AUTOMATED FEDERATION OF VIRTUAL ORGANIZATION IN GRID USING SELECT, MATCH, NEGOTIATE AND EXPAND (SMNE) PROTOCOL

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AUTOMATED FEDERATION OF VIRTUAL ORGANIZATION IN GRID USING SELECT, MATCH, NEGOTIATE AND EXPAND (SMNE) PROTOCOL

by

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PERTUBUHAN ORGANISASI MAYA SECARA AUTOMATIK DALAM GRID DENGAN PROTOKOL PILIH, SEPADAN, BERUNDING DAN MENGEMBANG

oleh

CHENG WAI KHUEN

Tesis yang diserahkan untuk
memenuhi keperluan bagi
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LIST OF ABBREVIATIONS

1:1	one-to-one
1:M	one-to-many
24/7	24 hours a day, 7 days a week
ACL	agent communication language
ADF	agent definition file
AFL	adaptive fuzzy logic
AHP	analytic hierarchy process
BDI	belief-desire-intention
CA	certification authority
CBR	case-based reasoning
CSP	constraint satisfaction problem
DAME	distributed aircraft maintenance environment
ELECTRE	elimination and choice corresponding to reality
FCM	fuzzy-c-means
FIPA	foundation for intelligent physical agents
GRAM	globus resource allocation manager
JADEX	java agent development extension framework
JVM	java virtual machine
LFS	load sharing facility
MAS	multi-agent system
MAUT	multi-attribute utility theory
MCA	multi-criteria analysis
NQE	network queuing environment
OGSA	open grid services architecture
PBS	portable batch system
QoS	quality of service
RBN	relation-based negotiation
RDF	resource description framework
RL	reinforcement learning

RMI	remote method invocation
ROC	rank order centroid
SLA	service level agreement
SMART	simple multi-attribute rating technique
SMNE	select, match, negotiate and expand
SOAP	simple object access protocol
SPAM	scalable protocol for anytime mediation
VO	virtual organization
VOMS	virtual organization membership service
WSDL	web service description language
WSLA	web service level agreement
WSRF	web service resource framework
XACML	extensible access control markup language
XML	extensible markup language

PERTUBUHAN ORGANISASI MAYA SECARA AUTOMATIK

DALAM GRID DENGAN

PROTOKOL PILIH, SEPADAN, BERUNDING DAN MENGEMBANG

ABSTRAK

Sekelompok sumber perkomputeran yang teragih dan berlainan jenis dalam persekitaran grid akan membentuk organisasi maya dan berkongsi sumber komputer. Kaedah terkini dalam perkongsian sumber komputer masih memerlukan penglibatan manusia dan ia memakan masa dan kos yang tinggi. Kekangan ini mencetuskan idea untuk menggunakan ejen secara automatik dalam memudahkan proses perkongsian sumber komputer. Keperluan bagi pihak yang berkongsi sumber komputer akan disenaraikan dalam polisi. Persetujuan di antara pihak akan tercapai dengan menggunakan mekanisme tawar-menawar. Kaedah ini bertujuan untuk meningkatkan taraf kepuasan antara pihak yang terlibat melalui perundingan. Satu rangka kerja untuk polisi undingan secara automatik telah dibentangkan dalam tesis ini demi menyelesaikan konflik antara dua pihak. Protokol yang bernama *Select*, *Match*, *Negotiate and Expand* (SMNE) ataupun Pilih, Sepadan, Berunding dan Mengembang, telah diperkenalkan untuk membantu pentadbir sumber komputer dalam perundingan semasa pertubuhan organisasi maya. Empat metrik penilaian digunakan untuk menilai protokol SMNE, iaitu integrasi ejen-grid, skalabiliti organisasi maya, fleksibiliti polisi serta reliabiliti perundingan. Satu simulasi perundingan yang melibatkan pelbagai ejen telah dibina untuk mengkaji pertubuhan organisasi maya secara automatik. Keputusan menunjukkan pendekatan pertubuhan-secara-berunding adalah lebih baik daripada

pertubuhan-secara-tidak-berunding dari segi kadar kejayaan dan taraf kepuasan dengan peningkatan sekurang-kurangnya 35% dalam kes yang dikaji. Bahkan, pendekatan pertubuhan-secara-berunding-kreatif menunjukkan keputusan yang lebih cemerlang dengan 10% penambahbaikan daripada nilai yang ditunjukkan oleh pertubuhan-secara-berunding. Pendekatan pertubuhan-secara-berunding-kreatif dapat menyelesaikan konflik dan kesendatan perundingan jika pihak terlibat gagal bertolak ansur. Maka, protokol SMNE adalah sesuai digunakan dalam pertubuhan organisasi maya secara automatik serta dapat meyelesaikan batasan seperti rigiditi dan kurang fleksibiliti bagi perkhidmatan konteks organisasi maya, kekerapan penglibatan manusia serta kekurangan kewujudan integrasi ejen-grid.

AUTOMATED FEDERATION OF VIRTUAL ORGANIZATION

IN GRID USING

SELECT, MATCH, NEGOTIATE AND EXPAND (SMNE) PROTOCOL

ABSTRACT

A group of distributed and heterogeneous resources in a grid environment may form a Virtual Organization (VO) to enable resource sharing. Early work on resource sharing requires human intervention which is time and cost-consuming. This limitation leads to the idea of applying the autonomous agent to ease the federation process during resource sharing. Resource sharing policy specifies the requirements of federation between various participants. A consensus among the participants is achieved through a bargaining mechanism, which aims at maximizing the satisfaction level of the negotiation. A framework of automated policy negotiation for the conflict resolution is proposed in the thesis. The Select, Match, Negotiate and Expand (SMNE) protocol is introduced to help resource administrators in performing automated negotiation during VO federation. Four evaluation metrics were used to assess the SMNE protocol, which are agent-grid integration, VO scalability, policy flexibility and negotiation reliability. A multi-agent negotiation simulator is constructed to enable the simulation of automated VO federation for the experimental testing. The results showed that the negotiation approach outperforms non-negotiation approach in terms of the success rate and the satisfaction level of negotiation result. The success rate of the negotiation approach is approximately 35% better than non-negotiation approach in our experimental cases. The creative negotiation approach shows even better result using

the same metric with an approximate of 10% improvement compared to conventional automated negotiation approach. The creative negotiation is able to solve the conflicts and bottleneck once the negotiated parties are unable to make further compromise. Therefore, SMNE protocol is applicable for the automated VO federation and is able to address current limitations, such as rigidity and inflexibility of VO context services, frequent human intervention and the missing of agent-grid integration.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Nowadays, people are looking for a possibility of integrating various computational resources to support compute-intensive and data-intensive applications. The grid computing [1] architecture is proposed to address this problem. The grid computing infrastructure provides a mechanism to dynamically aggregate resources to support the execution of large-scale, resource-intensive and distributed applications. The aim is to dynamically share and utilize geographically dispersed heterogeneous resources from various parties in grid environment. The process of joining an aggregate of resources is called resource federation. The parties involved may federate for a period of time as a team or a Virtual Organization (VO). Hence, a VO federation technique is required to facilitate the aggregation of resources.

However, the different types of VO characteristic complicate the federation process since a VO may vary according to several issues such as [2, 3]:

i. the purposes of participants joining,
ii. scope and duration of contribution, and
iii. the size or structure of the VO.

These differences require a robust federation technique to handle the variety of problems. For example, the federation technique could evenly distribute the resources according to diverse VO structure. The federation technique should not only apply a single solution for all incidents but instead creates more solutions in handling different circumstances. The dynamicity and flexibility of VO management complicate the issue

of scalability. The scalability indicates the efficiency in the dynamic growing process of self-managed and on-demand collaborative parties. A scalable federation technique can encourage higher participation because the participants in VO can join and contribute their resources easily. The participants are able to aggregate and share resources at any time as long as the VO policies are not violated.

A policy is a plan of action to guide decisions and actions. The term may apply to individuals or groups. Policies can be a mechanism arranged to reach a goal. The access and control over the VO resources are usually characterized by certain sharing rules or policies [2]. As shown in Figure 1.1, the policies state the object to be shared, the parties who are allowed to share and the conditions under which sharing may occur. During resource sharing, resource owners state the resource usage according to the context of local administrative domain. The VO administrator or keeper owns a distinct and separate set of VO administrative policies. Conflicts will arise when either side's of the policies contradicts each other. This issue is considered in order to reconcile the local and VO administrative policies on the precise level of control and usage over the resources.

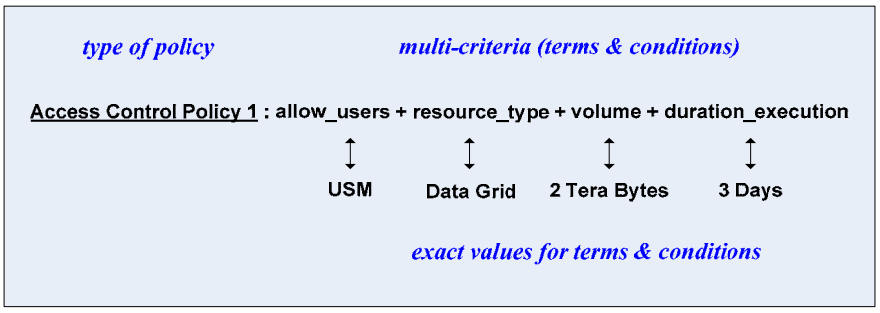

Figure 1.1: A sample of policy statement with the type of policy, multi-criteria terms and conditions with example values.

During resource sharing, the policy is important to define the Service Level Agreement (SLA) [4] and the roles being played by each VO participants. A SLA is a bilateral agreement between the service provider and the service consumer in a VO that stipulates a common understanding for the Quality of Service (QoS) that must be adhered to. In principle, a SLA is defined with various parameters. Each parameter represents a commitment on the condition of the provided resource. Most of the time, a SLA between a provider and a consumer consists more than one policy. Every policy consists of various parameters. These parameters are actually criteria to be fulfilled to enable resource sharing. The reconciliation of multi-criteria in diverse policies requires an agile, flexible and robust technique. The agility of the technique implies the simplicity and efficiency of the solution. The flexibility and robustness indicates the ability of conflict resolution in SLA reconciliation.

The conventional policies reconciliation in VO federation is performed by the administrator of both parties. In grid domain, the parties are VO keeper and site administrator. The VO keeper manages the overall VO federation procedure and site administrator controls and defines the usage of the local resources. In other terms, resource provider and resource consumer are also being utilized during VO federation. Resource provider is the VO participant who sharing the resources, and resource consumer is the one utilized others resource for a purpose. Nowadays, the policies reconciliation still depends heavily on the manual intervention of human administrator. It may cause bias in VO federation due to lack of standardization. Manual policies reconciliation becomes complicated and time-consuming during human management once there involved many policies. Therefore, we can foresee the needs to automate the

reconciliation process. During the automation process, administrators delegate machines with the corresponding authority, thus, these machines can perform the reconciliation according to predefine set of policies. Currently, the delegation process is assigned towards some automated software agents who act on behalf the VO keeper, site administrator, resource provider or resource consumer.

There are two types of automated policies reconciliation, namely non-negotiated [5, 6] and negotiated [7, 8, 9, 10, 11] approaches. Non-negotiated approaches require the policies to be fully committed without spaces for toleration. For example, since VO policies always put higher preferences in VO federation, local site policies are omitted if collide with VO policies. This approach is straightforward and faster in term of processing time compared to negotiated approaches. However, local site policies can be abandoned from the non-negotiated approach. The negotiation approaches increase the flexibility for the policies reconciliation because both parties (VO keeper and local site administrator) can bargain in the terms and criteria before a SLA is achieved. The VO keeper and local site administrator are compromised according to their own policies, thus, the level of bargaining's outcome satisfaction can be increased definitely after their requirements are met. The overbearing terms could be re-examined to accomplish the site autonomy (one of the grid concern) in VO federation.

The federation of VO involves the coordination of multiple initially mutual distrustful participants. Since the relationships of participants in VO are peer-to-peer, it requires a robust and autonomous ability to perform coordinating and negotiable operations, such as policy expression and authority delegation process. A dynamic relationship building process is necessary to encourage a healthy development of global

grid environment. Software agents provide an appropriate mechanism for autonomous problem solver and relation builder in various domains such as e-commerce [12], e-learning [13], web services management [14], load balancing [15] and machine learning [16]. Software agents interact and cooperate to perform the assigning tasks in achieving the provided goal. Software agents can also automate and replace the routine tasks of human administrators in VO federation. As mentioned by Foster *et al.* [17], there is a need to incorporate the agent-grid for current high performance computing and provides the ability of negotiation to increase the efficiency in VO formation and management.

According to the roadmap of Open Grid Services Architecture (OGSA) [18], as shown in Figure 1.2, the core research in this thesis focuses on the context services. The context services define the conditions and circumstances under which an operation takes place. For example, a VO is a possible context for a request to a service. A policy with terms and conditions helps to determine an exact match between a request and a service. It also states under which circumstance an execution can occur. The grid context is managed in a more organized and efficient form with the help of a robust VO policy management system. As mentioned earlier, a robust VO policy management system has the abilities of autonomy and negotiation. Besides context services, the OGSA also consists of other services such as data services, infrastructure services, information services, resource management services, execution management services, self management services and security services. Each category of services consists of the corresponding sub services as listed in [18]. Our work is also related to optimization and service level attainment under self management services, but these extra features are not emphasized in detailed in this thesis.

The VO formation and management depend heavily on the application of autonomous and flexible policy negotiation [17, 19]. The process of VO federation should be automatic and negotiable due to several reasons:

i. Automated federation increases the efficiency in term of time and cost which leads to faster policy reconciliation and less user's involvement with routine tasks.

ii. The negotiability helps in achieving a coherent satisfaction for both, VO and local administrative level. In other word, the satisfaction level for both parties in policies reconciliation can be optimized. The satisfaction level is referred to the comfortable and willingness of a party to accept the final deal. More negotiation requirements being fulfilled indicate higher satisfaction level of a party.

iii. The flexibility of automated VO federation with policy negotiation enables the formation of scalable VO. A flexible federation process should support a large, meaningful and structural data model for policy representation and negotiation. In grid computing, scalability means the structure of a VO can be easily enlarged without any problems during federation. This is obtained with a dynamic, self-managed and on-demand mechanism in each site to perform the collaborative process.

From the points mentioned, the increasing significance of VO in grid demands for a more agile, effective and robust federation technique. Since federation of VO varies in characteristic, extensive researches have been done covering a wide range of topics from theoretical background [3, 20] to the practical state-of-the-art VO federation technique, especially in the domain of grid computing [5, 7, 8, 9, 21, 22, 23, 24].

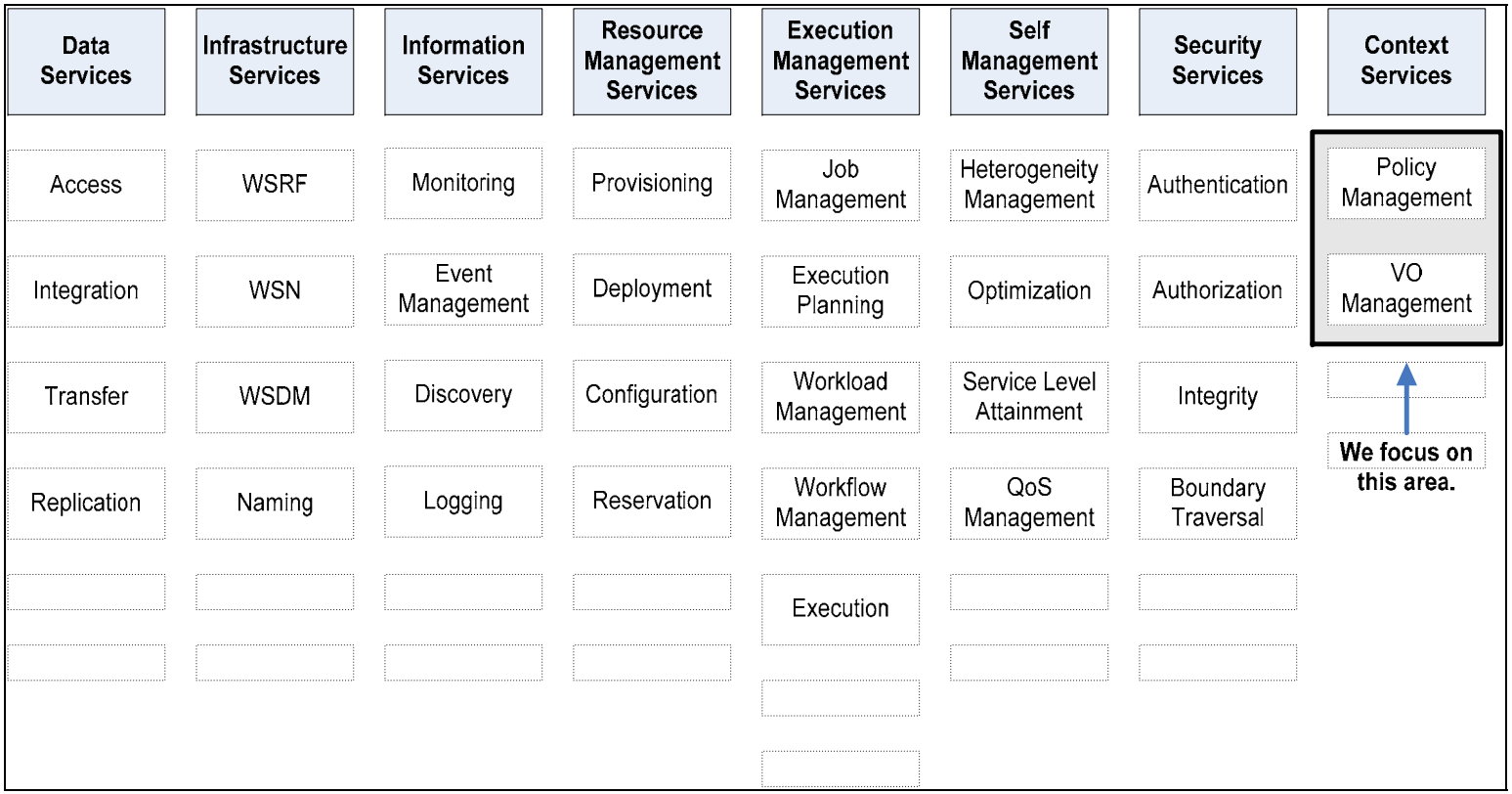

Figure 1.2: The roadmap of Open Grid Services Architecture (OGSA) [18] and the focus of our research.

1.2 Problem Statement

In this thesis, we investigate current problems in VO and policy management as listed in OGSA context services. The main research problem in this thesis attempts to address is to ***efficiently integrate agent-grid*** [17] ***with flexible negotiation ability in VO federation and management***. VO federation is complex due to the complexity of distributed and multi-administrator domains problems. The federation usually requires certain terms and conditions, which is referred to as policy. However, problems arise if policies contradict each other. As a result, several issues have to be addressed as follows:

- **Rigid and inflexible (VO and policy) context management complicate the process of the VO federation.**

  A structural form of policy representation is required to enable dynamic and flexible application of negotiation content during policy reconciliation. Several policy reconciliation approaches with static policy are currently available. However, the solution of policy reconciliation with dynamic and flexible policy requirement is an open area of research. Problems arise regarding the possibility of a dynamic and flexible policy contents using the current semantics.

  i. Which semantics is the most applicable in grid domain?
  ii. What mechanism can suit the dynamic and flexible behaviour of policy requirement?
  iii. Is agent technology a good solution?

- **Heavy human intervention during policy management.**

  The major routine tasks of VO federation such as policy receiving, verification, evaluation and validation, still depend heavily on the manual intervention of human administrator. All complex situations such as policy reconciliation are left for human decision. Theoretically, the high involvement of human administrators which it is believed can provide better understanding of the requirements during resource sharing. However, some researchers argue on the time and cost in dealing with the policies where the different policies may gradually complicate the federation process. Due to the limitation of human intervention, several problems occur, such as low turnaround time and lack of standardization. An idea to automate the policy reconciliation using software agent is proposed in this thesis, yet several difficulties are needed to be solved. For example,

  i. What processes should be automated?
  ii. How the selected processes are automated?
  iii. Is the automation result better than manual approach?

  Therefore, autonomous agent with intelligent decision-making ability will provide a good solution in policy management [17].

- **Automation of (VO and policy) context management without a common standard.**

  Two areas, policy evaluation and policy selection, are studied to automate the policy reconciliation. The policy evaluation and selection are needed since a

mechanism to properly define human preferences in policy is necessitated. This is to emphasize the significance of human preferences delegate correctly to the agent. Different types of policy require different evaluation criteria. However, in the thesis problem, all policies with different requirements are evaluated with a single mechanism. A reliable algorithm in policy management is needed since an agent may deal with many policies at the same time.

- **Achieving a consensus and a deal through an efficient automated policy negotiation.**

  According to the above problems, an automated policy negotiation is needed to achieve a consensus between negotiation parties but some other difficulties may exist. Many negotiation approaches have been proposed to address the problem of policy reconciliation. Most of the approaches are able to address the problem with static policies. However, VO federation tasks are more frequent with dynamic, flexible and iterative negotiation content. Compromise or tolerance is one of the criteria to increase the satisfaction level and success rate of negotiation parties. An efficient negotiation technique with such ability is yet to be designed and implemented. The ability of automated conflict resolution during bargaining may potentially increase the difficulties. Adaptability of the negotiation protocol is one of the considerations in the design as well.

1.3 Objectives

In light of the challenges mentioned above, the overall goal of the research in this thesis is to explore the applicability of autonomous agent policy negotiation in VO federation. More specifically, the research attempts to achieve the following goals:

i. To design a conceptual framework for automated policy negotiation, including agent negotiation protocol.

ii. To fine-tune and optimize the performances of the automated negotiation protocol using multi-agent simulation.

iii. To design a multi-agent negotiation platform with self-interested and collaborative agent, including comparison of the local and global utility performances.

iv. To examine and optimize a multi-criteria policy representation and selection technique which is suitable to be combined with the agent negotiation protocol.

This thesis also provides a more organized view of automated VO federation in grid computing using software agent and present insights on the new approaches.

1.4 Methodology

As mentioned in the earlier section, a multi-agent simulator is required in the research. The selected agent simulator must be able to automate the process of policy negotiation and performs several actions according to the predefined plans. An agent simulator with Belief-Desire-Intention (BDI) model is considered in the framework design. The BDI model is initially proposed by Bratman [30] and later being adapted by Rao *et al.* [31] to a more formal model which is suitable for multi-agent architecture. The concept of BDI model generates the rational agents according to human mental attitudes – belief, desire and intention. Beliefs capture informational attitudes, desires motivational attitudes, and intentions deliberative attitudes of agents. Agents with BDI model are believed to increase the scalability of a VO since the rational agents will perform actions on behalf of the human administrators with automatic mode. It is more efficient in term of time and cost.

Besides, the multi-criteria policy representation and selection problems are needed to be solved. In policy representation, extensible Markup Language (XML) [28] structure and semantics are used to define the multi-criteria policy. The policy in XML form can then be converted into a data tree structure for further policy selection. The tree structure is applied for further representation because a multi-criteria analysis (MCA) is performed on the various received policies. The flexibility of the policy selection technique is emphasized because human administrator preferences on the received policy might not be completed. The incompleteness of the preferences requires a flexible selection technique to overcome the difficulty in an accurate policy matching and determination. From the various available MCA techniques, ELECTRE III [32] is

applied in the framework due to the appropriate functionalities of the method. More detailed descriptions on ELECTRE III can be found in Chapter 3 (page 94-99).

As the core research in this thesis, a new automated policy negotiation protocol that performs conflict resolution is proposed. This protocol helps in addressing the limitations of existing conflict avoidance methods. For example, this thesis presents a one-to-many (1:M) policy selection, but a one-to-one (1:1) negotiation is being applied after the best candidates are sorted and chosen. The negotiation process always starts with the best candidate from the sorted list. Once bottleneck is met (maximum compromise from both is still unable to fulfil both requirements), instead of negotiate with second best candidate to further the bargaining, the conflict resolution technique provides a better solution to expand the current negotiation space to strike a deal. This action is more efficient and reliable because all effort is put into understanding of the negotiation parties' requirements, thus, making reasonable compromise from current constraints is more rational. The compromise also encourages the development of a proper relationship. The concept of Creative Negotiation [29] is the key idea of the policy negotiation framework in this thesis. The integration of the concepts with the policy negotiation framework is discussed in Chapter 3.

1.5 Research Contributions

As shown in Figure 1.3, the methods for VO federation in grid environment can be mainly categorized into manual and automatic approaches. The automatic approaches can further be divided into non-negotiation [5, 6] and negotiation techniques [38, 40]. The proposed conflict resolution method in this thesis falls under negotiation technique. Conflict avoidance is another type of negotiation technique which has been widely used in VO federation [7, 8, 9, 10, 11, 33, 34, 35, 36, 37].

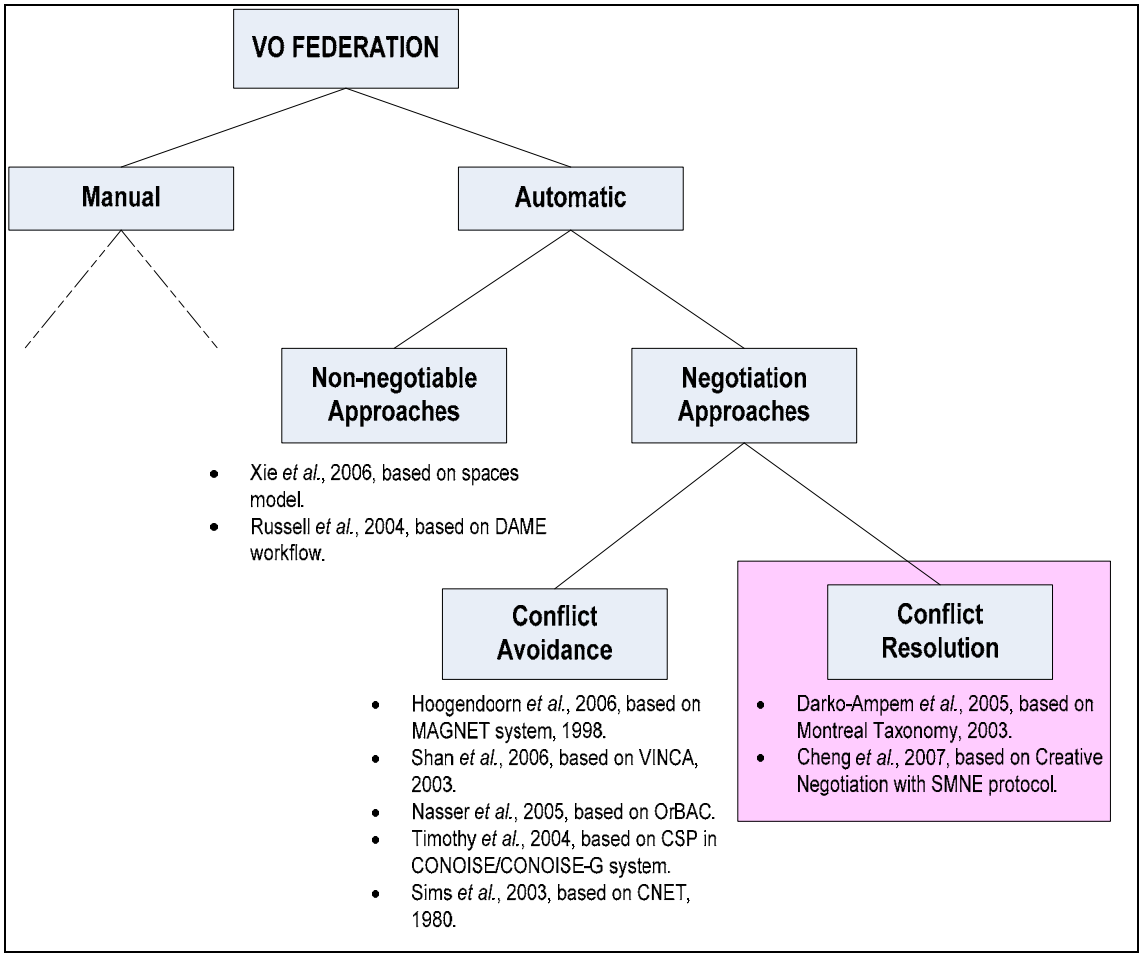

Figure 1.3: The specific area of thesis contribution.

Figure 1.4 summarizes the contributions of this thesis and positions it in relation to existing work. The features of SMNE protocol include automation of the VO, an increase of VO scalability, flexible policy management services and reliable conflict resolution. The limitation and drawback of current approaches are also listed.

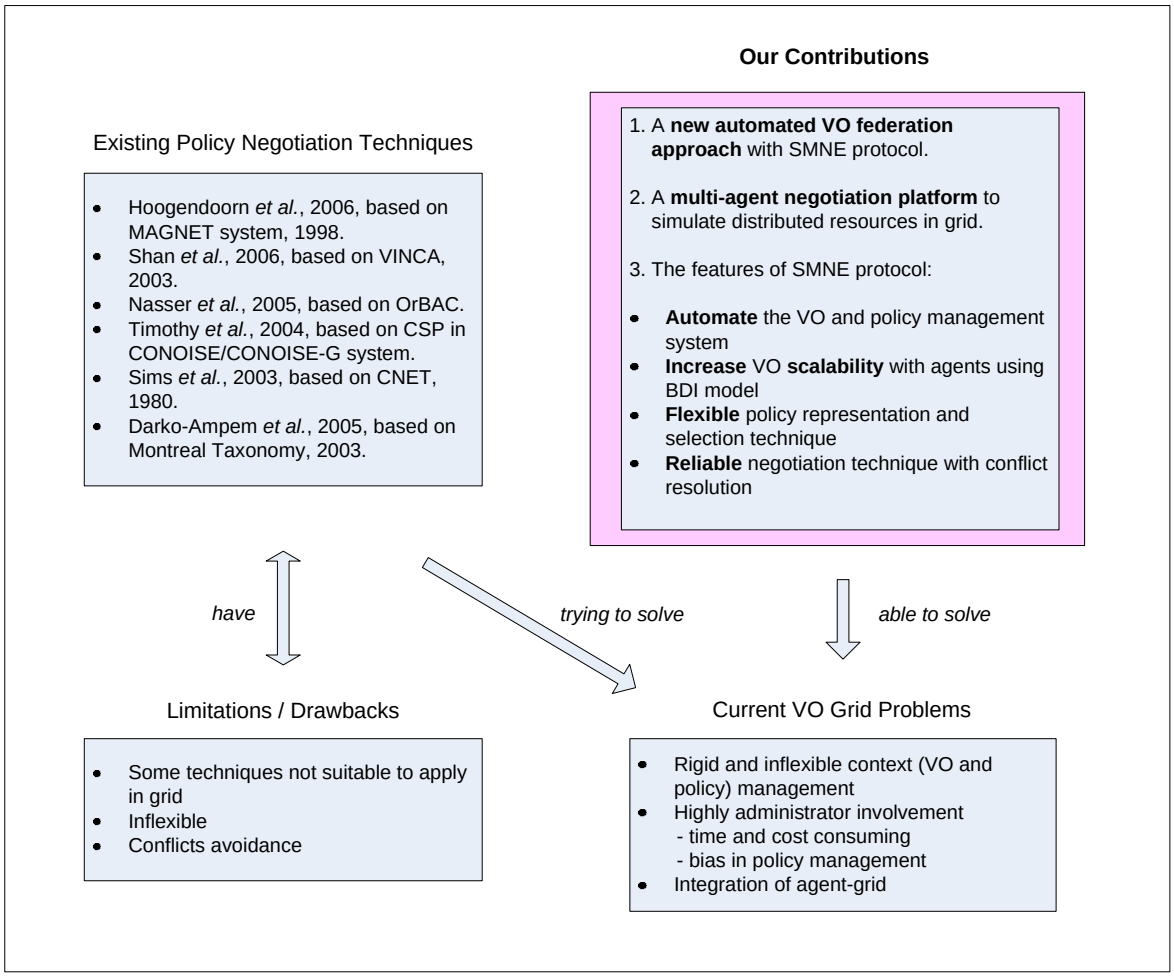

Figure 1.4: Thesis contributions.

The contributions of this thesis are as follows:

- **A new conceptual framework for automated policy negotiation in VO grid federation with SMNE Protocol**

  Various VO federation approaches in grid environment are studied and analyzed. The existing frameworks have some limitations and drawbacks (discussed in chapter 2). During formation of VO grid, the aspect of scalability is always being emphasized. However, the VO scalability can only be reached with the mechanism of automation and negotiation because it is more efficient in term of time and cost. As a result, a more scalable VO federation technique is proposed with the SMNE protocol for automated policy negotiation.

- **A multi-agent negotiation platform to explore this framework has been developed and validated**

  A multi-agent negotiation platform is developed to simulate the distributed resources in grid environment [39, 40]. A lightweight but expandable simulation mechanism on resource requirement expression and policy generation is provided to enable agent interaction, in order to imitate the real human-agent transaction. The validation of agent navigation, communication and negotiation functions is performed and examined [39, 40]. The multi-agent negotiation platform is validated once several types of agent can achieve a deal through negotiation in the experiment. The simulator helps to construct a general multi-agent negotiation platform but also enable us to apply in grid domain specifically.

- **An introduction of a scalable VO federation technique using autonomous BDI agent**

  In grid environment, scalability is achieved once a VO grows dynamically with self-managed and on-demand collaborative parties [2]. Autonomous agent with rational decision making ability is suggested to perform scalable VO federation [17]. In this thesis, several types of BDI agent [31] (VO keeper, site administrator, resource provider, resource consumer) with rational decision making ability are designed and evaluated in the negotiation platform. Those BDI agents are categorized into self-interested and collaborative agents. Both types of agent behave differently although in the same federation environment. Self-interested agent emphasizes local utility optimization while collaborative agent considers global utility optimization. Several testing on agent behavioural learning are performed to increase local performance [41]. The difference between self-interested and collaborative relationship towards the satisfaction of negotiation are also examined.

- **An introduction of a new hybrid form of flexible policy evaluation, selection and negotiation expansion technique using Rank Order Centroid (ROC), ELECTRE III and the concept of creative negotiation**

  The process of VO federation requires several pre-processing steps (such as participant policy expression, filtering and matching) before a valid VO participant can be verified. Generally, the involvement of various techniques during hybrid process complicates the overall integration. In the framework design, the

advantages between ROC, ELECTRE III and the concept of creative negotiation are successfully utilized during criteria weighting, policy selection and conflict resolution, respectively [42]. The modules in hybrid approach can easily and effectively contribution to each other, and also have successfully contributed to the decision-making process in overall multi-agent negotiation. A flexible policy representation, evaluation and selection technique is validated because the hybrid approach supports a large, meaningful and structural data model for policy representation, and also provides an expandable size of policy evaluation and selection according to different circumstances.

- **The concept of creative negotiation in conflict resolution, initially proposed by Gregorio Billikopf [29] has been implemented under automation mode**

  The various types of philosophy of human negotiation are studied and analyzed. Those human negotiation techniques are well-known and have been applied in the real world negotiation scenario. However, problems may occur when the negotiation process is adapted in an automated software agent. Furthermore, the ability of resolving conflict during a negotiation has always been an open issue. Several solutions have been proposed for different environment characteristics. A new reliable automated negotiation protocol with the concept of creative negotiation is proposed in this thesis to address the agents' conflict. The reliability of negotiation protocol is validated once conflict resolution successfully performs through SMNE protocol and also achieves better performances compared to conventional approaches.

1.6 Thesis Layout

The remainder of this thesis is organized as follows:

Chapter 2 provides a brief critical study and survey of the related work. In particular, the state-of-the-art of various VO federation approaches have been discussed and analyzed. Initially, a critical review on existing VO federation framework is presented, followed by the applications of policy selection and negotiation mechanism in the current domain. Various types of negotiation protocol, manual and automated, are analyzed as well. Some negotiation parameter definitions and formalisms are also introduced. This chapter ends with an analysis of the appropriate form of hybrid technique in automated policy negotiation.

Chapter 3 proposes a conceptual framework for policy negotiation applied in VO grid federation. The appropriate method for policy representation used in the framework is also discussed. A four phase protocol that is SMNE (selection, matching, negotiation and expansion of the negotiation space) protocol, with the overall seven stages of specific preparation activities are also proposed in this chapter.

Chapter 4 emphasizes on the design and implementation of the multi-agent simulator. It first describes the architecture of the various types of Belief-Desire-Intention (BDI) model agent in the simulator. Next, an analysis and validation of the agent performances during behavioural learning in different environment (self-interested and collaborative) are carried out. A testing scenario for VO federation is also discussed in this chapter.

Chapter 5 presents the experimental analysis and the evaluation of the proposed framework in various stages. Some empirical experiments are conducted to prove the concepts of the research. The chapter proceed by defining several metric systems used to assess the overall performances, then, the results of the negotiation protocol (before and after improvement) in multi-agent platform are analyzed.

Chapter 6 summarizes the overall findings in the research. This chapter also highlights the insights gained from the whole research and revisits the contributions of this thesis. Possible future plans are also listed in this chapter.

CHAPTER 2

RELATED WORK

2.1 Introduction

This chapter first explores the various types of available VO federation techniques. The discussion of VO federation techniques are mainly categorized into manual and automatic approaches. Later, a more details comparison between the non-negotiation and negotiation approaches under automated VO federation is given. The analysis of the features and limitations of the state-of-the-art of policy negotiation techniques are performed in our study. Besides policy negotiation, various policy representation techniques are studied as well, followed by policy selection techniques which is required during one-to-many (1:M) policy evaluation. The philosophy of human negotiation is a part of our literature review to determine a solution for our agent negotiation. A brief discussion and analysis on the integration of various techniques are discussed in the last section.

2.2 Virtual Organization Grid

VO federation in grid emphasizes flexible, secure and coordinate resource sharing. The flexibility on negotiation content and higher security during resource access provide the confidence for the VO participants in coordinating their resources. However, these characteristics bring several challenges in the field of user authentication, user authorization, resource access and resource matchmaking. This thesis focuses on a scalable VO with automated policy negotiation. A detailed analysis on the state-of-the-art and the trend of VO federation techniques followed by some major considerations in the framework design are also analyzed.

2.2.1 Manual Approach vs. Automatic Approach

The early work in VO is to select the members for a group. The selection process is being improved with the aid of electronic media such as e-mail and e-forum. During the selection, the resource owners or administrators play an important role in the communications since they are responsible to define the access and usage of the resources. From various member selection approaches, the most widespread implementation method is the Virtual Organization Membership Service (VOMS) [43]. The VOMS approach owns a database which contains authorization data that defines specific capabilities and general roles for specific users. If a new user accesses to a resource, a proxy-certificate from a given VO administrator is requested. The VO administrator further proceeds with the user identity authentication. After the authentication, user can use that proxy-certificate to submit the desired job to a resource that accepts the VO proxy-certificate. During the process of proxy-certificate exchange,

VO keeper is required to approve on the application request. This simple manual selection process only solves the authorization problem. In a large scale environment, this method is not sufficient for VO federation since a more difficult problem exists – access control over resources. The access control over resources is defined by the policies of the user's organization and the resource owner.

The resource owner or local site administrator defines the access control on a particular resource in the policies. The policies help in the definition of the terms and conditions for resource sharing in a more structural and organized manner. On the other hand, the VO keeper also applies several policies to determine the requirement and specification of resource demand. The matchmaking of local site policies with VO policies can be implemented in many ways using current technology. However, initial works on the matchmaking depend heavily on human administrators. The administrators performed sequential matching of policies on available resources to determine the final qualified participants who fit the resource request. A VO is established after both, local site and VO administrators, agreed upon the policies. This manual policy matching is believed to enable the administrator to be aware perfectly of the utility of any given policies and also assured most preferable decision is chosen from administrator perspective. However, problems arise since most of the current resource requests apply for a group of resources and each resource is also bound with complex policy terms or criteria. The limitations of manual policy matching are summarized as:

- Policies are difficult to search, organize and manage because nowadays the content of policies is complicated and overloaded,

- Manual policy matching tends to fail and requires a repeated process because administrators are unable to consider all the policies synchronously,
- Lack of global consideration since administrators are only limited to their awareness on frequent access policies,
- Perform policy matching manually increases the time and the cost in management because more time and effort are needed for human decision-making,
- The critical drawback of highly human involvement and intervention is human administrator failed to entertain requests in 24/7 (24 hours a day, 7 days a week) basic.

Due to the above limitations, some automatic approaches in policy matchmaking are designed and implemented for convenient resource sharing. Two of the famous automatic grid resources matching protocols are Globus Resource Allocation Manager (GRAM) [25] and Condor [26, 27]. Both apply resource matchmaking which is complemented by heuristic decision-making in resource selection. Major routine and trivial administrator workloads are being automated to simplify the overall process. For example, in Condor, a ClassAd mechanism is applied to match arbitrary resource requests with available resource offers. Several components like ClassAd specification, advertising protocol, matchmaking algorithm, matchmaking protocol and claiming protocol are designed in the matchmaking framework. The matchmaker tries to satisfy respective resource provider advertisements constraint (policy terms or criteria) and