CoFrame: A Framework for CSCW Applications Based on Grid and Web Services*

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Abstract

Though 20 years have passed since the birth of CSCW, the original goal of it is not reached as well as people expected. This situation is mostly due to the supporting technology especially the infrastructure. Today, great changes have taken place in technology, including Grid computing and Web services. These technologies, we think, will significantly affect the application of CSCW. In this paper, a framework called CoFrame is proposed to answer the challenges faced by CSCW. Based on the emerging Grid and Web service technologies, CoFrame provides some general yet flexible cooperation related services and organizes them into different layers. The elaborately designed services and architecture make CoFrame adaptive to diverse requirements of different domains. The paper details the framework and demonstrates its application with a case study in e-learning.

Keywords: CSCW, Grid Computing, Web Services, E-Learning

1. Introduction

The past twenty years have witnessed the prosperity of Computer Supported Cooperative Work (CSCW). As a milestone in information technology, CSCW aims to facilitate the interaction between people rather than to solve problems [1]. Based on the knowledge of cooperation, many systems have been developed such as teleconferencing, distance learning, workflow systems and cooperative authoring/design.

Though it is widely accepted that CSCW will become one of the basic means that people live and work, its application is now in a dilemma. On the one hand, the requirements on cooperative technologies become more and more intensified especially in business domain. For example, many organizations have adopted workflow systems to keep competing edge or to reduce running cost. There are still many other organizations that are ready to do so. On the other hand, though many systems/tools as mentioned above have been developed, they are not widely deployed. For example, it is not seen a commercial running group editor though the first one was developed more than 15 years ago. Consequently, they don't greatly improve cooperation efficiency as expected. How does such a situation form? What's the way out? For the first question, we argue that such a situation is mostly resulted from two reasons: 1) people have not gained enough knowledge and experience with CSCW, and 2) the related technologies are not matured. As stated by Mills K. L.[6], "CSCW technology generally relies on a big stack of computer and network technology, operating systems and protocols, data formats and user-interface devices." However, "the dissemination of such capabilities, while growing at a rapid pace, is far from ubiquitous, and even where these technologies have penetrated, the systems, protocols, formats, and software are far from homogeneous" and "even assuming that the necessary networking and computing technologies achieve complete penetration throughout society, the deployment of CSCW may still be retarded by various administrative and policy decisions". Today, great changes have taken place in technology along with the progress in CSCW, among which are Grid [2] and service-oriented computing [4]. We believe these technologies will significantly affect the design and implementation of cooperative systems. Roughly speaking, Grid provides a strong infrastructure for deploying cooperative systems while Web service reduces the cost of system/tool integration. Thus, if we can combine these new technologies and the knowledge with CSCW, more applicable systems can be obtained. As an endeavor in this direction, a comprehensive framework called CoFrame is proposed in this paper. CoFrame incorporates the emerging Grid and Web service

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technologies and can both ease the burden of system development and overcome the limitations laid on current systems.

The rest of the paper is organized as follows. Firstly we deliver an overview of CoFrame in section 2. Then section 3 details the framework. To illustrate the usability of CoFrame, a case study is given in section 4. The paper ends in section 5 with some discussion and conclusions.

2. An Overview of CoFrame

The starting point of CoFrame is the understanding of the entities involved in cooperation and the relationship between them as illustrated in Figure 1, where *Grid Environment* consists of various Grid resources such as computational power and storage capacity, which provides a basis for system running, and *Cooperative Task* bears the goal of cooperation. To achieve the given goal, *People* work together utilizing certain resources in environment through some *Devices*. Among these entities, *Cooperative Task* is the driving force of cooperation and it is the *Cooperative Task* that connects the other three parts, and *People* is the most active and dynamic element because users possess the related knowledge and can join and leave a cooperative scenario freely. As for *Devices*, they provide means for communication and interaction. The *Interface* between *People* and *Cooperative Task* plays an important role in system adoption.

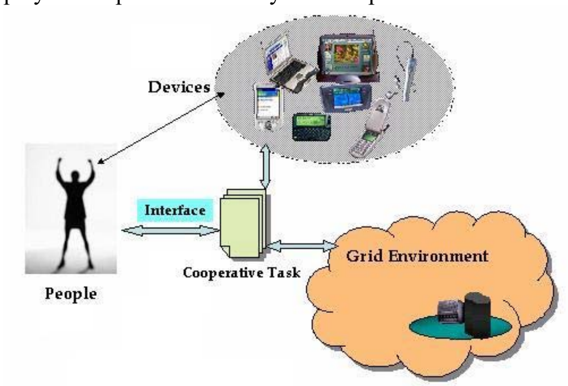

Figure 1. Entities Involved in Cooperation and Their Relationship

Two main obstacles for the wider acceptance of CSCW are resource limitation and tool isolation. By resource limitation we mean that the current underlying network doesn't provide enough support for resource management. As a result, developers must do much trivial work on resource management during cooperative system design. Usually the mechanism adopted is application-specific (mechanism deployed in one application is not suitable to the others) and is not scalable (It is hard to support new type of resources once the system is deployed). By tool isolation we mean that different tools are running separately and no interaction between them is taken into account. Consequently, people have to switch from one tool to another when handling even a single task. To increase productivity, it is necessary to combine various tools to form a comprehensive environment.

Grid technology presents an attractive vision for the future usage of computer and other electronic devices. Originating from high-performance computing, Grid has been accepted by most people as the next generation network infrastructure in recent years. Investigation into running Grid-related projects shows that most of them are concerned with resource coordination covering the topics such as Grid architecture, resource/data management or domain-specific applications. However, little effort has been dedicated to providing a systematical framework to support the rapid development of cooperative applications. In fact, cooperation is the ultimate goal for people to use information technology. In our opinion, the lack of cooperation support has become the largest barrier of Grid development. Taking all the factors above into account, we propose a comprehensive framework based on Grid technology to utilize the power of Grid to support large-scale and/or resource-intensive cooperation. To facilitate cooperation, Web service is also introduced into this framework to integrate various tools or domain-specific applications. The proposed CoFrame locates at the middleware layer of the whole architecture as shown in Figure 2.

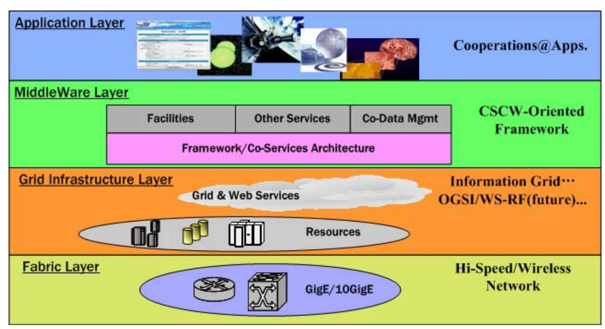

Figure 2. The Position of CoFrame

The underlying fabric layer in Figure 2 provides high-speed communication channel for upper layers. It supports most current network standards such as IPv4/IPv6 (e.g., Giga-bit Ethernet or 10 Giga-bit Ethernet) and 802.11b. As the wide adoption of powerful mobile devices, the support for ad-hoc network will be added to this layer in the near future.

Grid Infrastructure layer is divided into two sub-layers: Resource sub-layer and Services/Interface sub-layer. Resource sub-layer manages various resources such as storage, software services, computing power, instruments, and so on. Access to these resources is accomplished via

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Grid/web services interface in Services/Interface sub-layer. For research on Grid has gained some useful results (e.g., the release of Globus Toolkit 3), here we just adopt existing technologies (Though they are evolving and not matured, they are applicable at least to some extent) to construct Grid infrastructure. Instead, the focus is placed on cooperation.

CoFrame adopts service-oriented architecture. To bridge the gap between Grid infrastructure and the diverse applications, it ships various common services. With these services, developers can then quickly construct new cooperative applications simply by tailoring them and developing new domain-specific services. Details of CoFrame will be explained in the next section.

3. Framework Details

Figure 3 gives another view for understanding the framework. As shown in the figure, the framework consists of some common services and a set of facilities. Details of them are as follows.

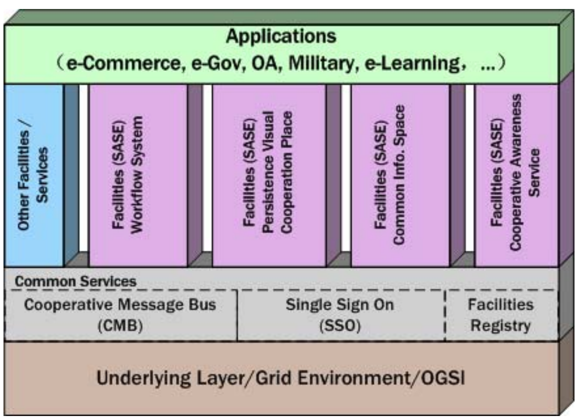

Figure 3. Functional View of CoFrame

3.1 Common Services

Common services are built right on top of the underlying Grid infrastructure. In CoFrame, Globus Toolkit 3 is adopted to construct Grid infrastructure. These services encapsulate some functions of the underlying Grid infrastructure and make them ease of use. The most important services are Cooperation Messaging Bus (CMB) and single sign on (SSO).

CMB provides an information exchange channel for facilities and other essential services of framework, including message specification and message transport. A message is defined as a tuple $<ID, D, S, C>$, where *ID* is the unique message identifier used to avoid duplicate transmission, and $D=\{d_1, d_2, \ldots, d_n\}$ is the destination set of the message with $d=<DID, DURL, DPORT>$ where *DID*, *DURL* and *DPORT* are the identifier, URL and access point of the destination service respectively, and $S=<SID, SURL, SPORT, EXCEPTION>$ is the message source with *EXCEPTION* indicating what to do when a message fails to reach the destination, and *C* is the message content that is usually application-specific. CMB provides well support for message routing and multicasting. This is done by the message transport module. Once a message is received, message transport module resolves it and tries its best to forward the message to the destinations. A destination can be located via its identifier (*DID*) or the URL (*DURL*) and port (*DPORT*). When *DID* is deployed, the transport module exploits service and/or facility registry to find out the real location of the destination service. Service and facility registry can be updated on the fly, thus dynamic service invocation is enabled. On account of service heterogeneity, semantic and ontology support is also introduced to help resolve message content. The implementation of CMB incorporates the idea of Service-Oriented Architecture (SOA), that is, all the modules of CMB are implemented as independent Web services. Compared with other message-oriented middleware [8, 9, 10], CMB is more flexible and reusable because it inherits the advantages (e.g., platform-independent, loosely-coupled and so forth) inherent in SOA. Therefore, users can easily extend or recombine existing services through the interface provided according to the real world requirement without modifying the underlying system architecture. This is an outstanding feature of CMB. In addition, CMB provides alternate data transport schemes as stated above. This makes it even more applicable.

SSO is deployed to facilitate system usage. It is implemented as an independent service. Since many literatures [13, 14] have discussed the features of SSO thoroughly, we will not repeat it here. But we'd like to point out providing SSO as a service shields the concrete implementation mechanisms and releases designers from adhering to the given architecture.

3.2 Facilities

Facilities are some utility services based on the common services supplied. Facilities are interconnected through CMB. The interconnection of facilities makes them as a whole to deliver more powerful and convenient functions for cooperative applications. That's the main difference with the standalone groupware. According to our understanding and experience of cooperation, three categories of facilities, that is, process management, awareness support, and other interaction-aided services, are critical and common to different domains and supplying these facilities will ease the burden of cooperative system development. This vision is favored by CoFrame.

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3.2.1 Process Management Facilities

Currently process management facilities include only one service, that is, workflow management service. There is a trend in workflow field that tries to make workflow management system (WfMS) to handle all situations. This full automation view always leads the system hopelessly complex and error-prone. In our opinions, the control flow in process management should be balanced between human and system to bridge the socio-tech gap [12]. To achieve this purpose, two steps are taken. First, we decouple workflow logic from real business logic. That is to say, workflow just tells right person ("who") to do the right thing ("what") at the right time ("when"). However, how to handle the workitem ("how") is left to users or applications specified by the user to decide. After the given workitem is handled, the actor reports the result explicitly. Based on this paradigm, we devise a set of cooperation patterns as the elementary units for process construction. Each pattern contains a solution to a common business goal. Second, AI method is introduced as does in Pegasus [11]. In more detail, a workflow planner is used to accept user's high-level requirement. Once a request is received, the planner tries its best to find out one or more patterns that could contribute to meeting the requirement and assemble them as an abstract workflow. This abstract workflow is then submitted to the execution engine to run. Along the progress in execution, some vague parameters in planning phase are identified and the abstract process is refined. Furthermore, when a process stops running due to exceptions or the changes in environment, the planning phase will be reinitiated. In this way, the flexibility and power of the system are greatly enhanced. One outstanding feature of our workflow planner is that efficient interaction with users is supported to keep the balance between full automation and human proactiveness and to better reflect user's intension. The workflow execution engine in CoFrame is unlike most existing ones conform to Workflow Management Coalition (WfMC) reference model [7] in that it is built on top of CMB and so it can easily communicate with the other facilities. For example, the message that a certain workitem is being handled can be sent via CMB to awareness support facilities and then perceived by others. With message as a basis, process instance can be adjusted on the fly simply by resending or forwarding the corresponding messages generated by some workitem. By this means, designers and developers avoid the intensive and trivial work on implementing various function-like business processes as does in traditional workflow management system.

3.2.2 Awareness Support Facilities

Awareness support is one of the most important features of cooperative systems [15]. It is hard to give a precise definition of awareness. The most intuitive perspective is to provide suitable information about the environment during the cooperation, including people presence, cooperation history, artifacts available, network status, etc. It is widely accepted that providing support for awareness will greatly promote the efficiency of collaboration. CoFrame aims to cover a wide range of cooperative applications, so awareness support must be supplied. In response to this requirement, cooperative awareness (CA) service is delivered. We'd like to point out the early work on awareness usually exploits very simple and inefficient strategy due to resource limitation and as a result, the power of awareness is not fully opened out. CoFrame is constructed on top of Grid infrastructure and such a limitation disappears owing to the enormous resources shipped by the Grid. Taking this advantage, we set up a "Poly-Awareness" model [5] which integrates basic information services, situation awareness, process context, user customized information, profiles of person and devices as a whole. With this model, when designing other services, designers can clarify such problems as what information is needed by CA and how to produce the information needed. The interaction between CA and other services makes all of them more powerful.

3.2.3 Interaction-aided Services

Just as the name indicates, interaction-aided services are deployed to facilitate the interaction between people for them to better complete the given task. In CoFrame, key services identified currently include common information space facility and persistence visual cooperation space facility. The common information space facility is responsible for the management of data needed or produced by cooperation. On account of large-scale and wide area cooperation, the requirements on data management include transparent access to data source, fast resource location and diverse service interface. To meet these requirements, common information space facility provides the following functionalities:

(1) Metadata management, including metadata naming, metadata publishing, metadata access, metadata analysis and redundancy cleaning. Metadata forms a solid foundation for transparent data access.
(2) Directory services. It can provide a uniform logic view for metadata so as to ensure that users can quickly find what they need. This is especially useful in wide area cooperation.
(3) Data storage and scheduling, including data transfer and replica management. The purpose is to guarantee QoS according to different network situations. Data transfer is done transparently and automatically.
(4) User-defined method support. It can be regarded as an extension to traditional trigger in database. This is

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supplied for some advanced purpose, e.g., dynamic information aggregation.

Persistence visual cooperation space facility is introduced to support the entire cooperation lifecycle including initiation, evolution, accomplishment and post-cooperation handling. It is a virtual place where participants can find potential collaborators and teams could get appropriate hints or assistances by exploring similar teamwork history archived before.

4. A Case Study

In this section, we will demonstrate the application of CoFrame. The example deployed is the distance education system of China Central Radio & TV University (CCRTVU).

4.1 Background

CCRTVU is the largest dedicated distance education institution in the world, which delivers as many as 13,000 multimedia courses to nearly two million students through radio, TV, print, audio-visual materials and computer software. At present this distance education system is made up of 1 central TV University (CCRTVU), 44 Provincial TV Universities (PTVUs), more than 690 branch schools at prefecture and city level and 1,600 study centers at county level. The main task of CCRTVU is to determine which course should be delivered, set the corresponding teaching plan and requirements, and administer the other subordinate universities, schools or study centers. Under the direction of CCRTVU, the other units may autonomously recruit students, write teaching materials or courseware, and organize teaching. Figure 4 shows the whole structure of CCRTVU system.

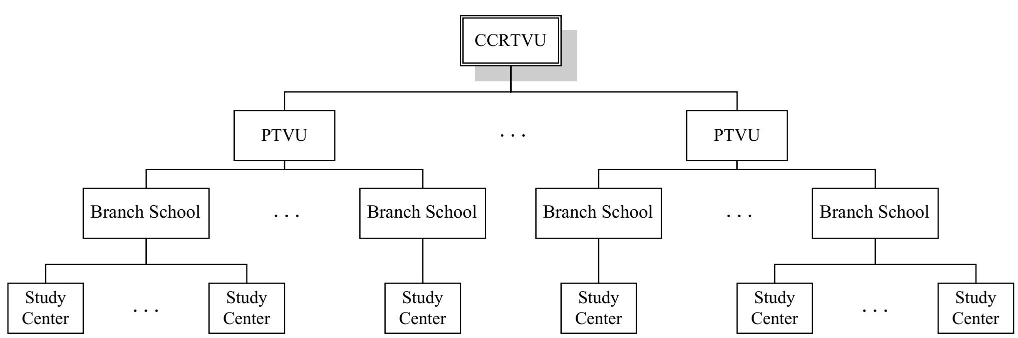

Figure 4. Organization Structure of CCRTVU

In recent years, CCRTVU has begun to adopt Internet and information technology as media for teaching. As the pioneer institution adopting e-learning technologies in China for distance education, now CCRTVU has established several e-learning systems, such as CCRTVU online[1], CRTVU-OZ e-learning classroom[2] and CRTVU e-library[3], to name a few. Today, the requirement for the e-learning systems is increased to support the whole process of education activities online, not only for implementing functions to deliver learning materials or learning administration/management in the early stage, but also for other functions to be used in teaching. For example, there are requirements for providing informal self-assessment to give students ongoing feedback about their progress, and for supporting summative assessment to improve teaching quality. The progress also promotes the requirement to support cooperative learning in these systems, through which student and teacher/tutor community can cooperate in both teaching activities and learning activities. This is an urgent demand raised by the institution because of the following reasons. Firstly, cooperative teaching is required to be supported. The CCRTVU has only around 400 staff members, and has invited more than 1,000 eminent professors, specialists and scholars from universities and research institutions both at home and abroad as main writers and presenters of its courses. At present, the total number of staff members of the PTVU system is 54 thousand, among whom 25 thousand are full-time teaching staff. In addition, there are 19 thousand part-time tutors who are recruited from conventional universities and research institutions. According to the staff composition, it is clear that most staff/tutors are distributed in a wide area, and they form teaching group for special curriculum dynamically. They need cooperation for flexible class scheduling, resource allocation, etc. Secondly, collaborative learning is also needed. Theoretically, collaborative learning is more effective than learning alone [3]. However, students of CCRTVU usually have no stable learning classroom, and traditionally they learn alone with the delivered materials from the university. If they have questions in their learning program, they usually can't find answers in time.

[1] http://www.openedu.com.cn
[2] http://www.crtuv-oz.edu.cn
[3] http://www.crtuv.edu.cn/elib/index.asp

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From the perspective of teachers/tutors, they haven't additional energy besides formative natural teaching activities due to the huge student amount. On the other hand, students are separated from each other and study alone. No learning group is formed for them to learn together and to help each other. While it is possible to support group learning across Internet, there are not available facilities that can really meet the requirement besides some simple cooperative tools, for example, BBS, Email, Newsgroups and so on. The number of students in CCRTVU system is as many as 2 million and as a result, the tools originated from Computer Supported Collaborative Learning (CSCL) research field usually fail to function.

4.2 Solution by CoFrame

The CoFrame is quite suitable for such an environment as CCRTVU. Roughly speaking, the common information space can be used to store various courseware and documents (e.g., homework, course arrangement and so on) produced during learning. With the underlying Grid support, the courseware can be replicated from one site to another (e.g., from CCRTVU to PTVU) when needed. Thus, students can access courseware as fast as possible. Moreover, this procedure is transparent to them. The persistence visual cooperation space can be used to replace the traditional classroom. Unlike the traditional one, here students can navigate the related learning history and advance their own studies. Also students can form various learning teams and perform collaborative learning. The provision of CA service makes the collaboration fluidly. The workflow facility can be exploited to support asynchronous learning. As to security management, it can benefit from SSO. In the following, we will show some use cases.

4.2.1 System Deployment

Corresponding to the organization structure, the real system is deployed as shown in Figure 5, where only some example servers and links are given. For each physical unit, a site server is deployed and also some dedicated servers are deployed to share resources (mainly courseware here). Each server runs the basic services of Globus Toolkit 3 (GT3) and acts as a Grid node. On top of GT3, full or partial functions of the common services and facilities in Figure 3 are provided in form of Web services for end users. In more detail, site server provides all functionalities besides data storage and scheduling, and user-defined method support functions of common information space facility. These two functions are served by resource servers. Users can access shared resources quickly with the metadata management and directory service deployed in site server. Site server of CCRTVU acts as the entrance of the whole system. It will direct end users to the proper site server to get the service desired. With the SSO provided, users only need sign-on to the system once to use all the resources in the system.

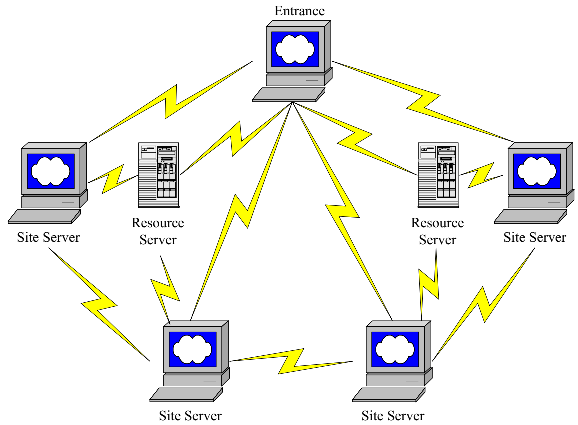

Figure 5. System Deployment Sketch

4.2.2 CA-driven Cooperative Process

The CA-driven cooperative process is shown in Figure 6. In CCRTVU system, CA is exploited to construct, transfer and process awareness events on learning assessment, artifacts (test paper here) and status changes of cooperators. Awareness events (working or remarking progress) on test paper are captured by monitor process on each node and then they are automatically processed by system and notified to the related cooperators. In this way, the status of cooperative process is tightly bound with the related cooperators. In addition, we should point out that the density of awareness is decided by the policy imposed on the test paper. Task related awareness events include task creation, task auditing, task publishing, task doing by students, result assessing by teacher, assessing result auditing and audited result notification. CMB provides a good basis for awareness service to unicast, multicast and broadcast awareness events. Cooperative awareness facility creates a loosely coupled cooperative environment and can support cross-organization process.

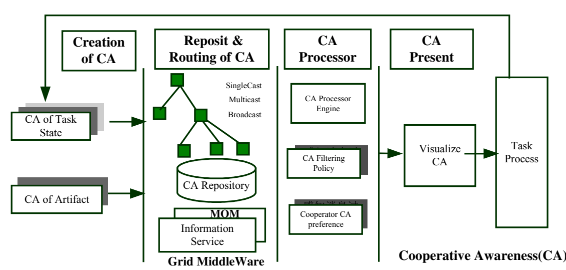

Figure 6. CA-driven Cooperative Process

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4.2.3 Resource Replication

In this system, resources are stored independent of working nodes. To publish a resource, the provider specifies a server to save the resource and at the same time, a message on resource metadata is generated and broadcast to all site servers via CMB. Each site server maintains a metadata repository of the resources available, with which users can find the desired resources. To ensure the quality of resource sharing, information space facility provides data scheduling functionality including resource replication and replica selection. As shown in Figure 7, the reasons causing resource replication include 1) network traffic (e.g., the occupied bandwidth to the server has approached to the threshold for some time), and 2) server load (the load of the server has exceeded the threshold specified), and 3) resource popularity (hot resources are accessed by many people at a certain interval), and 4) resource type/size (huge file should be placed as near as possible to the user). Two policies supported are full replication policy and partial replication policy. Full replication means the desired resource should be copied to all resource servers, while partial replication means the resource is only copied to the desired server. Because full replication is costly, partial replication is used for most time. Replica selection helps users find the most "proper" resource server to access the desired resource. By proper, we mean the server can provide the best service quality. Both the process of data replication and replica selection are done automatically and transparent to end users. In the end, we should point out the policy used here is naive, but it works. Indeed, there is a vast amount of more complex policies and algorithms [16, 17, 18, 19].

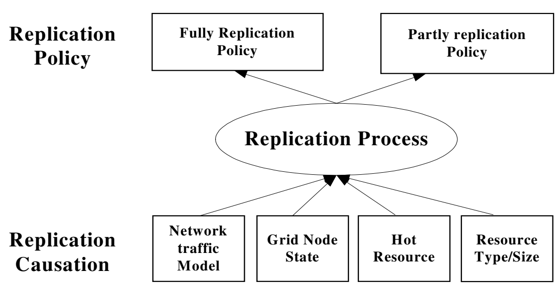

Figure 7. Resource Replication Policy and Causation

5. Discussion and Conclusions

In this paper, we present a cooperative framework based on Grid and Web services to address multi-domain requirements uniformly. The way deployed is to develop some generic common services on top of Grid and harmonize the interaction between these services. This work is somewhat advanced in the sense that Grid is far from mature. Though this is true, we argue the current obtained results are applicable at least to some extent. Taken this factor into consideration, layered design is adopted in CoFrame to shield the changes taking place in Grid infrastructure.

Recently, supporting collaboration over the Grid begins receiving more and more attention and some projects are carried out including CoAKTinG [20] and Advanced Collaborative Environments [21]. CoFrame borrows some ideas from them. For example, knowledge acquisition and consumption technologies are used in workflow planning phase while the design of persistence visual cooperation space refers to Advanced Collaborative Environments. These projects mostly concentrate on synchronous cooperation. However, CoFrame has a more ambitious goal, that is, to synthesize existing or emerging tools or technologies to facilitate cooperation of various modes. Though the case study in e-learning has shown the power of CoFrame, there are still many issues left unresolved. We think the following work can further our study.

The first is to develop monitor service. The future application systems tend to be large and complex. This raises great challenge to system administrators. A properly developed monitor service will ease their burden by gathering various information needed. Such a service should penetrate into all layers in Figure 2.

The second is to enhance service pro-activeness. This is to facilitate end-user usage. For example, the service can push desired resources to certain users once they are available. The basic idea is to introduce results in artificial intelligence into service design and development.

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