voluntary server will provide partial service on-demand for the local network when data traffic of one local server reaches a certain threshold, and the two-layer architecture is expanded into the multi-layer architecture[10]. Based on the above discussion, the scalable architecture of video grid illustrated in Figure 2 is established. The level degree is changed to allow a voluntary server to provide video services to other voluntary servers, which reduces the local server payload and improves the service capacity of the video grid effectively.

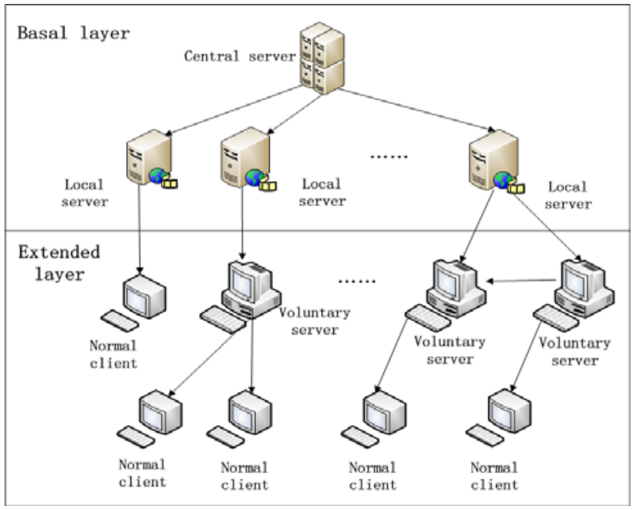

Figure 2 : The video grid of scalable architecture

SELECTION ALGORITHM OF VOLUNTARY SERVER

The voluntary servers with high performance are used to provide video services to others and equipped the video service software in advance. The local server manages these voluntary servers located on their sites, and logs the information of the voluntary servers, such as IP (Internet Protocol) address, hardware configuration, payload, video files saved in them and so on in an index table. On a site, when there are a few service requests coming from users, these requests will be processed by the local server. As the number of requests increases, the video data stream following out of the local server reaches the threshold value. Then the local server will send the instructions to the voluntary servers according to the collected information, which can invoke the video service software on these voluntary servers to prepare providing video services. A coming video request will be redirected by the local server to a voluntary server if the voluntary server has the needed video file and free power to provide the video service, otherwise, the service request will be forward by the local server. The service relationship between voluntary servers and local server is maintained by the local server. The voluntary servers only provide the service to the users and report the aforementioned information to the local server regularly.

The existing literature hasn't address how to select voluntary servers. In this paper, a strategy based on stability degree is used to select voluntary servers. The stability degree is a yardstick to measure the quality level of video service provided by voluntary servers. The quality includes not only the hardware performance, but also the reliability of video service.

Definition of stability degree of voluntary

The voluntary servers take full advantage of the resources of clients in the network, such as the upstream bandwidth of clients[11], CPU (Central Processing Unit) resources, and hard disk storage space, so the payload of local server is alleviated effectively. However, the voluntary server is not the real video server with good robustness, and cannot provide persistent and stable service. For instance, the voluntary servers in the network join or quit randomly, which may lead to the appearance of jitter[12]. This occurs when a client is enjoying the video service of voluntary server that quit without warning. Therefore, this paper utilizes a stability degree (SD) to determine the service capacity of voluntary server.

The mathematical model of the SD is described as Equation 1 and Equation 2. When evaluating the SD of voluntary server, the average online time ($Atime$), upstream bandwidth ($Uband$), packet loss rate ($Prate$) and network delay ($Ndelay$) are taken into consideration, and a weighting coefficient is applied to each measurement.

$$SD = w_1 \times Atime + w_2 \times Uband + w_3 \times Prate + w_4 \times Ndelay \quad (1)$$

$$w_1 + w_2 + w_3 + w_4 = 1 \quad (2)$$

In Equation 1 and Equation 2, $Atime$ represents the average online time of the voluntary server, which indicates whether the voluntary server can provide a long service, and the longer, the better. $Uband$ stands for the maximal upstream bandwidth provided by the voluntary server, whose size decides the efficiency of the video service. With a superior upstream bandwidth, the video requests of the clients will be satisfied in a short time. $Prate$ is the proportion of the data blocks which doesn't arrived to the total requested blocks. A voluntary server with a lower $Ndelay$ provides video service of better quality. Correspondingly, the four w_1, w_2, w_3, w_4 are the weighting coefficients, which can be adjusted to balance the influences of the measurements. The values of the weighting coefficients are determined by means of relatively comparison method.

The importance degrees of the $Atime$, $Uband$, $Prate$ and $Ndelay$, denoted as φ_k, are different in network environments, where $k = 1,2,3,4$. The importance degrees are compared one to one and the results are set to x_{ij} according to Equation 3.

$$x_{ij} = \begin{cases} 1 & if\ \varphi_i > \varphi_j \\ 0.5 & if\ \varphi_i = \varphi_j \ ,i,j = 1,2,3,4 \\ 0 & if\ \varphi_i < \varphi_j \end{cases} \quad (3)$$

The values of x_{ij} constitute a matrix $X = (x_{ij})_{4\times 4}$, and the weighting coefficient is shown as Equation 4.

$$w_i = \sum_{j=1}^{n} x_{ij} \bigg/ \sum_{i=1}^{n}\sum_{j=1}^{n} x_{ij} \ , i = 1,2,3,4 \quad (4)$$

The values of the four weighting coefficients can be got through Equation 3 and Equation 4. Therefore, based on the above mathematical model, the stability degree of the voluntary server is defined quantitatively.

The selection algorithm of voluntary

The selection algorithm of voluntary server, which is based on the Pastry algorithm[13] and the SD of the voluntary server, assembles voluntary servers into a routing loop (resource cluster) so as to form a core of fast query localization. When a local server receives a video service request from a client in its own region, it checks if the requested resource is on the voluntary servers. If not, calls Pastry routing algorithm to forward the request out. Otherwise, this local server finds a voluntary server which has optimal SD and low communication costs, and the threshold value is given by the local server, and then the information of resource will be returned to the client that requests the service.

The pseudo-code of the selection algorithm of voluntary server is shown as below:

```
Procedure begin
Find(FindMessage){
    if (FindMessage.ResourecID ∉ Region) { //Region is a resource cluster.
        forward (FindMessage,nextRId); //can not find the resource, forward the message.
        } else {
            LOOP1: Do{Ci=SelectR(Region); //choose a resource cluster.
            LOOP2: if (Ci≠null)
            {N=GetSDNode(Ci); //chose a voluntary server with optimal SD.
            Costi=GetCost(N,FindMessage.NodeMessage); //get the communication cost between two nodes.
                L=GetInfo(N,MessageNode) //judge whether the two nodes in the same region or not, the result is a Boolean('True' or 'False').
                    if (Costi<M&& L="TRUE") { //M is the maximum communication cost provided by local
                        server  Return Ci;}
                else{
                        if (Costi<M) {Return Pj; //Pj is the smallest cost.
                            }else{goto LOOP1;}
                    }
            }
                }Untill(Ci== null)
                    if (Ci=null){Pj=SelectMinCost());
                        Return Pj;}
                        }
            }
End procedure
```

The processing procedure of exceptional event

In the hybrid video grid, the video service process provided by the voluntary server would be broken when a voluntary server quits the video grid without a warning sign due to human factors or hardware malfunctions. In order to keep the QoS of the video grid, the exceptional event must be treated seriously.

The cache strategy[14] is employed while a client request is processed. The client downloads a short video data of fixed length from the server constantly into its cache space, and then begins playing the video in the cache space while the subsequent data is downloaded into the client computer. Therefore, the client could continue playing the video until the video data in the cache space is exhausted. This playing mode provides sufficient time to transfer the playing process from an invalid server to another server.

When a voluntary server in idle quits normally from the video grid, a message would be sent to the local server. Once receiving the message, the local server checks the information of the voluntary server and flags the state to "invalid". In other case, the client sends the service request to the local server again when its current voluntary server becomes invalid; meanwhile, the playing process to continue due to the cache strategy. When the local server receives the service request from the client, it would seek an appropriate voluntary server to replace the invalid server according the selection algorithm presented in this paper, and the client would link to the selected voluntary server to continue the video playing or continue the playing by the local server or the central server if no voluntary server was picked up.

ANALYSIS OF SIMULATION AND COMPARISON BASED ON ANYLOGIC

AnyLogic is a new software emphasizing functions of simulation and analysis, which is used to design discrete, continuous and hybrid behavior[15]. AnyLogic supports the most common simulation methodologies, including system dynamics, discrete even simulation, and agent based modeling. It allows the user to extend simulation models with Java code. This paper simulates the selection process of the voluntary servers by using AnyLogic. The design of the AnyLogic model in fact is to layout the classes of activity object, and define the relationship between them.

Creating of the model

The model of this paper is a distributed master (voluntary server computer) election protocol. A number of machines are connected with an unreliable network. The network loses, duplicates, and delays messages randomly. The machines themselves can crash and recover. The protocol is used to maintain a single master known to all working machines at any time. This is achieved by using synchronization and voluntary server election algorithm based on constant and random timeouts.

The model is composed of four classes including Command, Machine, LocalNetwork and Main. Three java class (source, destination and id) are used to create objects to send messages, and constructor functions are constructed correspondingly. The class Command constructs a function of Message. The agent class LocalNetwork is used to simulate a network environment for the clients and voluntary servers. The agent class Machine provides a series of parameters about message and the state of the machines, which compose the selection protocol of voluntary server. The agent class Main connects the interfaces of Machine and LocalNetwork to accomplish the whole model, and meanwhile adds the environment variables that can be adjusted in a certain range. Each machine executes the same algorithm specified as a state chart shown in Figure 3. We can force a machine (e.g. current master) to crash or repair and watch the elections on the color chart.

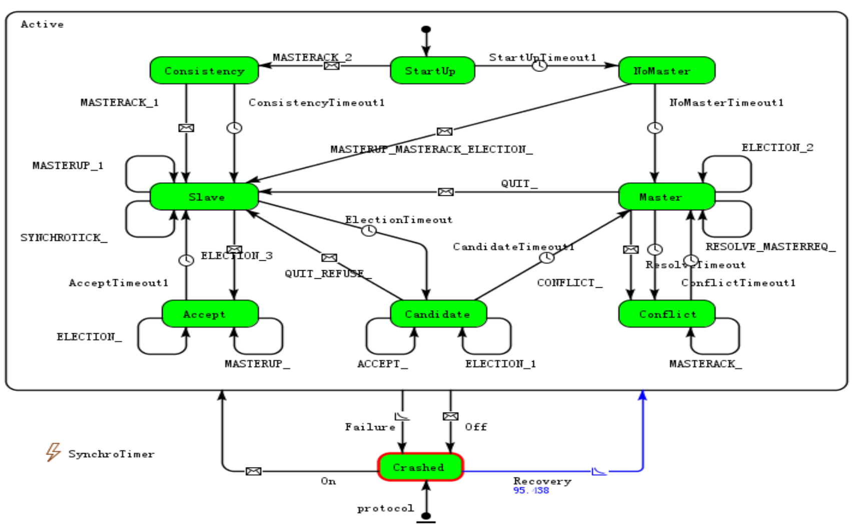

Figure 3 : Voluntary server selection algorithm protocol

We describe the mechanism of voluntary server selection algorithm using a flow chart that draws the relevant state of the machine out from the AnyLogic panel, sets its properties, and constructs the corresponding parameters and follows connection. All the clients have the status of StartUp, NoMaster, Master, Conflict, Consistency, Slave, Accept, Candidate and Crashed. The connections have two forms: trigger for message and trigger for timeout. For instance, as shown in Figure 3, the transition StartUp→Master is triggered by timeout, while the transition StartUp→Consistency is triggered by message. Each machine of the model is running in a user-defined condition based on the algorithm described in section 3.

Demonstration and result analysis of the model

At present, the simulation mainly adopts the methods of observation, which is analyzed qualitatively and quantitatively by the visualization of dynamic display and the output of graphics and data. The more intuitive dynamic connection diagram and time color chart are put to use and the connection state and efficiency of the model are observed by setting the relative objects attributions. In the model, according to Figure 4, parameters are set by using sliders whose value can be arbitrarily assigned. Assume that the loss rate of network packet is 0, the synchro timeout is 3, the network mean latency is 1, the conflict timeout is 5, the average recovery time is 100, and the time window is 100(the unit of time is the model time unit).

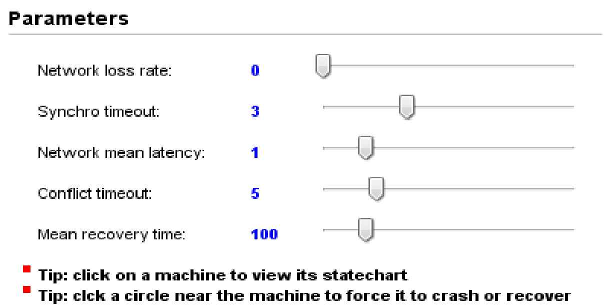

Figure 4 : Parameters of the model

As shown in Figure 5, the circular diagram consisting of twenty clients is the state graph of the clients at the time 120. The tick sign on the client represents the voluntary server computer which is in a working state, and the plus sign means the computer is in a normal running state, and the cross sign indicates that the computer is in a non-operating state (crash or power off), and the connecting line means that one end of the line is providing video service for the other. The plus sign with on connecting line illustrates the client is in standby mode (independent state). According to Figure 5, only one client computer is chosen as the voluntary server, which is providing services for nine clients computer, the number eighteen client computer is just in standby mode, and nine of the twenty clients are in a non-operating state.

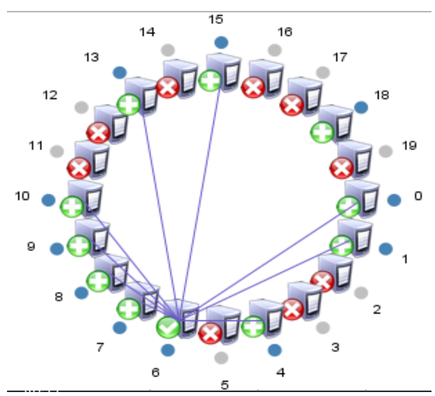

Figure 5 : State of the clients at a moment

The running state of each client in the period of 0-100(the time window is set to 100) is illustrated visually in Figure 6, which can be observed through different color grayscale. At the beginning time of 0, all of the twenty clients are in the state of "Crashed". With the time going on, the clients start to run one by one. The client of number 4, at the time of 18, is selected as voluntary server to serve for the client of number 7, 8 and 9 with a sustained and stable state. When the time goes to 70, the voluntary server of number 4 changes to be a normal client, meanwhile, the number 6, after a transitory time, instead of the number 4, begins to provide video service for others.

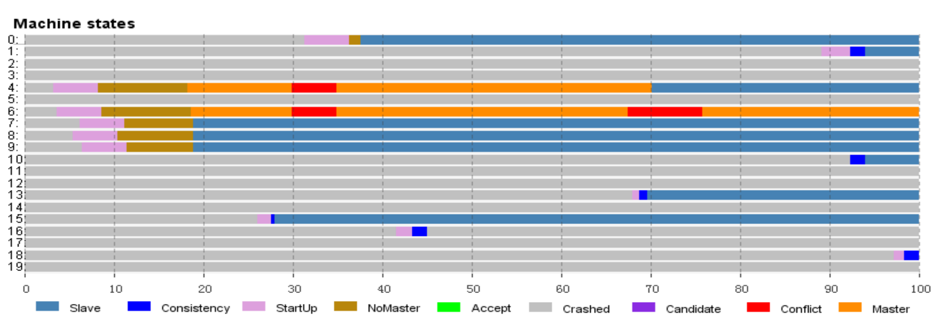

Figure 6 : State of the clients in a certain period of 100

In order to test the feasibility of the model, we extend the time window to 1000. As shown in Figure 7, most of the clients are in a state of “Slave”, namely, the state of connecting with a certain voluntary computer or connection request. Meanwhile, in the period of 0-1000, the time of the voluntary servers providing video service reaches around 80% of the total time including the time of no service request. The comparison of Figure 6 and Figure 7 shows that the model based on the voluntary server selection algorithm has good stability and more continuous connections between the voluntary server computers and the clients of resource request.

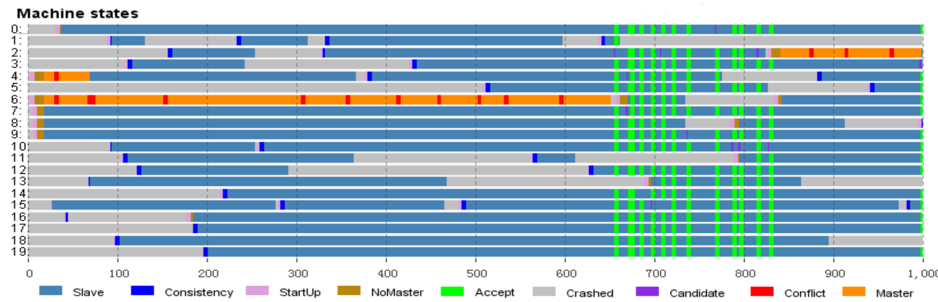

Figure 7 : State of the clients in a certain period of 1000

Comparative analysis of the models

In order to verify the superiority of the simulation model based on the algorithm provided by this paper, in the same situation of environmental parameters, routing status and condition of clients, we create the simulation model based random selection algorithm(choose one as the target from optional clients randomly)[16], and select the same period 0-1000. The experimental result in the way of time line chart is illustrated in Figure 8.

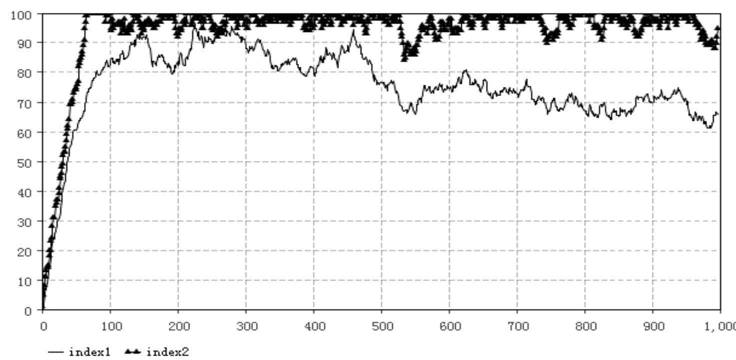

Figure 8 : Comparison of two algorithms for stability index of service

In Figure 8, index1 stands for the stability index of service of the model based on random selection algorithm, and index2 presents the stability index of service of the model based on voluntary server selection algorithm. From Figure 8 we can see, in the period of 0-50, the stability indexes of service of the two algorithms are very close. That is because there are a few clients in the beginning of the system, which lead to a low selectivity. So it is hard to distinguish the pros and cons of the two algorithms. As time goes by, the stability index of the simulation model based on the proposed algorithm is significantly higher than the stability index of the model based on random selection algorithm. This is due to the random failures of clients and voluntary servers, and the model based on random selection algorithm is difficult to maintain a persistent connection, which can not guarantee the stability of the service. Therefore, the proposed selection algorithm outperformed the random selection algorithm.

CONCLUSIONS

In the hybrid video grid, most of video service requests are provided by voluntary servers which are some high performance clients with good stability. Therefore, the payload of local server is lessened greatly. This paper proposed the mathematical model for describing the stability degree of the voluntary servers, schemed out the selection algorithm of voluntary server, and introduced the processing procedure of exceptional event to avoid jitter phenomenon as far as possible. The selection algorithm was simulated and emulated using the software AnyLogic. Compared with the model based on the random selection algorithm, the proposed voluntary server selection algorithm was considerably feasible in practical situations.

The voluntary server selection algorithm will be improved by importing the P2P technique to the video grid and more components will be introduced to enrich and perfect the model.

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