

# A Model of Agent and Grid-based Open DSS<sup>1</sup>

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*Abstract:* As the complexity of decision support applications on the Internet increases, it becomes ever more important and urgent to provide a new way to construct and manage the applications. The idea of Grid-based Open Decision Support System (GBODSS) is becoming a reality. As an application of Grid in the field of DSS, this paper introduces agent technologies into the research of GBODSS, and puts forward an improved model of Agent and Grid-based Open DSS (AGBODSS). AGBODSS model can effectively hide the heterogeneity of the low-level resources with the support of the Agent Grid layer for decision resources sharing and reusing. The model faces decision objects and organizes decision resources in the form of e-market, so the model improves the timeliness, openness and intelligent capacities of DSS, also enhances its ability to handle distribution issues. The structure, operating process and decision resource scheduling of the model are presented in detail. Finally, we take the National Economy Mobilization DSS (NEM-DSS) as a practical case.

*Key-Words:* Decision Support System; Decision Resource Scheduling; Agent; Mobile Agent; Grid

## 1 Introduction

The development of Decision Support Systems (DSS) shows that, every improvement of the network technology brings a great influence to the concept, framework and function of DSS. It seems that DSS has some new opportunities recently with the development of the correlative scientific fields. D.N. Davis et al. developed a Multiple Agent Decision Support System, which not only remains the architecture of the traditional DSS, but also introduces a flexible architecture of the Agent organization [1]. Manfred et al. discussed problems such as using distributed DSS to solve the complicated decision problems, and searching proper DSS components in the Internet space [2]. J. Y. Chi et al. referred to the new concept of Grid-Based Open Decision Support Systems and presented concept model [3]. Specialists have investigated DSS from different aspects utilizing new technologies. The research outcome has greatly promoted DSS. This paper presents a grid and agent based open DSS model, analyses the architecture and operation mechanism of this model in details.

## 2 Related work

Along with the birth of the first generation network technology (TCP/IP technology), the interconnection of computers was realized, and a shift occurred from mainframe-based DSS to client/server-based DSS. Along with the birth of the second-generation network technology (Web technology), the interconnection of web sites was realized, and a shift has taken place from client/server-based DSS to Web-based DSS, which is the most popular kind of DSS now. Web-based DSS has a lot of good characters, such as the friendly and standard user interface, the global connection and the richness of decision resource. But Web has some radical weaknesses as the platform of DSS, such as the feebleness of the connection between the sites and the web pages on it. The Web-based DSS cannot meet the decision-maker's needs in the heterogeneous, autonomic, dynamic and distributed decision support environment, because it only links web pages and lacks global mechanism to manage and coordinate decision support resources on the Internet. Grid has emerged as a global

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cyber-infrastructure for the next-generation of DSS applications by integrating large-scale, distributed and heterogeneous resources. It will improve DSS greatly, and bring profound revolution to DSS theory and its application [4].

With the advent of grid technologies, the idea of Grid-based Open DSS (GBODSS) is becoming a reality[4]. The framework of GBODSS summarized some basic characteristics. But the framework is not sufficient for a further study of GBODSS. In order to give a clearer picture of GBODSS and provide analyzing and designing methods for GBODSS, we introduce agent technologies into the research of GBODSS, and put forward an improved model of Agent Grid-based Open DSS (AGBODSS).

The improved model characterizes the relationship between the components and layers of the GBODSS and illustrates its openness and dynamic characteristics more clearly.

### 3 The architecture of AGBODSS

The new constructed DSS consists of three components: DSS control center, interior system and decision service e-market. The three components are analyzed as follows, as shows on Figure 1.

#### 3.1 DSS control center

DSS control center, the interface between users and the system, is the core of the new constructed DSS. It functions as problem-analyzing, solution-planning, resource arrangement, task assignment, task-monitoring, result-synthesizing and so on. Multi-Agent and Mobile Agent, which are the latest technologies in the distributed AI fields, are applied to function as DSS control center, to gain excellent human computer interaction, strong distributed, the ability to solve complicated problems, good intelligence, dynamics and openness [5].

(1) User Interface Agent (UI-Agent): User Interface Agent helps users' and DSS mutual cooperation with each other with its decision knowledge, self-knowledge and domain knowledge. It is so intelligent that it can do feedback and initiative adjustment according to users' reaction, and direct users' operation to lighten burden.

(2) Problem Disassembling Agent (PD-Agent): Problem Disassembling Agent disassembles decision problems that are gained from the User Interface Agent with its decision knowledge, self-knowledge and domain knowledge. A complicated decision problem can be disassembled into a series of sub-problems that can be solved individually. All results of the sub-problems can be synthesized into the solution of the decision problem.

(3) Solution Planning Agent (SP-Agent): The sub-problems are obtained by disassembling the complicated decision problem. So there are certain logic and time relations between the sub-problems definitely. Solution Planning Agent arranges the sequence of sub-problems according to the logic and time relations between them. Therefore, the sub-problem solving chain is formed, which can make the problem-solving process effective and rapid.

(4) Resource Arrangement Agent (RA-Agent): The decision resources used in the decision problem solving process have complex relations with each

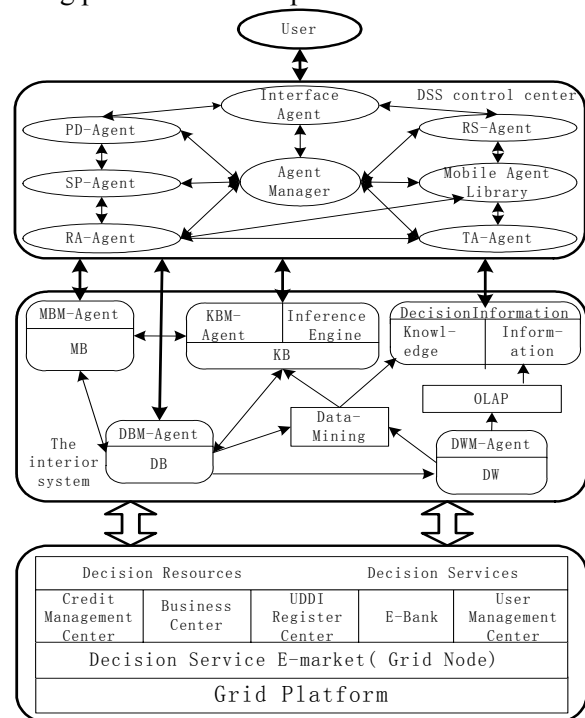


Figure.1, A grid and agent based open DSS model

other. The key to solve sub-problems is to decide the combination relation of all the models, the utilization relation between the models and data, and the coordination relation between model computing and knowledge reasoning, which form the decision resource arrangement chain. Resource Arrangement Agent makes decision resource planning and allocating in the system or outer resource market according to the need of problem-solving, thus to optimize the indexes such as time and costs of resource utilization, and the system stability.

(5) Task Assignment Agent (TA-Agent): Task Assignment Agent assigns problem-solving tasks , relative resource flow and resource address to proper Mobile Agent. Task Assignment Agent carry out the assignment according to the problem-solving chain and decision resource arrangement chain that are provided by the Solution Planning Agent and

Resource Arrangement Agent. Mobile Agents carry decision tasks to the server, which has the appointed decision resources to solve the problem.

(6) Result Synthesizing Agent (RS-Agent): Result Synthesizing Agent collects results returned by each mobile agent. It processes from bottom level tasks and gets the result of the upper level task according to the logic relation of the bottom level task. It finally obtains the result of the decision problem level by level, and then submits the result to the user by User Interface Agent.

(7) Mobile Agent Library: First of all, Mobile Agent is a software Agent that satisfies the target-driven characteristic of Agent and is intelligent and autonomic. Secondly, Mobile Agent can move to different address space to execute tasks among network nodes. The executing status can be saved when Mobile Agent is transferring. The execution process persists when Mobile Agent moves to the destination. Mobile Agent can not only carry on the codes and data needed in computing, but also the Mobile Agent's status, transferring information among diverse and various servers in the network.

The Mobile Agents can be divided into three types: resource management mobile agent, resource trade mobile agent and task mobile agent by the task of every Mobile Agent in order to gather them into a library to do good management.

(8) Agent Manager: Agent Manager is the core component of the new constructed DSS control center. It takes charge of Agent life cycle management, provides services for communication and information share among agents, and adjusts the relations of Agents.

### 3.2 The interior system

Traditional DSS is model-driven; IDSS combines the qualitative analysis of the expert knowledge and quantitative computing ability of DSS model to do the intelligent decision support; data warehouse, data-mining and OLAP based DSS focuses on data, and provides decision support to users by analyzing, and processing data to obtain information and knowledge. These three different types of DSS can support users to do decision at diverse aspects. With the development of the society, the decision problems and decision environment that users are facing are more and more complicated. In order to provide users with more comprehensive and intelligent decision support, model, data and knowledge need to be integrated together to construct a competitive and intelligent DSS, which is the trend of DSS development and research.

### 3.3 Decision Service E-market

Grid based decision service e-market is an environment where decision resources are shared, published and traded [5]. It provides a decision resource sharing platform for decision resource creators and users, which is the foundation of flexibility and dynamic expanding of DSS based on grid and agent. Decision service e-market provides decision resources such as models, data, algorithms, knowledge and decision toolkits, as well as decision service, which are the operation environment of decision problem long-distance and distributed solving. Decision service is a compounding system of decision resources and resource operation platform. It is an environment that consists of software and hardware set up by decision resource provider to solve certain decision problems. Countless commercial decision services offer a large number of alternatives for users buying decision resources and leasing decision services, which is the embodiment of the distributed, dynamics and openness of AGBODSS.

The new resource and service organization style, which makes decision resources and decision services as electronic commodity, changes the development and operation mechanisms of DSS. The market-oriented and cooperative development mode of DSS replaces the traditional independent and close mode. The operation mechanism of DSS does not limit to the centralized mode as well. DSS can operate in an open and distributed environment according to its needs, which promotes resource sharing, technology advancing, cost reducing and fields expanding of DSS.

## 4 Analysis of the operation mechanism of AGBODSS

AGBODSS is constructed on the new platform and it has a brand new structure whose components and relations of the components have all been changed. The analysis of the operation mechanism of grid and agent based open DSS checks the foundation of every component, and lays out a complete and transparent view to the users. Figure 2 shows the operation flow of the system.

In figure 2, the resource arrangement Agent manages decision resources dynamically that, which bespeaks the openness and dynamics of the system. The following text analyzes the three situations the resource arrangement Agent will face.

(1) Resource Management Mobile Agent searches all the decision resources needed in solving the decision problem in the interior system. Resource Arrangement Agent arranges the decision resources

according to the relative information returned by the Resource Management Agent, and creates the decision resource arrangement chain.

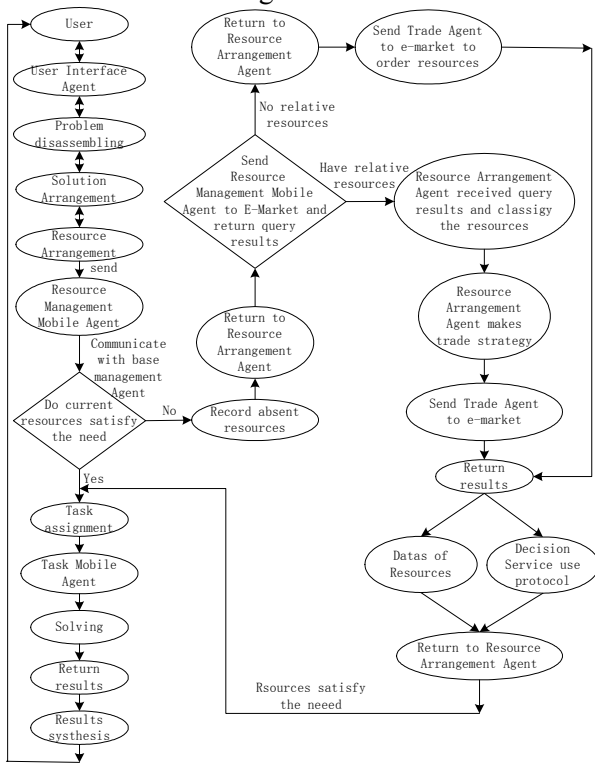


Figure.2, The flow chart of operation mechanism of grid and agent based open DSS

(2) Resource Management Mobile Agent finds part of needed decision resources in the interior system. Resource Arrangement Agent sends Resource Management Agent to decision service e-market to search the lacking resources. The information of the needed decision resources which is found at the resource register center will be returned to Resource Arrangement Agent, which will decide whether to buy or lease the decision service so as to achieve the optimization according to the information of the resources in the interior system.

Then, Resource Arrangement Agent makes the trade strategy and sends trade Mobile Agent to the e-market to do the resource trade. The resource data and specifications of the leased service will be given to Resource Arrangement Agent. Finally, Resource Arrangement Agent completes resource arrangement and makes the resource arrangement chain.

(3) If Resource Management Mobile Agent does not find all the decision resources at the interior system or the e-market resource register center, Resource Arrangement Agent will describe the function and interface parameters of the resources on order, make the resource order strategy, send trade mobile agent to the e-market to negotiate with the resource provider brokers and order the resources.

## 5 Decision resource scheduling process Based on Grid workflow

The workflow described in this paper incorporates the interoperability of Grid web services. An example of a decision support is given for multiple travel-related businesses. The initiating business is the travel agency company. The Travel Agency has internal services for managing customers' accounts and credit card numbers. However, the travel agency uses other third-party vendors to realize the hotel reservation and car rental reservations. The Hotel Reservation and Car Rental companies register their offerings as web services in a distributed registry, such as a UDDI registry. The Travel Agency uses these registry services as a part of its internal workflow. In addition, the Travel Agency has a partnership with an on-line publishing company that publishes the finalized itineraries. In this case, the travel agency has a static connection with the partner organization and is able to access services directly over a shared network connection. Problems occur in this domain when the online companies update or remove their service offerings. This requires a Grid workflow manager system that supports a methodology for process or workflow oriented service specification. This way would allow workflow developers to specify the process sequence and message exchange between local and distributed services. The specification approach must support both functional and nonfunctional concerns. Therefore when the process or services change, the specification can be updated and the supporting architecture automatically reconfigured [6].

Decision resource scheduling process Based on Grid workflow, in a general sense, consists of five steps as illustrated in Figure 3.

(1) Decision resource Discovery: Identify characteristics, configuration, capability, and suitability of Decision resource. This discovery can occur on services in UDDI registry or locally registered component-based services.

(2) Decision resource Capturing: Save the Decision resource characteristics in the service-oriented data model and then interact with Decision resource to establish their configuration and access cost. It creates a broker Decision resource list and the Decision resource performance data as predicted through the measurement and extrapolation methodology.

(3) Scheduling Process: The scheduling flow manager selects an appropriate scheduling algorithm for component decision resource depending on the user's requirements (deadline and budget limits, and

optimization strategy—cost, cost–time, time, and conservative-time).

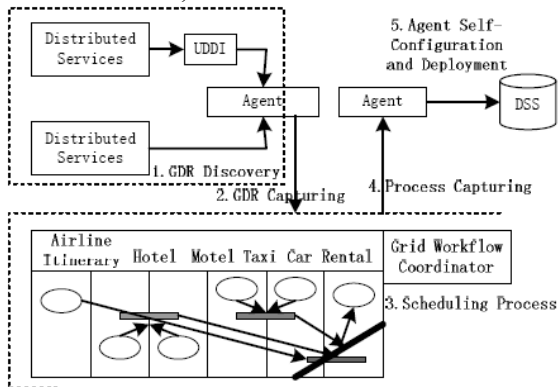


Figure.3, Decision resource scheduling process based on Grid workflow

(4) Process Capturing: When the resource Scheduling Process has finished, the Decision resource returns it to the broker’s receptor agent. It aids in predicting the job consumption rate for making scheduling decisions.

(5) Agent Self-Configuration and Deployment: application layer agents access the integrated data model and configure themselves for workflow enactment in the Grid environment. At the end, the agent returns updated Decision resource data back to the user entity.

In this process, scheduling decisions are made dynamically at runtime and are driven and directed by the end-users requirements. While a conventional cost model often deals with software and hardware costs for running applications, an economy model primarily charges the end user for services that they consume based on the value they derive from it. Pricing policies are based on the demand from the users and the supply of Decision resource is the main driver in the competitive, economic market model. Therefore, a user competes with other users and a resource owner competes with other resource owners.

### 6 Case study

We take the National Economy Mobilization DSS (NEM-DSS)[6] as a practical case. The National Economy Mobilization is a range of government activity to schedule economic and social resources for emergent affairs. The aim of the NEM-DSS is to implement unified and effective management of automobile mobilization activities, including generating plans, simulating plans and executing plans. It helps managers increase the effectiveness of making decisions.

The automobile mobilization involves several kinds of entity units, including components unit, assemble unit, transporting unit, warehouse and mobilization command center. Each entity unit is an autonomic one that needs interoperation and negotiation to form a final plan that should be coordinated in execution.

We should first create agent model for each entity involved in the automobile mobilization. The design for each entity agent includes its plans, competence, product model, inner spiritual states (e.g. beliefs, goals, intentions), communication module and reasoning module, etc. components unit agent, assemble unit agent, transporting unit agent, warehouse agent and mobilization command center agent are created at this stage.

We should divide these agents into different groups, according to their types and organizations which they belong to. For example, several accessory unit agents can be united into one accessory team and several transporting unit agent can be united into one transporting team. These agent teams composed Agent Grid Layer.

Next, we use entities agent of Agent Grid Layer to compose AGBODSS.

The first job is to make a static model of automobile mobilizing AGBODSS. We should determine several kinds of roles in automobile mobilizing according to mobilizing instructions, such as production, transportation, storage and command, and also to determine the goals, the planning abilities, the execution abilities of roles and relationship between roles (including controlling relationship, behavior interdependence and equality relationship).

The next job is to make a dynamic model of automobile mobilizing AGBODSS. We should describe the interaction between roles and define information type and cooperation protocol.

The last job is to choose proper entity agent to act the role in automobile mobilizing AGBODSS. The structure of AGBODSS is show as figure 4. With the knowledge, autonomy and learning ability of agent, this system can produce mobilization preparedness according to interaction and negotiation between agents and coordinate different works in executing the preparedness. The system also have good intelligence in running.

The AGBODSS has superior openness and excellent scalability. The entity agents can join and leave the AGBODSS dynamically according to the changing circumstances and tasks. The entity agents can sketch out mobilization plans through communication and negotiation, and they can coordinate to solve the problems in the execution of plans. The AGBODSS can efficiently utilize all kinds

of decision-making support services and resources on the Grid system.

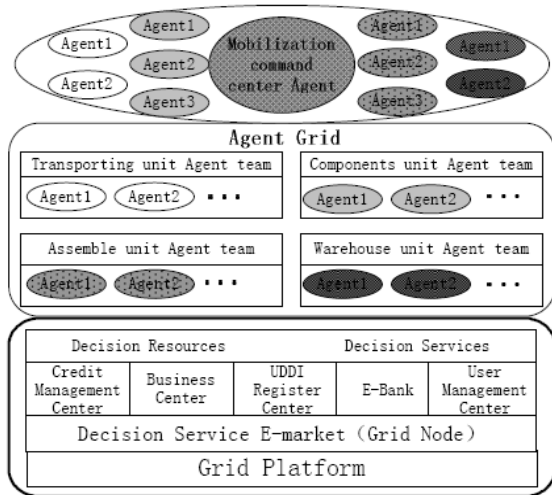


Figure.4, The model of National Economy Mobilization based on Agent Grid

### 7 The differences between AGBODSS and traditional DSS

After analyzing the operation mechanism of grid and agent based open DSS, we can conclude:

(1) AGBODSS is an open and dynamic system. The organization of decision resources is open, dynamic and flexible. Therefore, it can dynamically expand decision resources via the e-market that is on the grid platform according to the practical needs.

(2) AGBODSS is a decision problem driven system. The traditional model-driven theory impedes its openness, flexibility and the capability of solving dynamic problems at real time. AGBODSS orients decision problems and organizes the decision resources based on the problem-solving, so it has excellent openness and flexibility.

(3) AGBODSS focuses on the openness, dynamics and commercialization of decision resources. It transforms the mode of DSS development by utilizing the new resource organization, which makes decision resources as information commodities and trading them on the e-market. The development of DSS transforms from the independent and separated mode to the market-oriented open and cooperated mode, which brings DSS into a new era.

(4) AGBODSS is more intelligent. In this system, intelligent Agent can accomplish communication with users, disassembling problems, problem solving arrangement, decision resource arrangement, decision task assignment, result synthesis and so on. The intelligence and mobility of Agent enhance the intelligence and the capability of solving distributed problems of the DSS.

### 8 Conclusions and future work

Grid and agent based open DSS is the production of decision support technology combining grid with intelligent agent technology. Utilizing grid distributed resource sharing and cooperating ability, it improves the distributed cooperating ability of traditional DSS. At the same time, by using multi-agent and mobile agent technology, it enhances the intelligence and distributed problem solving ability. Analyzing the architecture and operation mechanism, the openness and flexibility of the new constructed system is manifested. Decision resources shared in the e-market is the foundation of the system's dynamic and open working. To publish decision resources in the e-market is our further research subject.

Our future work will focus on decision resource management and scheduling. We will be extending resource allocation algorithms to support optimal and QoS (Quality of Service) requirements based scheduling, using computational economy. In addition, we will assist its users in composing powerful grid workflows for decision resource scheduling by means of a self-adapting DSS.

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