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A Future Network Service based on PC Grid Computing and P2P File Sharing: YOHEIX (Your Own Hybrid Environment for Information Exchange)

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Abstract

We propose a new concept of P2P-style file sharing combined with distributed numerical computing (PC grid computing) to facilitate new types of P2P business as a future network service. Considering the basic mechanisms of PC grid computing and P2P file sharing, synergistic effects are achieved by establishing a framework of metadata discovery, appropriate division of computational units, and money flow using settlement functions. This framework can be extended to support various business models, such as content delivery and medical applications.

1. Introduction

P2P communication has come into the spotlight as a new trend in Internet usage, and its fields of application have broadened. Distributed computing is one of the major domains of P2P, which provides a means for sharing computing power, storage capacity, physical devices, data, and applications. Each machine participating in a P2P network executes its own assigned processing unit as a peer, rather than having a central server play the main role. By interconnecting thousands or even millions of individual machines, a cost-effective virtual computer can be constructed to perform the huge amounts of computation required in scientific analysis, weather forecasting, feature-film animation, protein modeling, genome-related research, and other fields. However, these distributed computing services, referred to as PC grid computing, have not yet become commercial or profitable.

Another major facet of P2P communication is file sharing, which offers a quick, easy way to directly exchange files and contents. Unfortunately, file sharing has also made P2P infamous for copyright infringement, blinding many people to the many advantages of the technology. Incorporating appropriate digital rights management (DRM) and charging and settlement capabilities into P2P file sharing networks, however, could lead to the healthy growth of P2P content delivery services.

Here, we reflect on why commercial grid computing has not become very popular. Two major reasons are the difficulties of finding available PCs with unused CPU power and of settling the fee for computation. Considering that files are generally exchanged by always-on users with broadband access, it would be appropriate to use their terminals (PCs) for grid computing.

In this paper, we propose a hybrid system combining PC grid computing and file sharing called YOHEIX (Your Own Hybrid Environment for Information Exchange) to facilitate a new type of P2P business as a future network service. In the next two sections, we examine the main mechanisms of PC grid computing and P2P file sharing. We then clarify and analyze the proposed system and explain our implementation with screen-shots of the graphical user interface. Next, we discuss expanding the system and establishing various business models. Finally, we consider the problems and future prospects of this approach.

2. PC Grid

PC grid is a P2P-based computational model, also referred to as the master-worker model, as shown in Figure 1. A typical example is the Search for Extraterrestrial Intelligence (SETI@home) project [1], which seeks signs of intelligent life beyond Earth. Currently, similar projects are also underway in various other fields [2][3][4][5][6].

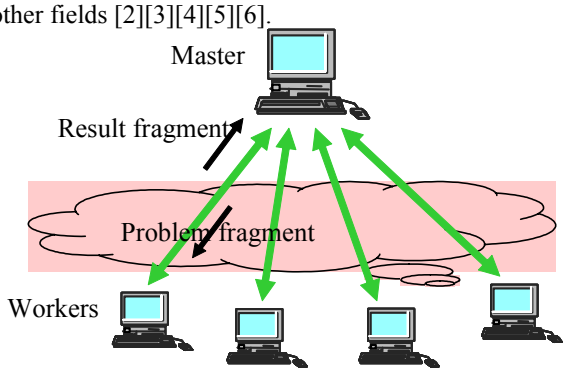

Figure 1. PC grid: master-worker model.

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2.1. Current Example of Major PC Grid System

In SETI@home, radio signals from other stars are picked up by telescopes and then sent to volunteers. The signals are automatically analyzed for artificiality by a program running on the volunteers' computers. The analysis program takes the form of a screen saver that runs when the computer is not otherwise in use. Similar projects in other fields also rely mainly on the cooperation of volunteers. This means that the most important factor is how to gather volunteers. The computational power of the volunteers' PCs must be idle.

2.2. Application Domains

We implemented some trial PC grid applications for future network services [7]. To apply PC grid technology to an actual business situation, it is important to establish a method of gathering PC (computing) power over the network. However, it is generally difficult to find volunteers to work for someone else's benefit.

2.3. Standardization Activities

Much standardization activity is in progress in the field of distributed computing. The Globus Project [8] is developing the fundamental technologies needed to build computational grids, and it provides a tool kit for integrating the instruments, displays, and computational and information resources managed by diverse organizations in widely dispersed locations. With the Open Grid Services Architecture (OGSA) [9], the Globus tool kit is being refined towards an integrated grid system architecture combining grid and Web service concepts and technologies. The initial technical specifications are currently being proposed through the Global Grid Forum (GGF) [10]-[11].

Although grid technologies are being applied for Web service domains, which are one of the most important areas of the IT business field, there is little active work on standardization of technologies for gathering PC grid volunteers.

3. P2P File Sharing

3.1. Major P2P File Sharing Networks

P2P file sharing has become infamous for illegal file exchange through networks like Napster, Gnutella, and their clones. Napster, a typical hybrid P2P-based solution, was forced to close down, but Gnutella and its clones, which are typical pure P2P solutions, are still very widely used throughout the world because copyright infringement cannot be traced in these networks.

3.2. Characteristics of P2P File Sharing

In Japan, the most popular file sharing tool is Winny [12]. It has the following characteristics:

(1) A high degree of anonymity is guaranteed.

(2) The amount of contents you can download is proportional to the amount stored on your local PC.

(3) PCs are always on and connected to a broadband access line. Little CPU power is used, although a very large amount of bandwidth is consumed.

(4) Almost all files are exchanged illegally without consideration for copyrights. No charging or settlement mechanisms have been established.

Note that characteristics (3) and (4) are the same as in the case of Gnutella [13] and WinMX [14].

4. PC Grid File Sharing Hybrid System: YOHEIX

As stated in Section 1, the barriers to the popularity of commercial PC grid computing are the difficulties of finding available PCs with unused CPU power and settling the fee for computation. The file sharing network system discussed in Section 3 overcomes these barriers. It provides an environment in which always-on PCs with broadband access can be easily and quickly identified and charging/settlement can be performed.

To remove the illegality from the current P2P file sharing systems, YOHEIX introduces "points" (money) which can be used in the YOHEIX system. Users in the YOHEIX system can obtain (purchase) files (merchandise) when they have enough points. Users earn points for their amount of PC grid work.

To include a huge number of users, it is required to guarantee that the users can fairly earn points for their amount of PC grid work. YOHEIX has a function to guarantee that a user who provides more amount of PC grid work earns more points.

We made the centralized manager (YOHEIX manager), which controls the points based on the amount of PC grid work. How to balance the points and the amount of PC grid work is key to establishing the actual and business system.

4.1. Proposed Network Configuration

The proposed network consists of the two layers shown in Figure 2. The PC grid layer is situated over the file sharing layer. Both layers are constructed upon a P2P network platform such as LimeWire [15] or JXTA [16].

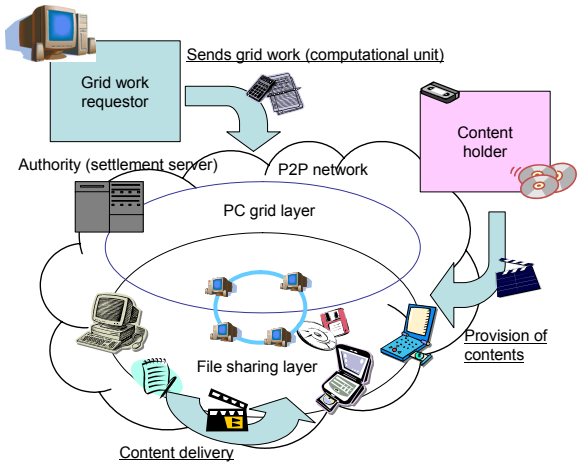

Figure 2. PC grid-file sharing hybrid system: YOHEIX.

In terms of software implementation, the two layers are implemented via the common P2P platform shown in Figure 3. Over the P2P platform, each PC executes a file sharing program and the PC grid program socket. After one or more authenticated PC grid programs have been plugged into the socket, the PC can perform PC grid computing.

The PC grid program can communicate with the file sharing program. This enables the provider of the PC grid program to access information about the shared files, such as information about which files are the most popular.

Note that even when more than one PC grid program is installed on one PC, these programs cannot communicate with each other. Instead, they establish separate regions of the PC grid layer over the single P2P file sharing layer. The PC gird program can be described as computational logic with communication only with the pre-defined communication partner.

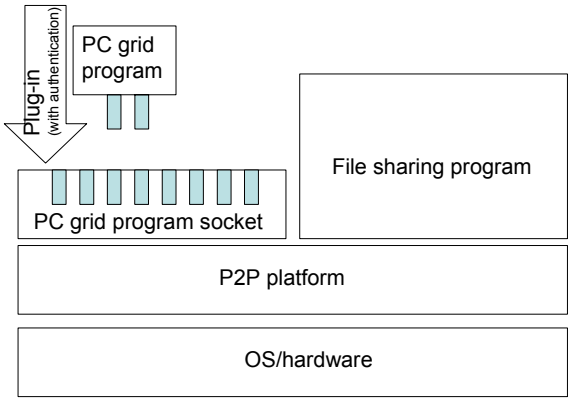

Figure 3. Software implementation of YOHEIX in a user's PC (peer).

4.2. Discovery Phase Procedure

The discovery phase for PCs participating in grid computing is performed in the file sharing layer, which has functions for keyword matching to find designated file names and metadata matching to find designated file properties. In particular, the latter capability is utilized to find PCs with appropriate characteristics in terms of CPU time, performance, schedule, memory size, and computational fee.

4.3. Computational Phase Procedure

After discovering the required number of PCs with appropriate characteristics, the requestor sends a unit of computation to each participant. It is well known that the overall performance of PC grid computing depends on the balance between computational power and communication capability, whereas supercomputers are not concerned with the granularity of computation. Therefore, the computational unit to be processed in the PCs should be well defined, and the computational schedule should be properly managed. Also, appropriate application fields should be selected.

4.4. Business Flow

A service network typically includes an authority, i.e., a settlement server. This server usually collects fees from content users and calculates the total usage charge after adding a commission. The PC grid business flow follows basically the same procedure. First, the requestor shows the computational fee at the time of discovery. PCs that satisfy the requirements start working on the computational unit received from the requestor once they ask for and receive

confirmation from the authority (the settlement server) that the requestor is trustworthy with regard to payment. The server collects the fee from the requestor after the computation has been completed and pays it into the user's bank account. The basic money flow described above is shown in Figure 4.

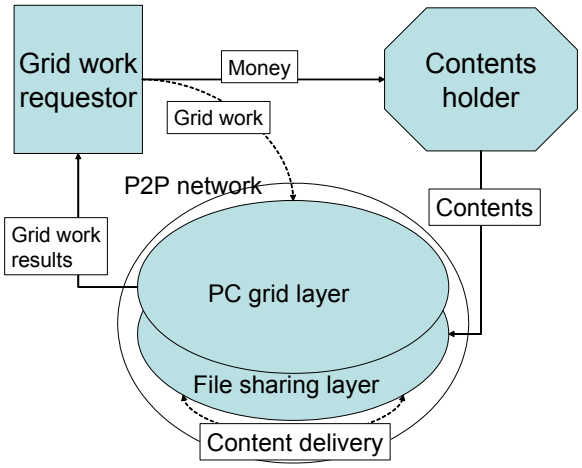

Figure 4. Basic money flow.

5. Implementation

For experimental evaluation purposes, we implemented YOHEIX. We chose the gnutella protocol as a P2P file sharing protocol and Globus toolkit 3.2 [17] for the grid work process.

As one experimental implementation, we made the centralized manager (YOHEIX manager), which controls the grid work and grid work result flows and mediates the money flow between the Grid work requestor and the contents holders as shown in Figure 4. The YOHEIX manager accepts and distributes the requested grid work and gathers the results.

A grid work requestor issues a request to the YOHEIX manager together with some amount of money via a Web server, as shown in Figure 5. The YOHEIX manager determines the priority of the grid work based on the amount of money and the available CPU resources.

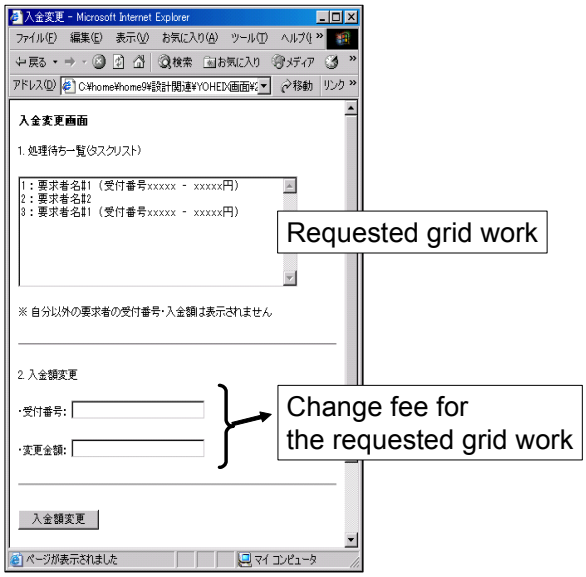

Figure 5. Grid work requestor's screen.

Currently, we have not implemented any facilities to enable the contents holder to publish the contents, but the YOHEIX manager recognizes the contents and notifies the contents holders of it. The YOHEIX manager maintains a table of correspondence between the contents and the contents holder. The operator of the YOHEIX manager can control the correspondence table by using the Web server, as shown in Figure 6.

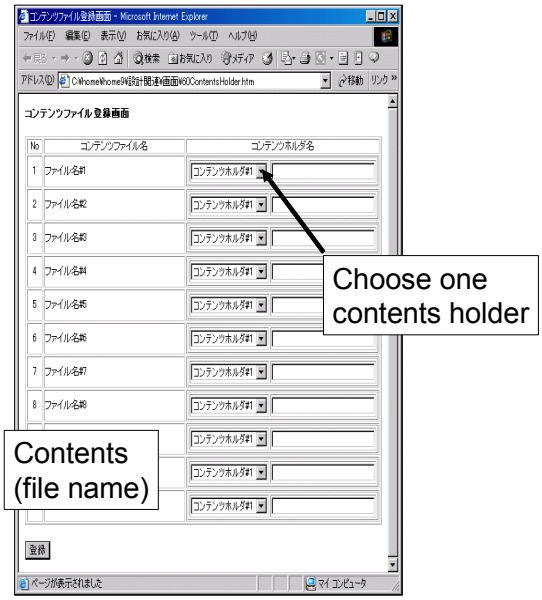

Figure 6. Maintenance screen of correspondence table.

Currently, the users, who enjoy P2P file sharing managed by the YOHEIX manager discover and obtain the files in the same manger as in existing gnutella clones. But they can check their own user points and content-point lists via Web browsers (as shown in Figure 7). The user points can be used like actual money to obtain files. They can be earned by performing grid work on the user's local PC. Each row of the content-points list shows how many user-points are required for that item of content, rather like a price list for the contents.

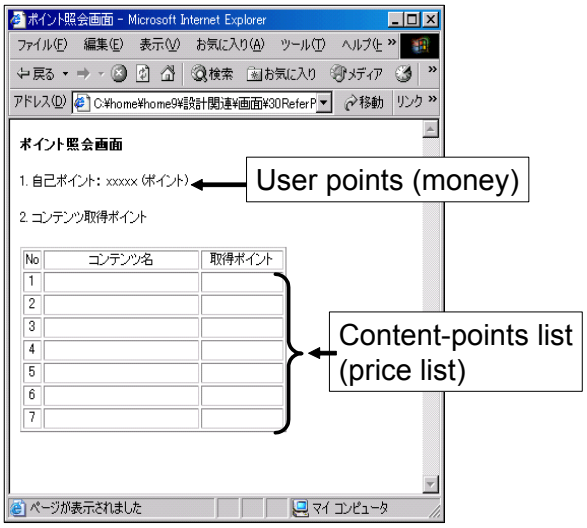

Figure 7. User points and content-points list checking screen.

Note that the user points expire after a limited term. Currently, they expire on the last day of the next month of the day they were obtained. This can decrease user-point inflation. Our system does this because user points are not money but are created by the user's effort for the grid work. Furthermore, the YOHEIX manager can reduce the content-points (price) of popular content.

When a user makes new digital content, which is shared in P2P style, from other media, e.g., CDs or DVDs, the YOHEIX software on the user's PC accesses the YOHEIX manager. If the YOHEIX manager detects that the content has not yet been shared in the system, it sets the default content-points for the content. Currently, the YOHEIX manager pays the appropriate money to the contents holders based on the quantity of content delivered.

6. Expansion and Various Applications

Based on the YOHEIX framework, various business models can be constructed.

6.1. Popularity Counting for Content Delivery

The Winny system deals with contents (files) such as music, video, and photographs. However, it conceals the underlying processing from its users. It encrypts fragments of files being exchanged, or complete files, and keeps them in a cache. In addition, the names, genres, and properties of the stored files cannot be identified. The user is not allowed to delete these files, so that other peers can download them.

However, because an identifier is given to each file kept in the cache, the user can know the ID number of the file that is currently the most frequently accessed or copied from the access log. This investigation processing is performed as a grid computation request. The processed statistics are sent back to a requestor such as a research company. The results can be used for quota control to distribute the total amount of revenue to each content holder when the service network does not operate strict DRM processing (charges are not calculated per content but overall). The business flow of this system is illustrated in Figure 8.

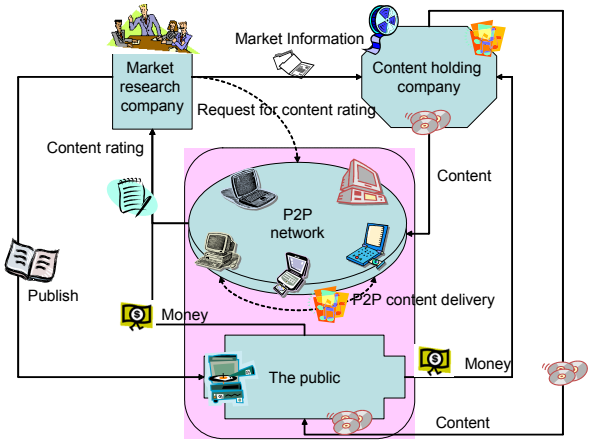

Figure 8. Business flow of popularity counting system.

6.2. Medical Content Delivery and Computing

The PC grid file sharing combination system can also be extended to serve as a medical community network. A group of medical organizations can

exchange high-resolution image files or live videos of operations by specifying metadata for the required content (e.g., the field of specialty or region). At the same time, simulations for investigating new medications can be performed by applying PC grid computing. Medical companies may request computation services from this type of community network, thus leading to another profit center. From both the research and business viewpoints, a company does not want its research to be revealed to other medical companies (rivals). Therefore, the system can conceal the names of requestors, computation contents, results, and so forth. These can all be encrypted and the discovery/delivery direction can be hidden.

This separation is achieved by utilizing two techniques. The first is to use only metadata to select the PCs. This means that it is difficult to determine which PCs are executing the PC grid program with data from a particular company.

The second technique is to use the PC grid program socket. As shown in Figure 9, different medical companies can give different PC grid programs to PCs in the P2P network. By installing these different programs (as plug-ins), the companies can utilize separate regions in the PC grid layer.

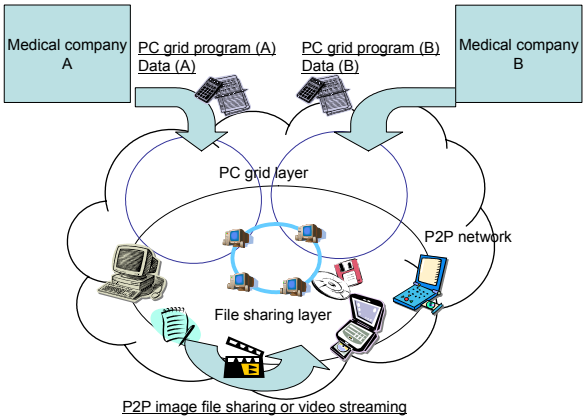

Figure 9. Separation of PC grid layers.

7. Conclusion and Future Work

To establish new types of networking services, we propose YOHEIX, which combines PC grid computing and file sharing, to generate new types of P2P business. Considering the basic mechanisms of PC grid computing and P2P file sharing, synergistic effects are achieved by establishing a framework for metadata discovery, appropriate division of computational units, and money flow using settlement functions. The YOHEIX framework can be extended to support various business models, such as content delivery and medical applications. Development of the PC grid program plug-in remains as a technical hurdle for future research work. The proposed system could overcome the unfortunate, inaccurate reputation of P2P networks as a technology used only for illegal file sharing.

We have to evaluate the performance and usability of the actual implementation of YOHEIX with actual users. We have to clarify how to balance the points and the amount of PC grid work, precisely how the system should observe the shared contents, and how the system encourages the users (incentive control) to join the system. The evaluation method is very important (in legal aspects) and still remains our future work.

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