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Build grid-enabled large-scale collaboration environment in e-Learning grid

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Abstract

As a new branch of grid computing, e-Learning grid is emerging as a nationwide e-Learning infrastructure, which can provide innovative learning experience for learners. In such a grid environment, collaboration services will be the key elements due to the pervasive requirement for cooperative work and collaborative learning. Although there exist enormous research efforts on grid-based collaboration technologies, most of them have many limitations. In this paper, with the findings from the computer support cooperative work (CSCW)/computer support collaborative learning (CSCL) and advantages provided by grid, we propose to build grid-enabled large-scale collaboration environment (GLCE). GLCE focuses on distributed, large-scale, and cross-organizational collaboration through creating group-centered next generation collaboration environment, where both intra-group and inter-group collaboration could be supported. With this idea in mind, we present a grid-based cooperative work framework (GCWF), which aims to implement GLCE with an "upper layer" collaboration middleware based on the special-purpose grid infrastructure designed by our team. The preliminary results of our research on GLCE have been applied to build the learning assessment grid (LAGrid). The goal of LAGrid is to support the formative assessment business in China Radio and TV University (CRTVU) and large-scale collaboration within virtual organization (VO) has been realized.

Keywords: Learning assessment grid; Grid-enabled large-scale collaboration environment; Grid-based cooperative work framework; CSCW; CSCL

1. Background

Grid can resolve the drawbacks in existing e-Learning platforms, such as scalability, interoperability and availability, and that is why e-Learning grid is emerging. Furthermore, e-Learning grid provides new possibilities for further development of e-Learning, and among them, cooperative work/collaborative learning is the most exciting one for innovative learning experience.

1.1. e-Learning grid

Grid infrastructure is built with a set of grid middleware, which work together to provide transparent resource sharing environment for upper application. There have been many distinguished middleware platforms, such as Globus Toolkits (Foster & Kesselman, 1998), Legion (Grimshaw, Wulf, & James, 1994) and Condor (Litzkow, Livny, & Mutka, 1988) etc. The success of these platforms makes it possible to build new grid infrastructure for more wide resource sharing, and results in the establishment of global grid forum (The First Grid Forum, 1999) for grid technology standardization. As a result, OGSA/OGSI (Foster, Kesselman, Nick, et al., 2002) specifications and its successor, WSRF (Joseph, Emest, & Fellenstein, 2004) came into being, which make grid computing converge with Web services, and this service-oriented grid architecture represents the new generation of grid towards the open grid services available anywhere.

In e-Learning field, there have many isolated e-Learning platforms, in which learning objects/functions are platform-dependent and can not be used outside the system, and the collaboration between actors of different systems

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became more complicated. Therefore, e-Learning has met challenges nowadays, which increasingly addresses learning resources/services sharing and reuse, interoperability, and this is where grid technology comes up (Capuano, Gaeta, Laria, et al., 2003). Today, grid is evolving from its original concept as computing resources sharing to a means of supporting enterprise computing across distributed virtual organizations, which can provide support for both distance and traditional learning process, and there have researches on e-Learning grid, such as the works by LeGE–WG (Dimitrakos, Randal, & Ritrovato, 2002).

Until now, much grid development has not yet been exploited widely in e-Learning context. e-Learning community should address technical issues and move actively into e-Learning grid service design and implement phase, and there have some efforts in this direction, for example, European learning grid infrastructure project (EleGI, 2004.2.1–2008.1.31) aims to "address and advance current e-Learning solutions through collaborative use of geographically distributed computing and educational resources as a single e-Learning environment" (Gaeta, Ritrovato, & Salerno, 2003).

1.2. Collaboration requirements in e-Learning grid

e-Learning grid will facilitate the evaluation of new learning approaches and provide innovative learning experience for learners, and collaboration technologies are the most promising approach for this direction.

First, lifelong learning (Longworth & Davies, 1996) has brought the need to support a broad community of learners throughout their lifetimes to learn together, and learning from others enables them to acquire new knowledge in a fast and efficient way. In this new environment, learning activities are aiming to aid the learner to construct knowledge other than to memorize information, and collaborative learning can be used for the requirements to enhance the learning experience and improve the learning results (Slavin, 1995).

Second, computer supported collaborative learning (CSCL) is regarded as a new paradigm for collaborative learning (Koschmann, 1996), and there have research efforts towards the development of platforms for CSCL applications (Ana, Bacelo, & Karin, 2002; Asensio, Dimitriadis, Heredia, et al., 2004). In fact, CSCL is a sub-field of computer supported cooperative work (CSCW) and it inherits findings and fruits from CSCW. Many groupware systems in CSCW were used in CSCL directly with minor modification (Appelt, Ruland, Skarmeta, et al., 2002). While CSCL pays more attention to the technologies suitable for collaborative learning scenarios, CSCW is an interdisciplinary research field for general collaboration technologies, and both of them are needed in e-Learning environment by teachers, administrators, and learners, etc. Therefore, both of cooperative work and collaborative learning environments should be provided for various groups in e-Learning grid.

Nowadays, there have many research efforts on grid-enabled collaboration technologies in worldwide gird research community (Atkins, Droegemeier, Feldman, et al., 2003; Bote-Lorenzo, Vaquero-González, Vega-Gorgojo, et al., 2004; Corrie & Leigh, 2003; Neal, Kunori, Bunn, et al., 2003; Shum, Roure, Eisenstadt, et al., 2002), for example, Caballe proposed to develop a generic CSCL platform with grid technologies (Caballe, Xhafa, Daradoumis, et al., 2004), which aimed to provide collaborative learning purpose library (CLPL) and grid-enabled collaboratory for scientific research (GECSR) is a project which plans to integrate existing collaborative tools and build next-generation collaborative framework (Neal et al., 2003). However, most of these efforts are just developed for quick prototyping, which result in the difficulty for creating natural collaboration environment. On the other hand, while considerable work has been done on collaborative tools to assist in performing collaboration, little has been done on the mechanisms for establishing/maintaining the structure of collaboration, which is the key for large-scale collaboration. In this paper, we argue that the endeavor for grid-enabled collaboration technologies should focus on large-scale collaboration environments, which aims to bring the full potential from grid for collaboration and create natural next generation cooperative work/collaborative learning environments, therefore, the collaboration of large number of participants who perhaps belong to many different organizations can be enabled.

The rest of this paper is structured as follows. In Section 2, we analyze the development of collaboration technologies in the field of CSCW/L from holistic perspective, and summarize the inherent requirements of cooperation based on the state of practices in CSCW/L, and then we study how grid computing technologies can be used to satisfy these requirements, which result in our viewpoint of grid-enabled large-scale collaboration environment (GLCE). Afterwards, we propose grid-based cooperative work framework (GCWF) to realize GLCE, and describe the framework in detail. In Section 3, we first introduce learning assessment grid (LAGrid), which is designed with the idea of GLCE, and then describe how the large-scale collaboration environment is implemented in LAGrid. LAGrid is the initial results of our long-term efforts on GLCE. In Section 4, we compare our work on GLCE with some other research efforts, and also compare the work of LAGrid with existing e-Learning platforms in China Radio and TV University (CRTVU). Section 5 draws the conclusion and discusses future directions.

2. New approach for grid-enabled collaboration technologies research

Current learning platforms do not support all requirements of collaborative lifelong learning, therefore, it is valuable and necessary to find appropriate solution for how to build such platform in grid environments.

2.1. State of the art of CSCW/L development

Historically, how to enable people to collaborate more efficiently is a continuous effort of CSCW, and many excellent groupware systems have been developed to support cooperative work in this field. However, only limited or highly application-specific cooperative mode for limited group is supported by these systems compared to the requirements of real-life Cooperative Work. For example, workflows were built for a pre-designed categorization of work interactions, and the tightly structured representations of work raise concerns in CSCW (Chalmers, 2004). Nowadays, there need natural collaboration environments to support real-life collaboration, which should integrate various cooperative mode into one cooperation space, and this requirement also arises in CSCL (Guzdial, Hmelo, Hübscher, et al., 1997). To sum up, there are mainly two problems blocking the further development of collaboration technologies.

First, collaboration technologies failed to achieve widespread application. Research in the paper (Mills, 2003) indicates that the value derived from CSCW technologies improves in an exponential proportion to the number of people who posses the technology, however, most on the shelf groupware systems in CSCW only aim to support small-size groups, and can not be directly used to support large-scale collaboration in cross-organizational scenarios. The reason is that CSCW/L is at the end of a long food chain of technologies, and "it generally relies on a big stack of computer and network technology, operating systems and protocols, data formats, etc., and the dissemination of such capabilities is far from ubiquitous" (Mills, 2003), furthermore, the deployment of CSCW/L may also be hindered by various administrative policies, and especially when the potential collaborators exist within separate administrative domains.

Second, due to the fragmentation philosophy of existing groupware systems, it is difficult to integrate activities supported by these systems into one cooperation space. The solution to the problem is "integrate" approach, and there have some works focusing on integrating various cooperative systems together (Bote-Lorenzo et al., 2004; Ramesh & Mohan, 2001). Different to these existing "integrate" efforts, we emphasize that real "integrate" of cooperative systems is not the traditional integration with software engineering technologies, and it should rely on comprehensive cooperative work framework, which should reflect the essential requirements of cooperation. This level of "integrate" has just been attention-getting, for example, Yordanov proposed the necessary of an infrastructure that supports all CSCW related issues (Yordanov, 2004), and Collaboration@work is proposed for guiding the research on cooperation technologies during 2005–2010 in Europe, which suggest to create next generation collaborative working environment (NGCWE) with comprehensive cooperative work framework (Rügge, Ralli, & Quemada, 2004). Therefore, researchers in CSCW should exploit new cooperation technologies for building comprehensive cooperative work framework besides the traditional ones (e.g., workflow, cooperative authoring), and in our viewpoint, *awareness* and *cooperative context* (related to group memory, knowledge management, and common information sharing, etc.) are two key technologies for the realization of natural cooperation, and they should be pillars of the new cooperative work framework.

Cooperative context is a resource aggregation that has to be cooperatively managed through its specialized coordination mechanisms, and acquiring, using, and sharing context creates a new potential for the way people work together, and adding real world context to CSCW will enable a better quality of cooperation. At the same time, *awareness* is having an increasing influence on both social and technical research in CSCW, until now, awareness problem is still very far from being solved, and further efforts are needed on awareness from the viewpoint of designing a supportive technology (Simone & Bandini, 2002), which requires a deeper understanding of the means people adopt to deal with awareness as well as integration of awareness with tools supporting other forms of coordination.

Summarizing our research on state of the art of CSCW/L, we think that the development of collaboration technologies has attained to a new stage, and researchers should pay more attention to large-scale collaboration environments, where both wider and deeper cooperation should be studied. Cooperation characteristics of groups in different size are different, and they should be supported with suitable technologies in these environments to enable these groups to collaborate in whatever mode at the appropriate time.

2.2. Facilitate the research on grid-enabled collaboration technologies with comprehensive principle

How can grid computing facilitate the development of collaboration technologies in the new stage?

Given the influence of Web services in the emerging grid standards, it is obvious that the capacity of coordinated resource sharing by grid will become more ubiquitous, which is very important for the further development of CSCW, especially for the realization of large-scale collaboration, because limitations aforementioned are relaxed with service oriented architecture (SOA) supported by Web services.

Second, in grid environment, a virtual organization (VO) consists of multiple distributed and heterogeneous individuals/organizations providing resources/services, each of which must confront diversities of access technologies among its participants. VO is mainly shaped by grid security infrastructure due to that security concerns in grid environment go far beyond the traditional establishment of trust relationships between a client and a server, such as the mechanism of single sing on (SSO) provided by grid security infrastructure, whereby a single action of user authentication and authorization can permit a user to access all computers and systems where he has access permission, without the need to enter multiple passwords. VO management and grid security services are important facilities for distributed large-scale collaboration, because free and open communication need ability to know the participants' identities (e.g., personal identities, group identities), which can be easily implemented in grid environment. Users in VOs are organized into groups which in general form a hierarchical structure with the VO itself as the root, and with the structure, mechanisms for establishing/maintaining the structure of collaboration can be provided to promote group-centered cooperation. Furthermore, the secure collaboration environment can be designed to support informal, spontaneous collaborations as well as highly formal collaboration (refer to Fig. 1), while there have intensive researches on the functions of VO management, such as community authorization service, identity management in VO, etc. (Demchenko, 2003; Pearlman, Welch, Foster, & Kesselman, 2002), there has no work to provide service for structure collaboration described in Fig. 1.

Third, grid program model provides basic framework for creating natural cooperative environment to facilitate deeper cooperation, which is crucial for implementing ''integrate'' CSCW, for example, OGSA provides a set of core services that can be extended to implement high-level services, including service discovery, dynamic service creation/cancellation, life management, etc., and these services are necessary for the realization of ''upper layer'' collaboration middleware with normative encapsulating (encapsulated into ''grid service'') and integrating (reference to a comprehensive cooperative work framework). There have some work in this direction, for example, Amin proposed open collaborative grid services architecture (OCGSA) over OGSA (Amin, Nijsure, & von Laszevski, 2002), and Vaquero-González proposed to use grid service for CSCL application development (Vaquero-González, Hernández-Leo, Wattenberg, et al., 2005).

In summary, grid provides technical underpinnings for CSCW/L, and we can build grid-enabled large-scale collaboration environment (GLCE). First, GLCE can benefit from VO management with establishing/maintaining the structure of group-level collaboration. Second, natural workspaces in GLCE can be created with the program model of grid, which can provide next generation collaboration environment for groups. Third, awareness service can act as light-weight background collaborative facility for collaboration inside intra-groups and inter-groups in large-scale collaboration, which can be used to resolve social issues of cooperation and facilitate group-level cooperation. This awareness service will be based on grid message oriented middleware (MOM) and can be deployed in wider area with grid infrastructure to serve large-scale community.

2.3. CSCW/L-oriented grid architecture

Grid infrastructure is the base for the realization of GLCE, and although there have some distinguished grid platforms, but they are designed for computing-intensive or data-intensive applications, and cannot be used directly to realize GLCE, for example, GLCE need grid MOM middleware to realize awareness service, which does not exist in these existing grid platforms, and PKI-based (public key infrastructure) grid security service in these systems is also inefficient in high-interactive collaboration scenarios, besides, availability of these existing grid infrastructure is low, which is the reason of the establishment of open middleware infrastructure institute by UK e-Science Programme (Atkinson, DeRoure, Dunlop, et al., 2004).

Therefore, we decide to build special-purpose grid infrastructure, called collaboration gird, and consequently, we proposed CSCW/L-oriented grid architecture as shown in Fig. 2, which has five layers from the bottom to the top. The bottom is infrastructure layer, which provides basic

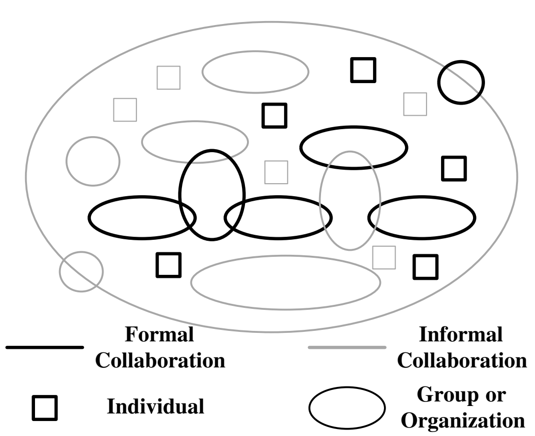

Fig. 1. VO-based structure collaboration.

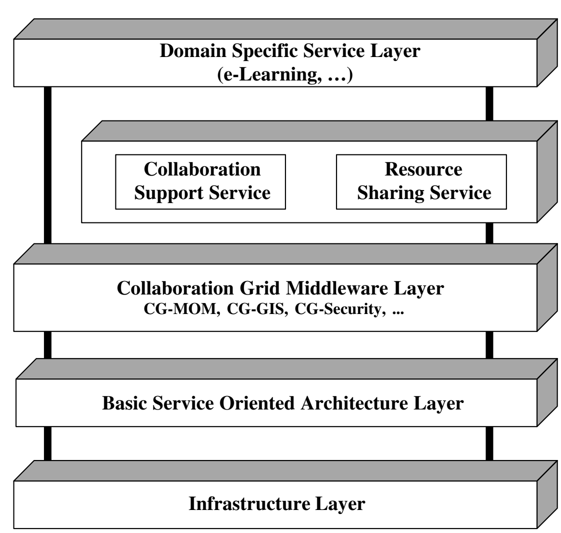

Fig. 2. CSCW/L-oriented grid architecture.

networking environment, including computer, network, network protocol, etc. The second is basic SOA layer, which provides core functions for realizing SOA on Web services, including protocols of HTTP, XML/XMLS, UDDI/SOAP/WSDL, OWL-S, etc. These protocols provide the basis for availability and interoperability of various services distributed in wide area. The third is collaboration grid middleware layer implementing the characteristics of grid for coordinated resource sharing, which is redesigned for the requirements of GLCE, such as collaboration grid MOM (CG-MOM), SKI-based (symmetric key infrastructure) grid security service (CG-security), collaboration grid information service (CG-GIS), etc. The fourth is common service layer, which is the focus of our research where collaboration middleware for GCWF locates, and this layer is based upon collaboration grid middleware layer for building cooperative work/collaborative learning environment and resource sharing environment. The fifth is application layer, which is oriented to special application domain.

The architecture is designed with special considerations on the GLCE's requirement for grid infrastructure, and it guides the design of LAGrid, which is an instance of the realization of GLCE, and the middleware of collaboration grid have been realized in LAGrid.

2.4. Grid-based cooperative work framework

In order to implement GLCE, a cooperative work framework is strongly needed, which is the foundation for constructing "upper layer" collaboration middleware.

Real-life cooperation is carried out alternatively in synchronous and asynchronous mode, furthermore, some cooperative procedure can be pre-defined and many others cannot be defined in advance due to the ad hoc activities that happen in non-repeatable manner, which may be preponderant in some area, such as knowledge building activities for collaborative learning. These features indicate that cooperation is characterized by a fine grained co-presence of formal and informal forms of collaboration as well as the continuous shift between them. Moreover, every group has their own way to collaborate, and cooperative systems should be scalable and tailorable.

Our solution for the above requirements is to build cooperative work framework based on coordination mechanisms, which is embedded in every ongoing cooperation process, and we take previous research work on coordination mechanisms (Alberto & Hugo, 2002; Malone & Crowston, 1990; Schmidt & Simone, 1996) one step further by classifying coordination mechanisms into three categories according to its feasibility for pre-description, that is, explicit coordination mechanism, implicit coordination mechanism and improvise coordination mechanism (Li & Shi, 2004). These different coordination mechanisms require quite different support technologies (refer to Fig. 3), and the developing technologies (e.g., cooperative awareness, cooperative context) are very important for supporting

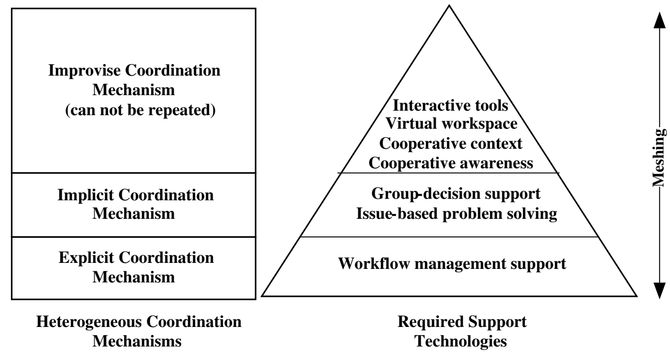

Fig. 3. Heterogeneous coordination mechanisms and its support technologies.

improvise coordination mechanism. In fact, these coordination mechanisms are interweaved together, and so the new cooperative work framework should be able to construct single coordination mechanisms as aggregations of heterogeneous coordination mechanisms, which demands services by different support technologies can be meshed together.

Besides the requirements of support for deeper cooperation, there are also requirements of support for wider cooperation. Cooperation characteristics of groups in different size are different, for example, in team and small group, members know each other, and they collaborate to achieve a common goal, so their interaction is highly focused. On the other hand, in group of community, members do not all know each other, and cooperation usually happens with common interests or preferences, and their interactions are loose. There needs a cooperative facility to cover these diverse features, and we think that awareness service is the most promising candidate.

With the functions of three aspects of grid for GLCE and requirements of real-life cooperation in large-scale collaboration aforementioned (see Section 2.2), we propose the framework of GCWF, which is illustrated in Fig. 4, and the framework is composed of eight logical modules, and every module has its special role in the realization of GLCE (explain the relationship in Fig. 4): (1) GLCE is a group-centered cooperation environment, and every group in this environment has its own teamspace (just one) despite its group size, which is realized by *virtual teamspace service*. Information about the group for special teamspace comes from *collaboration relationship management* service, which implements the function of VO management of human. The teamspace is used to maintain cooperation in groups, where users can locate each other and rendezvous easily for intra-group collaboration so that both formal and informal cooperation can be supported within the rendezvous; (2) facilities for collaboration can be binded to teamspace in configurable way, which include *group memory service*, *various collaboration services* and *cooperative context management service*. In more detail, a teamspace can bind only one group memory service, be configured with multiple collaboration services on demand, and utilize

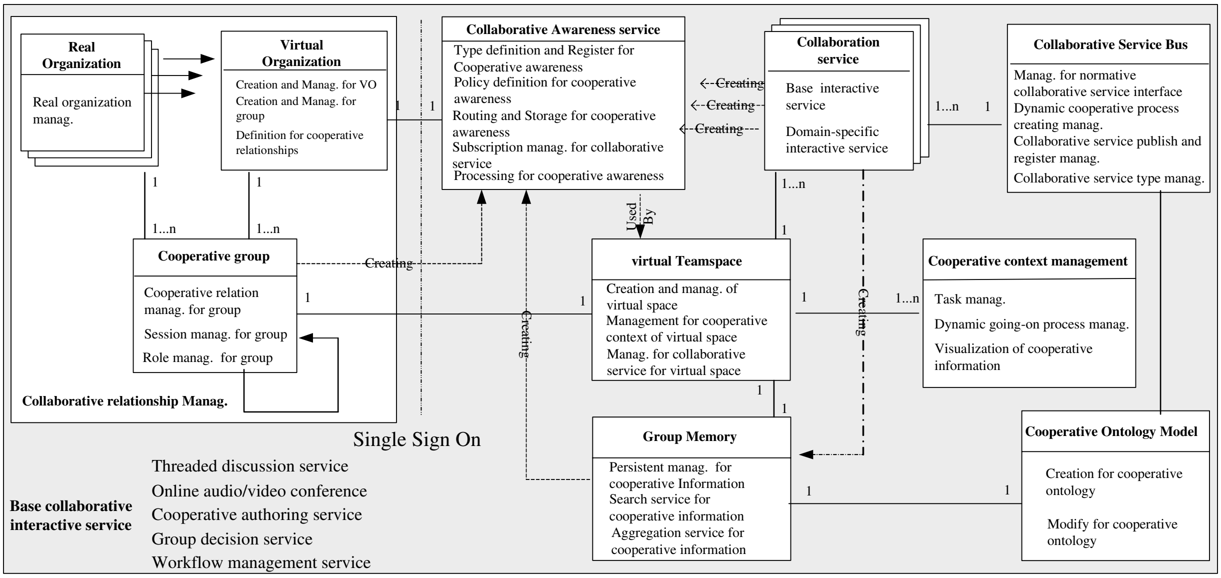

Fig. 4. Grid-based cooperative work framework.

multiple cooperative context management service according to the number of tasks processed at the teamspace; (3) different to traditional collaborative systems, collaboration facilities binded to a teamspace can be integrated into one cooperation space, which is realized with *cooperative ontology model* as the foundation. The collaborative ontology describes the concepts and relations between them in collaboration systems, and it acts as meta-model for both unified collaborative information space (provided by the group memory service) and collaboration service interoperability (provided by collaborative service bus). With the model, information produced by various collaboration services can be mapped into semantic-abundant group memory, which facilitates advance processing of the information, such as advanced querying. At the same time, the ontology model also be used to support the realization of *collaborative service bus*, which realizes the integration of various collaboration services at semantic level so that data and control can be transferred between them automatically; (4) *collaborative awareness service* is the key element for GLCE, which facilitates both intra-group and inter-group cooperation, and it will be realized with event propagation mechanisms. In GLCE, VO is the boundary within which cooperation happens, where groups in hierarchical structure of a VO share same awareness service. Awareness information comes from collaboration services, group memory service and collaborative relationship management service, which is designed with 3-dimension cooperative awareness model (3-DCAM) (Li, Gong, & Shi, 2004).

Collaboration grid provides critical support for the modules in GCWF, which are used to realize GLCE:

(1) *Enable collaboration relationship management with gird VO management*. The collaboration relationship management service is implemented with grid VO management function as its core component, with which information about wide distributed organizations/individuals is organized into hierarchical structure of groups, and the structure can act as background index for large-scale collaboration. In grid environment, user information of different organizations may be stored in different grid nodes deployed in wider area. Security requirements such as authentication and authorization of VO management are satisfied by grid security service, fore example, the function of SSO can be used for collaboration relationship management, with which each user of GLCE needs to login the system only once and then work in consistent and transparent way.
(2) *Realize true large-scale collaboration with collaborative awareness service based on grid MOM*. Awareness is the core of GLCE, which acts as both "background" light-weight collaborative facility for inter-groups cooperation and enabling facility for natural intra-group cooperation. With the service, informal and spontaneous collaborations are enabled in such two situations with providing non-intrusive and flexible ways to collaborate. Inter-groups cooperation is realized with the basic connectivity provided by group-level awareness, which promotes the formation/evolution of structure collaboration.

Collaborative awareness service in GLCE is implemented with event propagation mechanisms, which needs the functions of event storage, event routing, event aggregation/processing, event distribution to destination groups. For event storage, event routing and event distributing, there needs grid MOM to provide reliable event delivery. For event aggregation/processing and event distribution, there need advanced awareness processing capability, and we have designed grid-oriented cooperative awareness language (GOCAL) for this purpose, which is a rule-based event processing language. The runtime of GOCAL has been finished to provide the service of new awareness type defining, publishing, awareness rule defining, and awareness information subscribing, etc., and it also provides interface for other collaborative service in GLCE to enable them to integrate with the awareness facility.

(3) *Facilitate sharing of collaboration services with grid infrastructure*. Cooperation is actually realized with collaboration services, but traditional collaboration services could not be shared because of their isolated design philosophy. In GLCE, all collaboration services are wrapped into "grid service" and published into grid for sharing through grid infrastructure. A component model with standardized interface (group management interface, awareness interface, context interface etc.) is provided, with which one can create reusable and interoperable collaboration services. As a composable framework, GCWF offers various interactive tools and a set of domain-independent interactive services are selected first to be implemented (refer to Fig. 4), which fall in the scope of different coordination mechanisms as shown in Fig. 3.

It should be point out that all collaboration services are designed and wrapped with procedure approach, and they target a continuum of interaction modes for dynamic process enacting, and the collaborative service bus is designed to integrate different collaboration services into one cooperation space at semantic level. Besides, conventional grid can be used to provide advanced collaborative service, such as functions provided by AccessGrid.

(4) *Provide cooperative context for large-scale activities with grid service aggregation middleware*. There are two modules for cooperative context, one is the cooperative context management service, which is the foreground of the group memory module, and it provides functions of querying collaborative information, tracking active-task procedure, and showing "to-do list", and the other is group memory, which is constructed based on the collaborative ontology model. Because of the distribution of group memory information, there needs service aggregation middleware to support cooperative context management service for context display, which is very important for large-scale collaborative activity.

To sum up, GCWF defines an open and extensible framework for distributed and advanced collaboration environment. In this environment, groups are connected with background awareness facility and work in their own teamspaces, where cooperator is assumed to be the composer of cooperation so that control flow can be interpreted by human and computer alternately in trade-off manner, and cooperators can modify collaborative facilities binded to the teamspace to configure the mode, length and scope of their interactions, then, once logon is passed via the grid portal, the user can collaborate in the consistent environments, where he can use various collaboration services/resources transparently.

3. Learning assessment grid

CRTVU is a nationwide open distance learning system, which is the biggest one in the world comprising central institution, 44 Provincial RTVU (PRTVU), and more than 900 municipal branch schools, and it provides remote education for more than 2 million learners dispersed around China now. e-Learning grid is promising to provide a comprehensive solution for nationwide collaborative lifelong learning environments for China, and LAGrid is coined under such situations as an initial and important attempt towards the ultimate goal of constructing the national e-Learning grid. LAGrid is an instance of GLCE and its related design aforementioned.

3.1. The business process of LAGrid

LAGrid is a grid system that addresses formative assessment problem in e-Learning for CRTVU. Formative assessment is a kind of learning assessment method designed to assist the learning process by providing feedbacks to learners, which can be used to highlight areas for further study and hence improve future performance (Boston, 2002). The timeliness of feedbacks is a key factor in the success of formative assessment, so collaboration between different roles is important for timely response to learners, and there are cross-organizational "big" processes in LAGrid, which require large-scale collaboration environments to support collaboration for different users from hundreds of organizations. A typical "big" process and its role's activities in LAGrid are described in Fig. 5, in which roles are played by users from nationwide distributed organizations.

3.2. The architecture of LAGrid

LAGrid is proposed and designed according to the aforementioned collaboration grid architecture and the design of GLCE. The architecture of LAGrid is displayed in Fig. 6.

- *Grid middleware layer*
  All gird middleware of collaboration grid have been implemented in LAGrid, and they are *LAGrid–MOM*, *LAGrid–GIS* (grid information service), and *LAGrid–RBFT* (reliable bulk file transfer). *LAGrid–security* has also been developed for higher interactive response, which is SKI-based grid security service. *LAGrid–SA* (service aggregator) provides function to aggregate many services as a new service timely so that the

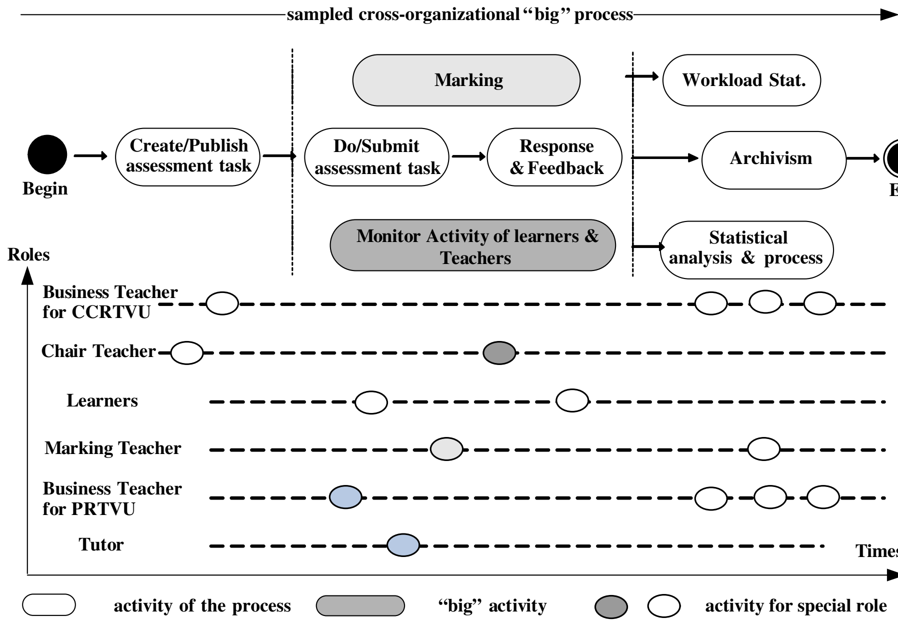

Fig. 5. A sampled large-scale collaboration process and its role's activities in LAGrid.

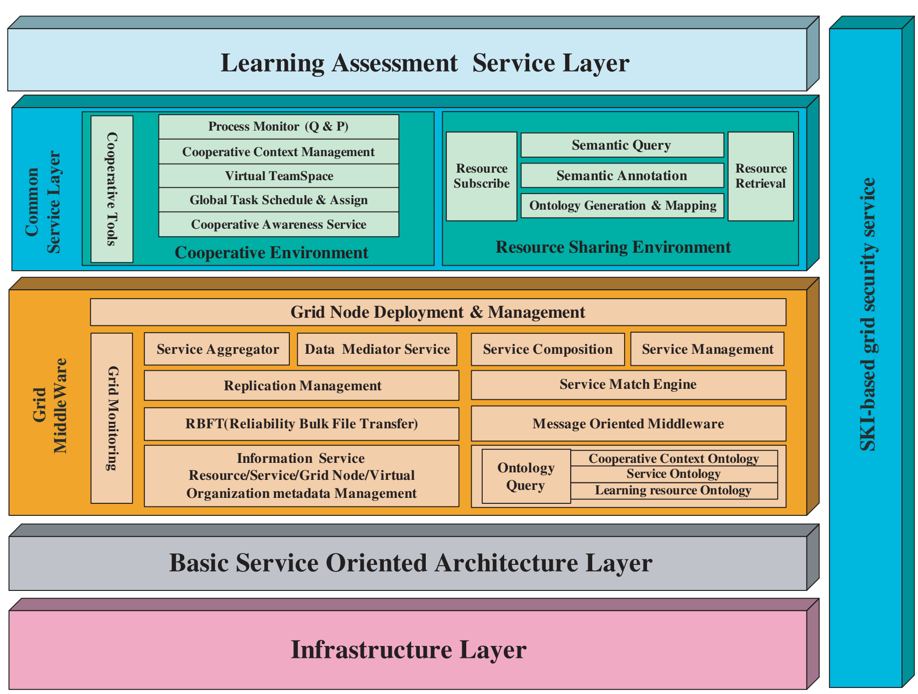

Fig. 6. LAGrid architecture model.

complexity of dynamic and heterogeneous of the services can be shielded from users.

Besides, LAGrid extends the categories of middleware in collaboration grid for e-Learning: (1) *Replica management service* provides guarantee for better quality of learning resource sharing, which implements functions of transparent data copy, copy selection, etc.; (2) for creating knowledge grid environment, LAGrid provides middleware of *ontology service*, *service composition*, and *service matching engine*; (3) in order to enhance the availability and maintainability of LAGrid, *grid monitoring and service management* are developed. Other functions in this layer are finished by the module of *grid node development and management*, which provide scalable management for LAGrid, and a new added grid node will be integrated with existing grid infrastructure inherently so that the nodes in LAGrid can be expanded dynamically and adaptively to the scale of its business.

Because of limited pages, more details of these middleware can be found in the paper (Wang, Li, Yan, et al., 2005).

- *Common service layer*
  For large-scale collaboration environment, we now mainly focus on collaboration in the domain of whole VO for effective execution of the aforementioned "big" assessment process, and *cooperative awareness* service has been implemented as the base for the execution of the process. Resource sharing environment provides deeper sharing capability for learning resources in cross-organizational scenarios based on metadata technology with resource push/pull model.
- *Learning assessment service layer*
  The top layer is assessment services layer, which provides work environment for different roles in LAGrid. Particularly, the layer provides personalized learning space based on the results of learning assessment and the environment of learning resource sharing.

3.3. Grid-enabled large-scale collaboration for "big" collaboration process

Based on the grid infrastructure of LAGrid, initial large-scale collaboration environment has been developed to show the feasibility of the concept of GLCE. Because of limited pages, we just describe the key services that are significant for the realization of the large-scale collaboration in LAGrid, such as awareness service, global task scheduling.

3.3.1. Grid-based awareness facility for large-scale dynamic collaboration

Cooperative awareness service is the core component of GCWF, and it acts as light-weigh collaboration facility of GLCE, for this reason, advanced awareness processing based on GOCAL has been finished firstly in LAGrid. The details of GOCAL and its runtime (called CA processor engine) will be published in another paper, and here, we just show how the service is used for the realization of the large-scale collaboration in LAGrid.

For awareness environment, the most important thing is to identify awareness type, which acts as awareness event scheme, and 3-DCAM (e.g., dimensions of cooperator, artifact and task procedure) is proposed for this purpose, with which we define the following awareness types for the large-scale process shown in Fig. 5:

AssessTaskToAudit,	AssessTaskAuditedResult,	AssessTaskPublish,
AssessStudentSubmit,	AssessMonitorStudentBySystem,	AssessMarkeredAuditing,
AsesscoreAuditedFinish,	AssessMonitorStudent,	AssessMonitorMarkTeacher.

In more detail, the type of "AssessStudentSubmit" in GOCAL syntax is described in the following:

```
AWTYPE AssessStudentSubmit groupid VO ARTIFACT_ASYN
{//awareness for student submitting, which is available for VO
   OwnerOrgID string;          //organization ID of assessment task
   SubjectID string;           //assessment course
   TaskID string;              //number of assessment task
   OrgGranularity string;      //granularity of the awareness
   OrgName string;             //source organization of the awareness
   NotifyMessage string        //display content for the awareness
} WITHIN TODAY                 //valid time
```

Here, "AssessStudentSubmit" is the name of this awareness type; "groupid" is ID of group from which the awareness event originates; "**VO**" is the destination domain of this awareness, which indicates that the awareness is available for whole VO for this instance, and the value of this field can be "VO", "INTRA-GROUP" or "INTER-GROUP", which provides mechanism for unifying inter-groups and intra-groups cooperation in one environment. "**ARTIFACT_ASYN**" is the dimension from 3-DCAM, which indicates that the awareness is related to artifact in the collaboration environment. For the demo awareness type, awareness event of the awareness type will be broadcast to whole grid by LAGrid–MOM, which has multiple-routing policies (e.g., unicast, multicast, broadcast).

Awareness information is consumed by destination CA Processor Engine with awareness rules, which define the way of processing for special awareness event, for example:

```
RULE AssessStudentSubmitrule {      // remind of marking task
   AssessStudentSubmit.SubjectID = "CSCW"    //awareness related
                                               to the course
                                               of CSCW
} DO {
     AWARENESSNOTIFY
     {EMAIL                              // awareness display
                                            means
        {MarkingTeacher}                 //aimed role
     AssessStudentSubmit.NotifyMessage   //displaycontent for the
                                           awareness
     }
}
```

The rule defines the processing for the type of AssessStudentSubmit, which provides several awareness processing functions: how to filter awareness information, how to utilize special awareness information (e.g., awareness display via different means, automatic-process driven). Rule-based awareness processing provides flexible for the realization of the large-scale collaboration.

With the awareness facility, awareness events can be distributed conveniently and efficiently to related users, and therefore, cooperators can work together tightly according to their roles in the "big" collaboration process spanning in wide area.

3.3.2. Supporting "big" activities with global scheduling

Because of the enormous number of learners and the relatively limited number of tutors, the reasonable utilization of tutor resources becomes very critical for the success of formative assessment. Furthermore, the ratio of tutors to learners is diverse in different member organizations of CRTVU. That is, tutors are scarce in some places, whereas learners are populous, and vice versa. A direct result of such unbalance is the slow feedback in one organization but the waste of tutor resources in another organization. Thus cross-organizational collaboration of tutors can eliminate such institutional unbalance and hence improve the effect of formative assessment, in other words, tutors from different organizations come together virtually to attend "big" activities.

We propose and implement a distributed global scheduling scheme in LAGrid, through which a formative assessment task could be globally scheduled to any available tutor (according to his role in the system and his speciality) so as to allow sharing and collaboration of tutors from different member organizations of CRTVU. The global scheduling scheme could be modeled as a queuing system as illustrated in Fig. 7. In such a distributed scheduling model, grid nodes are modeled as task queues for receiving and storing the formative assessment tasks submitted by learners, and tutors are modeled as servants that get tasks from the task queues and assess them. Situated between the servants and task queues, the scheduler is responsible for selecting a non-empty task queue and allocating a task from the selected task queue for an idle server.

We assume that the time a learner spends in finishing the formative assessment task has an exponential distribution with parameter λ. For both the local scheduling model (getting assessment task just from local grid node) and the global scheduling model (getting assessment task from any grid node in LAGrid), when there are n learners who have not submitted their formative assessment tasks, the probability distribution of the remaining time until the next arrival to the task queue is the distribution of the minimum of the remaining time for the n tasks. Properties of the exponential distribution imply that this distribution must be exponential with parameter $n\lambda$. We further assume that the service time spent by any server in assessing the formative assessment task has an independent and identical exponential distribution with parameter μ. Then the global scheduling model can be described with a finite source population variation of $M/M/s$ queue, denoted as $M/M/S/\infty/N$.

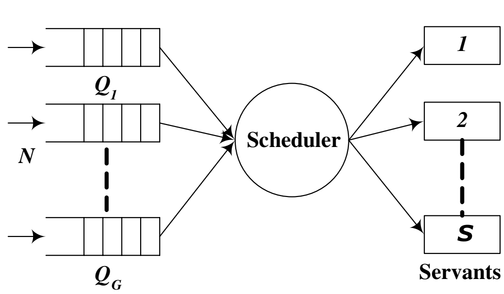

Fig. 7. Global scheduling model in LAGrid.

Table 1
Performance evaluation of LAGrid system with/without global scheduling

	i	S_i	N_i	ρ_i (%)	T_i
Local	1	6	130	96.1	0.25
	2	7	110	74.2	0.12
	3	8	180	98.3	0.29
	4	9	210	99.4	0.35
	5	10	200	92.5	0.16
		$\bar{\rho}$			$\bar{T}$
		92.6			0.24

	S	N	ρ	T
Global	40	830	97.1	0.14

Given G is the total number of grid nodes in the system, N is the total number of learners who participate in a formative assessment task and S is the total number of tutors who participate in formative assessment task. We further assume that there are N_i learners and S_i tutors at the grid node i, i.e., $N = \sum N_i$, and $S = \sum S_i$, wherein $1 \leqslant i \leqslant G$. $\lambda = 0.5$, $\mu = 10$, $G = 5$.

Then we can analyze the performance of the global scheduling model based on the queuing theory. The details of analysis will not be included here. We just give a numeric analysis result as shown in Table 1. We take the response time of assessment feedbacks and utilization of tutors as two metrics to evaluate the performance of LAGrid system.

Table 1 shows the performance of the system with the global scheduling and without the global scheduling (referred to as local scheduling). We can find that in the local scheduling model, each grid node has a variant number of servers and tasks, which results in a variant mean response time and a variant utilization at each grid node. We can further find that the global scheduling model is preferable to the local scheduling model in that the former has a shorter response time and a higher utilization than the latter. The shorter response time means quicker assessment feedbacks to learners and the higher utilization means full use of tutor resources. The above results further hint that the differences caused by the unbalanced distribution of learners and tutors can be eliminated through the global scheduling of the formative assessment tasks.

4. Application and comparison

For GCWF, here we discuss the projects which scope and goals are similar to our framework: (1) The architecture of OCGSA is used as building block for design collaboration

Table 2
Compare GLCE with some other state of the art projects (plans) of collaboration technology

Compared features	OCGSA	GECSR	NGCWE	CHEF	GLCE
Gird-based	Yes	Yes	No	No	Yes
Large-scale collaboration	No	No	No	No	Yes
Group-centered collaboration	No	No	No	Yes	Yes
Awareness support	No	Yes	Yes	Yes	Yes
Cooperative context	No	No	Yes	No	Yes
Degree of integration	Lower	Lower	High	High	Higher
Cooperation framework	Yes	Yes	Yes	Yes	Yes
Group-centered cooperation and its evolution	No	No	No	No	Yes
Support formal and informal cooperation at the same time	No	No	No	No	Yes
Integration at cooperative semantic level	No	No	No	No	Yes

services within grids based on the OGSA to provide high-level grid services that can be integrated within future collaborative applications and automatically grid aware (Amin et al., 2002). Unfortunately, OCGSA mainly focuses on a set of core components based on OGSA to provide base integrating framework with no attention on the concrete collaboration services and their relationships for new generation collaboration environments; (2) GECSR was proposed to provide environment with integrated cooperative tools (Neal et al., 2003). However, the project focuses on technologies used to integrate existing cooperative tools with little or no attention to the developing cooperation technologies which may bring revolutionary change on CSCW, such as awareness, cooperative context. Moreover, the project is not used to provide collaboration for group-level interaction that facilitates the evolving relationship for inter-groups in large-scale community; (3) GRIDCOLE (Bote-Lorenzo et al., 2004) and CLPL (Caballe et al., 2004) are two proposals to built collaborative learning environment, but they do not concern large-scale collaboration; (4) CompreHensive collaborativE Framework (CHEF) is another project who aimed to create group-centered collaboration environment (Charles, 2004), but it also has limitations compared to GLCE. In order to further explain the philosophy of GLCE, here, we compare it with the projects or plans aforementioned in this area (refer to Table 2).

Compared to the initial realization of GCWF (e.g., LAGrid), traditional e-Learning services of CRTVU are supported by traditional 3-level platforms before LAGrid, and learning services are distributed on tens of servers. Users from different organizations logon different server to get services in that domain, and learning resources and services in different organizations cannot be shared across organization boundary, furthermore, administrators of CRTVU cannot monitor learning/work status of students/teachers in time, because work processes are fragmentised and the burden of notification in organizational business process is on users. In a word, collaboration for learning/work is not supported effectively by these existing platforms, and the problems are all resolved in LAGrid.

LAGrid provides large-scale collaboration environment in wide area, which supports distributed collaboration process in cross-organizational scenarios and provides environment for solving "big" task transparently with global view. It has provided better solution for both "big" process and "big" collaborative activity. Successful application of LAGrid will set out an evolutionary roadmap to construct e-Learning grid for China with grid computing technology.

5. Conclusion

Collaboration technologies are significant for e-Learning grid. In this paper, we argue that GLCE should be the new direction on grid-enabled collaboration technologies. In order to implement GLCE, the framework of GCWF is proposed, which run over collaboration grid infrastructure. LAGrid has been developed as an instance of GLCE, and key middleware of collaboration grid has been developed in LAGrid, including LAGrid–GIS, LAGrid–MOM, LAGrid–Security, LAGrid–SA, etc. Furthermore, high level services, such as awareness service, global task scheduling, etc. have been implemented over these developed middleware. Initial large-scale collaboration environment inside VO has been realized based on these developed services and middleware. LAGrid has been deploying in the nationwide region now.

The idea of GLCE and the framework of GCWF will be further validated, and future research in LAGrid will be carried out in two aspects. *One* is to construct the large-scale collaboration environment into group-level inside VO to realize structure collaboration, which is more significant for the implementation of GCLE described by GCWF. *The other* is to expand LAGrid with other learning service to support full learning process, such as learning administration, active on-line learning activities, etc., and in this process, the functions of GLCE will be integrated into various learning activities. With these efforts, e-Learning Grid for the national public e-Learning platform will be realized, and advanced collaborative lifelong learning environments can be created.

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