A Novel Architecture for Collaborative Environments

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Abstract

A novel architecture, called Cognitive Social Knowledge Grid, is introduced as a solution for collaborative environments. The CSKG performs information and knowledge operations through collaboration of agents and services in a service-oriented context. Its services and mechanisms have been described and relationship models of its components and services have been presented using UML. Utilizing capabilities of social network services, user profiles information, social characteristics of human and operational environment, CSKG collaboration management services form communities to perform an activity submitted by a user or an application program. We believe that our proposed architecture supports collaborative knowledge societies. Ultimately, CSKG performance and execution capabilities in large-scale collaboration networks have been evaluated. Furthermore, community formation based on user profiles similarities and social parameters like trust and commitment is argued using weighted cosine similarity function.

Keywords: *Knowledge Grid, Collaborative Environments, Community Formation, Social Network, Service-Oriented Architecture*

1. Introduction

Rapid growth of communication and IT infrastructures results significant changes in the way that organizations work and also causes relationships among these organizations. Collaboration in complex systems and organizations has turn to one of key factors in today's research and industry. We introduce a novel architecture, called Cognitive Social Knowledge Grid (CSKG), for collaborative environments. It is introduced as a solution to perform information and knowledge operations, and collaboration of agents and services in a service-oriented context and in various scenarios with different scales like open systems. This architecture includes three groups of social network services, application services, and management services. Social network services supply a communication environment for users; application services present single and distributed services; and management services are used for total system management, security, discovery, monitoring and service improvement, and collaboration management. We describe CSKG services and mechanisms and model the relationships among its services and components using UML.

In this research, we have focused on social and semantic aspects of collaboration in an environment. Therefore, to utilize social preferences, social network has been proposed in order to come over limitations caused by information flows in collaborative environments. In addition, we use technologies and semantic platforms [3] to able users to have collaboration and semantic interactions. The CSKG is a context for executing application programs which need any kind of knowledge or information to perform their tasks. Because of scale (number of people and services) and temporary nature of collaborations, finding one or a number of right partners to perform a common task or solve the problems in collaborative environments is a controversial issue. In recent years, the way for human collaboration in collaborative environments [7] and social networks [4] has been considered in web. Therefore, using capabilities of social network services, user profiles information, and cognitive and social characteristics of human (like trust and commitment), CSKG collaboration management services form a community to perform an activity submitted by a user or an application program. Eventually, CSKG performance and execution capabilities in large-scale collaborative environments have been evaluated. Then community formation based on user profiles similarities, and cognitive and social parameters like trust and commitment will be argued. We use weighted cosine similarity function to find one or more right partner, collaboration, and operation common performance. After all, measures like collaboration quality and accuracy, and answering time are discussed and evaluated.

The remainder of this paper is organized as follows. Section 2 deals with the related works. In Section 3 we outline motivating scenarios, definition and characteristics of the CSKG. A layered model for CSKG is introduced in Section 4. We present the CSKG architecture, its services, and relationships among services in Section 5. We discuss collaboration and simulate, and evaluate community formation in collaborative environments in Section 6. Then Section 7 concludes the paper.

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2. Related Works

The concept of virtual communities is increasingly used to enable the collaboration between geographically distributed members belonging to various organizational units. Studies on distributed teams focus on human performance and interactions [5]. Service-oriented architectures (SOA) have emerged as the defacto standard to design and implement open enterprise systems. Web service technology [1] enables cross-organizational interactions in collaborative networks [7]. Social networks have received tremendous attention recently from both research and academia. It becomes essential to adapt and influence the information exchange in an automated manner [28]. Social networks become more and more interlinked with enterprises and collaborative platforms [5]. Collaboration networks are among the most extensive databases of SNs considered to date. In particular, Newman [20]-[21] has shown that scientific collaboration networks have all the general ingredients of small-world and scale-free networks, while Barabasi et al. [4] have followed a complementary approach more focused on the dynamical processes determining the network evolution.

F. Berman proposed the concept of knowledge grid in 2001 which supports the synthesis of knowledge from data. Development of a knowledge grid will require the design and deployment of sophisticated tools that allow application developers to synthesize knowledge from data through mining, inference, and other techniques [2]. Cannataro and Talia designed a reference software architecture, which they called the knowledge grid (KG), for implementation of parallel and distributed knowledge discovery systems on top of grid toolkits such as Globus [6],[9]. We developed an extended architecture for the KG [22] using Social Network [3] and Semantic Overlay Network approaches [12]. [23] introduced an Intelligent Service-Oriented Architecture for Distributed Data and Knowledge Management which utilizes some features of data, semantic, and knowledge grid architectures to provide more advantages. Zhuge proposed the principles and methodology of establishing knowledge grid as a human-machine interconnection environment [30].

A virtual organization is a temporary connection between organizations that come together to share their skills, capabilities, and resources to respond better to business opportunities. Collaboration in such organizations supports by computer networks [8]. Nowadays, SOA concepts, like WSDL, support virtual organizations. Human can participate in such networks and provide services in a uniform way using Human-Provided Services framework [24],[25]. Social trust in service-oriented systems has become a very important research area. Depending on the environment, trust may rely on the outcome of previous interactions [19],[27] and skills and interests similarity [14],[26],[32]. Application of trust relations in virtual organizations and team formation have been investigated in [17],[27]. In our approach, metrics like trust and commitment express social behavior influenced by the context in which collaborations take place. Commitment [10],[11] is a concept describing contracts, tasks, and promises that are aligned between couple of agents.

3. Cognitive Social Knowledge Grid (CSKG)

Today increasing growth of information and knowledge in the world and organizations, and presenting right information in the right time and to the right person is a matter of controversy. To find the answer of their questions, internet users spend hours in web and face millions of web pages and huge volume of information which may not be reliable. Through the definition of standard mechanisms to work with services, semantic grid [13] is able for collaboration with P2P technology and also provides components collaboration in a scalable network using autonomous computing. In addition to services collaboration which is provided in service-oriented architecture, human and agents collaboration should be provided to perform various activities. Therefore, different collaborative environments can be presented as stimulus scenarios for collaboration in this research.

An environment to share reliable information is a scientific collaboration network made up of national and international researchers and experts. Network members collaborate to answer research challenging questions and also to enhance scientific publication impact. Besides, they work on common projects, and some other special attendees may support them. For instance, present services regarding to the considered research project and interact with them through well-defined and accurate interfaces. Furthermore, human agents should be able to ask their questions from other network agents, to present research information with some other agents to reach consensus, common decision, or voting, to share their findings, and to perform some tasks through task allocation to users.

We present a new architecture, called Cognitive Social Knowledge Grid (CSKG) in order to discovery and involvement of experts and agents to perform common operations, in distributed collaboration scenarios. This environment supplies services by human-provided services, and using service-oriented and social network concepts. The CSKG is an environment for collaboration of people and services, information and knowledge management in decentralized and P2P networks, and is also a context for executing application programs which are in need of any kind of knowledge and information to perform their activities. It provides agents interaction and collaboration, form a community and joint decision making, and other collaborative services. Consequently community members interact to reach a determined and defined goal. This should be noticed that using the word Grid does not necessarily mean using grid infrastructure but it should be considered as the concept of communications and network between system nodes. CSKG is a cognitive social network (grid) in which geographically distributed people and resources collaborate to perform concerning operations and solve problems, and

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provide services using different methods and in knowledge, information, and relational cycles. Semantically described capabilities of agents, by means of reasoning methods in CSKG, lead to choosing and discovering agents to form communities to perform various activities. These agents interaction is performed based on social, cognitive and semantic priorities which forms those capabilities. CSKG suppose to increase network individual and social awareness by means of comprehending semantics which is available in form of ontology in system or is applied to the system. This will result in formation of suitable behavioral pattern within the network. So that, based on this behavioral pattern and enjoying high awareness, network agents can show the right functionality in emergence of events or even before them.

4. CSKG Communication Infrastructure

We present a three-layer model for CSKG organization infrastructure which has been shown in figure 1. All process components of CSKG respond to submitted requests through presenting their capabilities as services; and the layer of network infrastructure which CSKG is located on. Besides, CSKG directly uses all communication network services to communicate and make the interaction possible. The layers of this model have been described below.

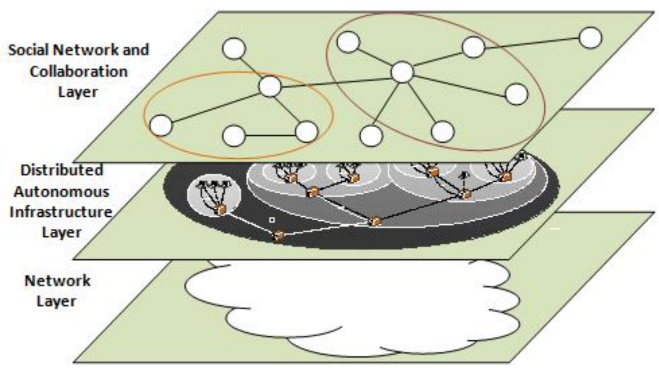

Fig.1 Layered model for CSKG organization infrastructure

Social network and context layer: This layer is the highest communication level of agents and is the only layer which users are able to observe and change the neighbors and nodes which are in communication with. Furthermore, in this layer, agents can interact and collaborate with each other using social network services in CSKG. Main application services, to perform, need collaboration of agents and finding agents which can cooperate with. In fact, each agent should be able to find its right partners to perform an activity and to interact with.

Distributed Autonomous Infrastructure (DAI) layer: DAI is an infrastructure for servers and workstations to execute in a service-oriented context and network infrastructure. While DAI structure has a hierarchical approach, this should be em-p[phasized that the system survival is still possible even in case of having failure in some parts of the network. Therefore to describe DAI, two different levels of concepts should be considered. First level is the process of making network domains in whole structure (how general structure of network is to get form and how to produce a new domain), and the second level talks about inner structure of a domain and communication between inner nodes with each other. Moreover, we consider a procedure to provide backup that makes coherence possible in case of any danger for the central node. General structure of DAI divides whole network to hierarchical domains, which is considered as an operational domain. These domains have been considered as nested circles and also every domain divides to several subdomains. Therefore, nodes in every domain use a main server which provides management and security services regarding to that domain. Other services may locate on the main server or any other nodes. Each user is defined in a special domain and is able to use network services only in subsections of that domain.

***Network infrastructure layer*:** Every communication is to be done in communication network context. All interactions and communications are performed using communication network services.

5. CSKG Proposed Architecture

CSKG is a system which helps users to interact in various researches, business and industrial environments and to collaborate with each other in order to reach the goal of decentralized system. Entering CSKG, every user connects to information services and can use them. Generally, services which need interaction of a number of agents and also services which are individually performable and don't need agents' interaction, both are located in CSKG. CSKG architecture has been illustrated in figure 2. All interactions in CSKG happen in a service-oriented context. CSKG services are divided into three groups which can be invoked directly through API or GUI and respond the requests. These three services are: Social Network Services, Application Services, and Management Services. In figure 2, there are two types of arrows. The filled arrows show orthogonal relations between services and blank arrows point to normal relations between them. The latter part means that it is just possible for some services of that group to interact with services of another one and use them.

5.1 Social Network services

We introduce the concept of social networks for collaboration infrastructure and communication between users to perform various operations in decentralized P2P environments, and cross organizations. This mechanism provides the possibility of information and knowledge flow between users and forming communities in order to execute the requested operations in large-scale and dynamic networks. Social network services respond to social network requests submitted by other services or users which are arranged in a social network manner to interact together.

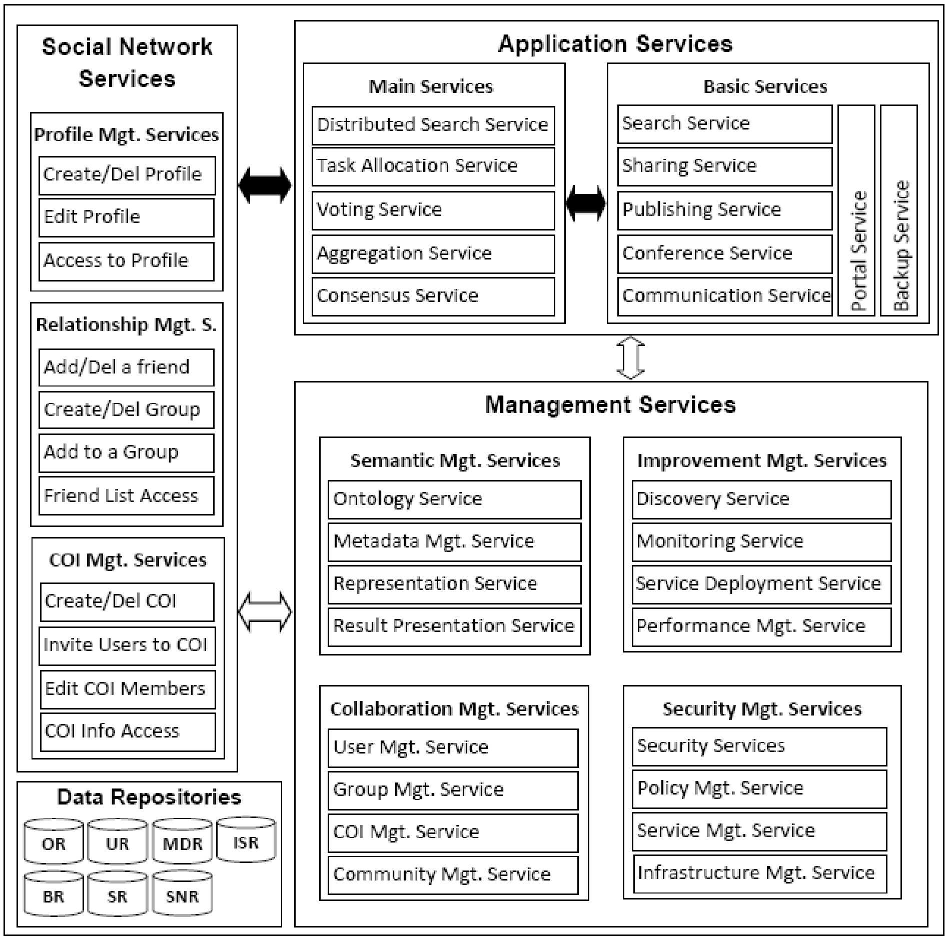

Fig.2 The CSKG Architecture

Connections in social network are established using system primary ontology (i.e. applied semantics to CSKG).

Regarding to dynamics of semantic and awareness in system, connections between nodes in CSKG network can be updated in two different ways. First method which is called local update, happens when an individual intentionally cuts its relationship with a friend (removing a connection between two nodes) or asks to make a new connection with one of available members in network that in case of acceptance, one neighbor will be added to their neighbors (making a new connection between two nodes). The second method, which is called global update, occurs when a new policy (in form of an ontology or semantic) is applied to the system which in this case, a global update will happen in most links of network nodes. Indeed, global update will happen according to former happenings and also regarding to the monitoring and discovery of the nodes, communications, services and operations in system, a new policy may be taken and it will also lead to global update. We use the concept of semantic overlay network (SON) to apply ontology and semantic management in the CSKG. SONs are networks of nodes which are defined according to introduced ontology for system. Actually semantic communication between nodes has been determined using SON and result in global update in the social network. The CSKG network state diagram has been illustrated in figure 4. Forming primary network occurs based on primary ontology. All changes applied in the network in one state (SNi) are equal to local update. In transition from one state to the further one, we have general update based on changes in the system ontology.

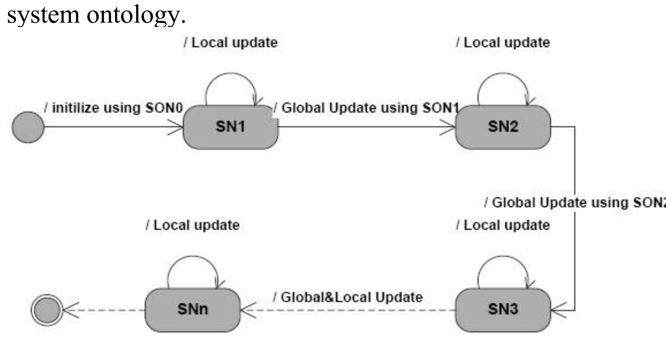

Fig.3 CSKG network state diagram

All relevant information about social network members, profiles, friend lists, groups, COIs and defined accesses in social network level are stored in a data repository called social network repository (SNR). This repository is not necessarily found in all nodes but it is just stored in those ones which include social network services. As illustrated in figure 2 social network services are divided into three main groups: *Profile Management Services*, to create, delete, edit and access to a user profile; *Relationship Management Services*, to manage users' connections and groups, friendship relations between users (User groups are groups which classify people according to a common characteristic like being from the same family, or being classmates or colleagues); *Community of Interest (COI) Management Services*, to manage COIs, which classify people with common characteristics.

5.2 Application Services

Application services are the most important services which are the reasons of CSKG to be. These services are set of services which perform various operations to reach information and knowledge and also individual or community goals. Application services can be directly used by the user (through API or GUI) or requested by social network services. They are not restricted to the noticed services but they can be developed to the other ones if necessary. This should be considered that these services are semantic services and semantic is applied on them using semantic services.

- *Main Application Services:* Main application services are the most important CSKG services. These are services which are presented in distributed environment and with the various agents collaboration, besides users need them to perform different knowledge and information activities. Main application services include Distributed Search Service, Task Allocation Service, Voting Service, Aggregation Service, and Consensus Service. The main application services are not limited to the mentioned services and developers can develop and add new ones if necessary.

- *Basic Application Services:* Basic application services are services which main services, end user, and application programs enjoy their facilities. These services are not limited to the presented ones and it is possible to add some other services to them by developers. The basic services contain Search Service, Sharing Service, Publishing Service, Conference Service, Portal Service, Backup Service, and Communication Service.

5.3 Management Services

These services supply the possibility to control other services. Application services and social network services are under control of these ones. User, group and COI management, presenting security, semantic, and infrastructure management services, creating new services and applying changes in presenting services, are all to be done by management services. In addition, these services can make CSKG policies and security considerations change. Besides, they consider and monitor tasks and services and propose suggestions to improve other services quality.

- *Collaboration management services:* These services manage users, groups, and communities of interest. Moreover, collaboration management services are used for cooperation management, and make communities of users to perform different activities. Differences between group, COI and communities are one of the key points of CSKG. Groups and COIs are population of users who are interested in a subject but with different types of subjects. Users in groups may know each other through a special place, like university or work place, or be in a family relationship, while COI users just are interested or expert in a determined issue, and may not meet o know each other before. Groups and COIs are the groups which are resistant in the system during the time and just remove when their managers or creators want to. While community is a group in which people participate just to perform a special activity, and it will remove after it is done. It is necessary to notice that community log remain in system to use in the similar situations. A community is defined based on a special mission and performing a special activity. This service invites different agents according to their cognitive characteristics and uses the capability to add or delete a user. In communities, each agent chooses one or a number of tasks and performs it to reach the determined goal. This service determines groups of agents according to human and environment cognitive, social and semantic characteristics. To perform, main application services use community management service to determine attending agents. This service will describe and discuss in detail in section 6.

- *Security management services*: These services manage security of users and services. They manage other services and control security in every components of system. Policy management service manages public and privacy policies which should be applied on CSKG. All services should follow policies applied by system manager. Also this service helps CSKG managers to have security and management policies under control. Besides, security services containing authentication, authorization, access control, and encryption are provided for the other services by this group of services.

- *Semantic management services*: These are services which apply semantic to the system entities. Creating and editing ontology, their storage and management, and the possibility of definition, storage and management of metadata in CSKG, are all to be done by semantic management services. Ontology management service makes creation and editing ontology possible. Ontology is used to define CSKG semantic. Also this service can receive a defined ontology by managers, store, maintain and manage it. Using this service, reaching common definitions of concepts in organization domain will be provided. Indeed, storing all system metadata is to be done by metadata management service. Any kind of data which is used in any

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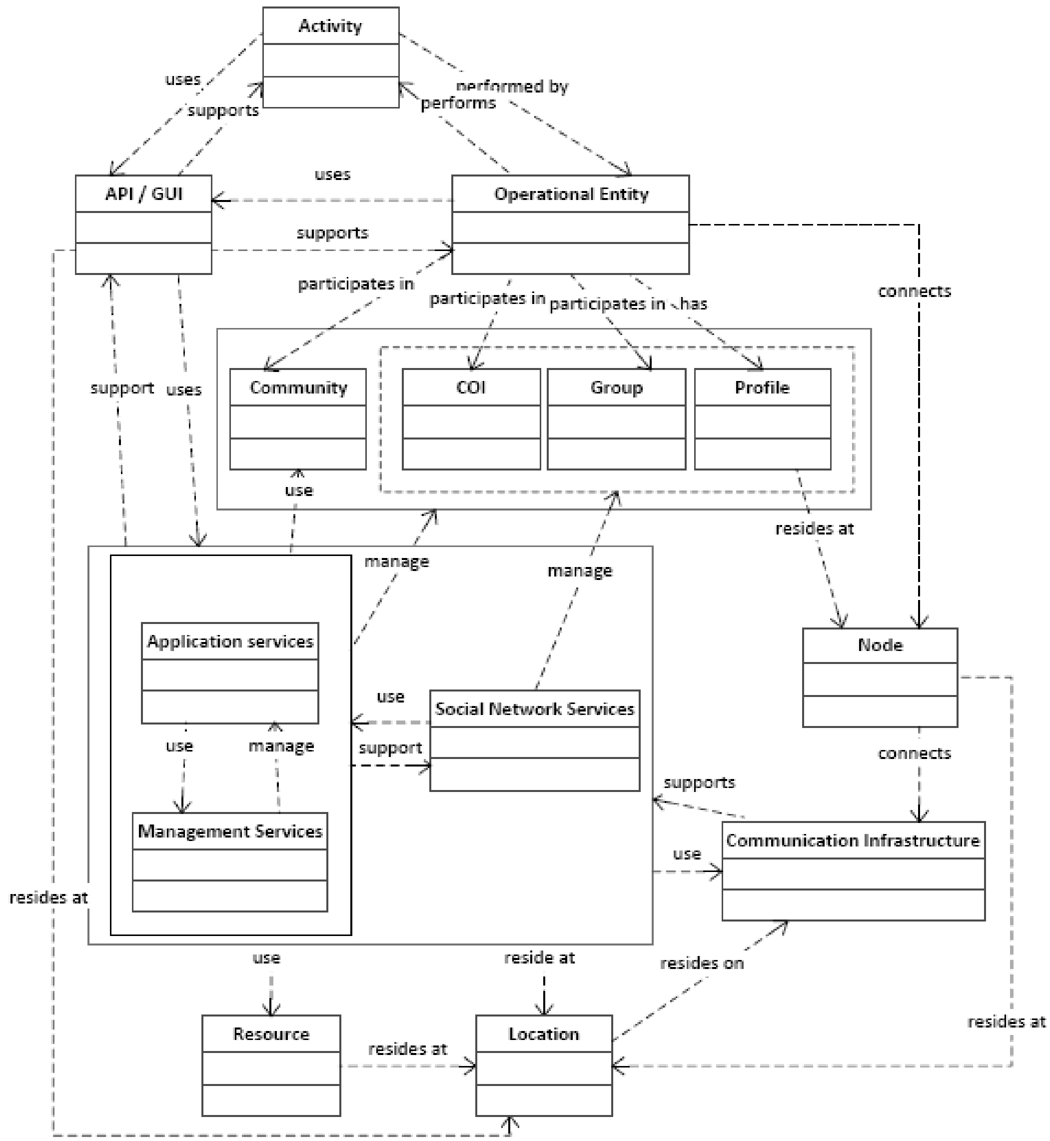

Fig.4 Class Diagram of CSKG

service should register its metadata in this service. Besides, it provides the possibility of converting all kinds of metadata to each other.

- *Improvement management services*: These services are presented to improve system's quality and efficiency and to supervise the other services and monitor them. They also propose new suggestions to the other services through data mining and reasoning and make services' development possible. Evaluating quality parameters in CSKG services is to be done by this service. Data parameters and information determined by development standards (i.e. usage data) have to be sent to monitoring service by CSKG services. It sends registered data to discovery service, which is used by system developers, not normal users, to improve services. Data discovery services receive registered data from monitoring services and system policy from policy management service. Discovery services extract useful data and send it to monitoring service. Moreover, discovery services send some suggestions to the other services including management and application services to improve their functionality.

5.4 Architecture services relationships

Class diagram of CSKG which shows its components relationship has been illustrated in figure 4. Details have not been drawn to have better and simpler demonstration and they have been presented in a more general way. As illustrated, an operational entity may be an individual, software agent, application program, or different groups of them (COI and group). They can submit an activity in CSKG and request for its run. Entering CSKG is possible in two ways: through GUI for users and through API or web-services for application programs. There are many various nodes in CSKG which all of them are in communication.

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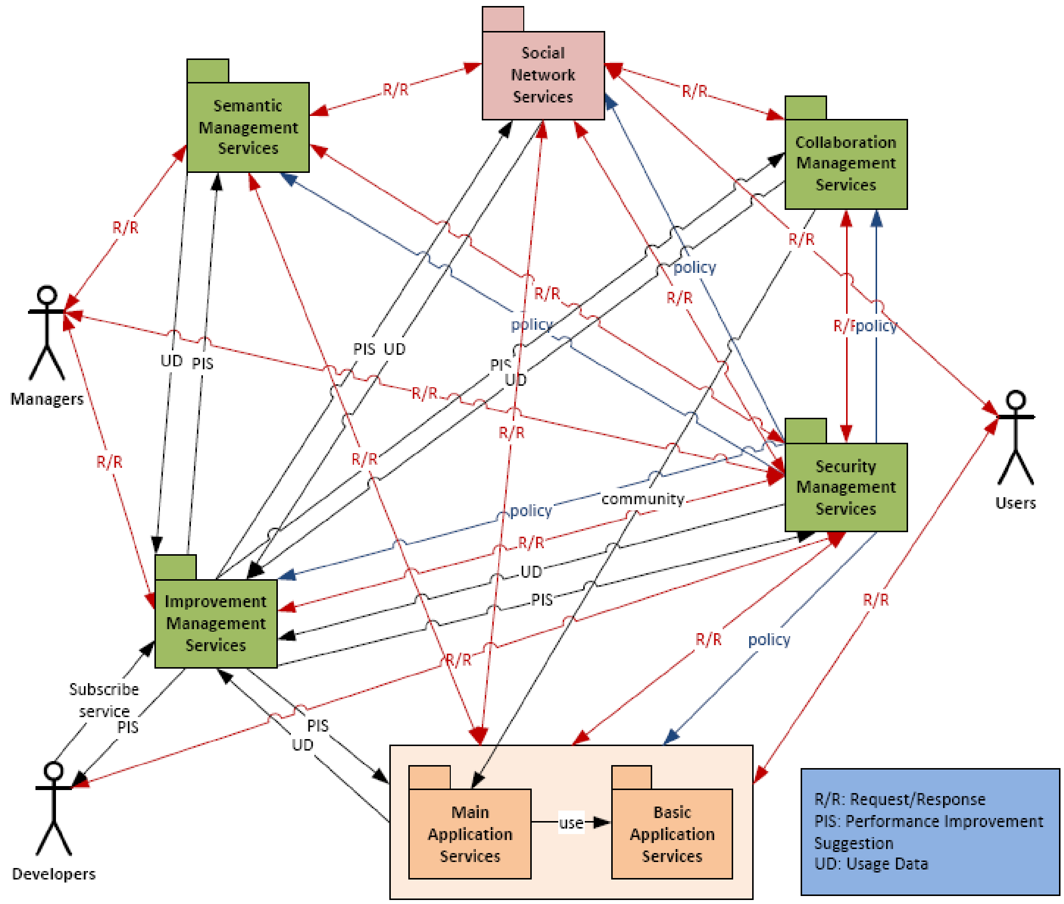

Fig.5 ER diagram of CSKG management services with application and social network services

Relationships between four groups of CSKG management services, social services and application services, and also system users have been shown in figure 5. Avoiding figure's complexity, details of services and relationships have not been demonstrated. Security management services are in a Request/Response relationship with all users and other services in order to provide security for them, inform other services about system policies, manage other services, and interact with system managers to manage the system. Improvement management services monitor other services performance. Monitoring services collect other services usage data, analyze them and send registered data to discovery service. After extracting usage data, discovery services send them to monitoring service again. Also this service sends some suggestions to management and application services in order to improve functionality of services (i.e. performance improvement suggestion, PIS). Service deployment service is in communication with system developers and adds and deploys new services to application and semantic services if needed. As can be observed in figure 5, semantic management service performs creation, editing, receiving, storage, and management for system ontology and metadata and it provides ontology and metadata for other services. Collaboration management service manages users, groups, and COIs. Furthermore, this service is used to manage collaboration, community of agents, so that community management service creates communities of users to perform an activity or to use by main application services according their needs. Social network services are in interaction with application services to submit requests for different services and also to receive services from them. Users can directly request for social network and application services and receive services from them. Social network services are perpendicular with application and management services (except improvement management services). Basic application services are invoked by main application services and other services. Besides, application services are perpendicular with management services while management services are not orthogonal.

6. Discussion

The idea to design cognitive social knowledge grid is to decrease manager role and seek the self-management environment in collaborative scenarios. We ask agents to work autonomously in environment. While agents are

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interacting and collaborating with each other, global awareness and eventually their awareness grow during time. Therefore, they can innately work in the system and know to whom collaborate. Considering semantic and Social characteristics of agents and environment, like trust, commitment, reputation and etc, help them to increase their awareness and collaborate accurately and consciously.

6.1 Collaboration in CSKG

Helped by social network services and other parameters like user profile information, social characteristics (like trust and commitment), and performance environment, CSKG collaboration management services create a community to perform a main application service or a submitted activity by a user or an application program. In such community, not only people attend and supply some services for the others, but also autonomous software agents and semantic services, which are able to do complex reasoning, play role.

Considering trust in relationships to choose people, services, and needed resources results in more efficient collaboration and combination of software and human services. Trust is one of the parameters considered in agents relationships to form collaboration networks or communities to perform activities. We do not look at trust from security aspects, but focus on it with a social approach. The other parameter considered to form a community is commitment. Commitment is a concept extracting semantic of a couple of agents (neighbor agents) in their relationships. This concept has been set up to express promises, contracts, and tasks between two agents. We consider the concepts of trust and commitment for agents in order to have successful collaborations in a community. Agents have been described by their profiles. Each agent is in a friendship relation with one or more other agents. Groups and COIs have been composed of agents and also are able to have common members which means that each agent can be member of more than one group or COI. Different agents perform submitted activities by means of collaboration. Each agent plays a special role in this performance. To perform an activity, agents form a community based on their characteristics, their relations properties, that activity's characteristics and parameters determined weight in that activity.

In addition to characteristics like age, sex, place, skills and education, each agent utilizes individual characteristics like motivation and self-accuracy, and social characteristics like trust and commitment. This should be mentioned that the two first groups of characteristics are totally individual while social characteristics are signified in agent relationships with its neighbor agent.

Profile vector Pui of agent ui in Eq.1 shows the values of agent ui characteristics which have been considered above. The attk is the kth agent characteristic and m shows number of agents characteristic.

$$Pu_i = \{Patt_{i,k} \mid k=1..m\} \quad (1)$$

Social network between agents has been shown by an undirected graph in which every agent is connected to a number of agents through an edge as a relation. Connection between two agents of ui and uj has been illustrated by edges eji and eij. Characteristics like trust and commitment can be defined on a directed graph mapped to the main graph. We use a matrix of n*n to show trust, and one for commitment, to provide measure of trust and commitment between two related agents in network. Parameter n is considered as number of nodes. Both trust and commitment values are valued a number between 0 and 1, which 0 means no trust or commitment and 1 mean a fully trusted or committed relation.

Besides, activity Ai has an activity vector AVi, which determines its characteristics. The activity vector characteristics are correspond to characteristics of agent profile vector, but with different values. Moreover activity Ai has a weight vector WAVi, which shows importance of any characteristic in the corresponding activity. These vectors have been illustrated in Eq.2 and Eq.3:

$$AV_i = \{Aatt_{i,k} \mid k=1..m\} \quad (2)$$

$$WAV_i = \{w_{i,k} \mid k=1..m\} \quad (3)$$

When an activity is submitted to CSKG, the similarity between agent vector of initiator agent's neighbors with activity vector is calculated by means of weighting cosine similarity (WCS) function and regarding to activity's weight vector. Then if the calculated amount exceeds a determined threshold, considered agent will be chosen for collaboration, and similarity function for that agent's neighbors will be calculated too. This process will be continued to a determined number of hops, and collaboration agents will be determined to perform that activity.

$$WCS_m(Pu_i, AV_j) = \frac{\sum_{k=1}^{m} WAV[k] * AV[k] * Pu[k]}{\sqrt{\sum_{k=1}^{m} WAV[k] * AV[k]^2} * \sqrt{\sum_{k=1}^{m} WAV[k] * Pu[k]^2}} \quad (4)$$

To measure collaboration among agents, using Eq.5, the average similarity of final agents chosen for the formed community with submitted activity has been calculated. In fact, this amount shows the level of agents' collaboration performing an activity. Also in this formula, *na* represents the number of agents participate to perform the activity.

$$Co = \frac{\sum_{i=1}^{na} WCS_m(Pu_i, AV_j)}{na} \quad (5)$$

6.2 Simulation

To simulate agent-based complex systems, each agent has been defined by a set of important and effective parameters. Simulation softwares for multi-agent system emphasize on agent aspects and forming social patterns. Netlog [29] is a programmable modeling environment to simulate social and natural phenomenon and also social behavior analysis. This tool is appropriate for modeling complex systems variable during time. Besides, an instruction can be defined for many agents working independently. We use Netlogo to simulate

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our collaborative environment. Agents, their characteristics, relationships, and community formation to perform different activities have been simulated in this environment.

In this simulation, first a social network will get form of agents. Each agent enjoys characteristics which their values are determined in time of their creation. After forming network and determining value for agents characteristics, groups and community of interests will create. Agents will become members in groups like family, colleague, and coworker groups. In addition, agents can become member of COIs according to their interests. Each agent can be member in a number of groups and COIs, which means that groups and COIs may have common members. As considered before, every agent has individual characteristics like motivation and self-accuracy, and social characteristics like trust and commitment in addition to characteristics like age, sex, location, and skills. Agents' characteristics, their definition, and their domain of values include: age has been considered variable in range of 20 to 40; sex is valued by 0 for male and 1 for female; location of agent has been considered variable according to the number of agents involved in social network; skills will be chosen from a determined domain that its values change according to the collaborative environment; motivation is the level of individual's general information for attending in collaborations, which have been defined a value between 0 and 1; self-accuracy is how much an individual believe in their capabilities to perform tasks, which have been defined a value between 0 and 1. Mentioned characteristics are individual characteristics of agent. Two other characteristics used in this simulation, trust and commitment, are social characteristics of agents which can be meant only in relationships between agents and their neighbors. Both trust and commitment have been defined in the interval of [0..1], that 0 means having no trust or commitment and 1 means having complete trust and commitment. Since these two parameters are mutual characteristics between agent and its neighbors, we use a matrix of n*n to show trust, and one for commitment, to provide measure of trust and commitment between two related agents in network. The measures which we evaluate in this simulation composed of:

- *Collaboration accuracy and quality:* The results of running CSKG should enjoy an appropriate accuracy and quality. Therefore, this measure is monitored as one of main quality indices by CSKG managers. To calculate this parameter, we consider collaboration not only in one time execution of an activity, but also, to improve accuracy in result and calculations, the average collaboration of a number of submitted activity which have parameters with the same weight have been calculated.
- *Answering time:* Answering time is one of the most important measures in CSKG. We evaluate answering time for a various number of executions of activities with the same weight.

We run 10 activities in a social network containing 100 nodes. The activities were different but with the same activity weight vector due to accuracy. There were three groups, family, colleagues, coworkers, and five communities of interest. Users of nodes selected to be member of which groups or COIs. There is no limitation for group and COI membership, therefore, users could be member of every groups and COIs. The results of collaboration of agents showed that trust and commitment cause the more qualified cooperation to execute activities. The similarity of agents who participate in the formed communities, help to find more similar agents who understand each other much better. This eases the process of executing an activity like making a decision through consensus service. Therefore we provide an architecture which agents can interact and collaborate in a qualified, fast, and accurate manner to execute activities.

7. Conclusion

This paper has presented a novel architecture for collaborative environments which agents, services and applications can interact through a standard GUI or API. We utilize a service-oriented infrastructure to use its standard technologies in interaction of services. Indeed, the CSKG uses social network approach to communicate and collaborate human agents besides services. Semantic overlay network has been proposed to semantically enrich the CSKG architecture and update social network relations based on the semantics applied to system. The cognitive social knowledge grid architecture consists of three types of services. Social network services to provide human interactions and collaborations; application services to perform the activities submitted by users, services, and applications; and management services to manage and monitor the services, perform security and policy services, and deploy and improve services. In addition, in this paper, we introduced organization infrastructure containing three levels which let CSKG services to execute. The middle layer, which is a novel distributed autonomous infrastructure, is an architecture that shows how the servers and workstations work together.

We investigated the CSKG performance in collaborative environments. The community formation based on user profiles similarities and social parameters like trust and commitment will be argued. We proposed a method to find partner for agents. We assumed an agent vector for any agent, consisting its personal information, cognitive information and social characteristics. Besides, we introduced an activity vector and a weight vector for any activity. Then the weighted cosine similarity function has been used to compare agent vectors and activity vectors to find the right partners for any submitted activity. We simulated our approach for collaboration and showed that using social preferences like trust and commitment enhance the community formation in collaborative environments. Community is the group of agents who interact and collaborate to execute an activity. The similarity of these agents helped to find more similar agents who understand each other much better. This eased the process of executing an activity like a consensus decision-making. Hence, we

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provided an architecture which agents can interact and collaborate in a qualified, fast, and accurate manner to execute activities.

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