# An agent-based and semantic service oriented approach for service discovery in Network Centric Warfare (NCW)

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**Abstract**

In the new age one of the most challenging aspects of the information age is discovering the desired services with most accuracy and speed. In this paper a new semantic model is presented for the service discovering process in network centric warfare (NCW). The model is based on predefined ontology which is determined for the most important aspects of NCW in the application level. Services is based on a service oriented infrastructure and implemented as a grid which is developed as independent services. In the model, service discovery mechanism allows each of service agents to interact with its agent neighbors semantically and form a service chain for a specific task dynamically. The introduced model considered the semantic SOA which can overcome the undesirable time-delays and overhead corresponding to complexity of service discovery at heterogeneous environment such as NCW.

***Keywords:*** *network centric warfare, brokering, service agent, ontology, semantic similarity function.*

## 1. Introduction

If we analyze the recent worlds, we come to this understanding that traditional war approaches cannot help us achieve the goals of the information era. The consequences of information era and the change of the notion of the power from technology toward informational concepts as well as transmission of power toward the edges of the system have caused profound changes in the management of organizations(specially in military fields). In the information era, the process of power establishment consist of getting row data, combining and processing those data for the purpose of producing information and extracting knowledge from them, and making appropriate decisions and finally reconsidering the results for correcting the future decisions[1]. Considering the nonlinear and undetermined nature of the war environment, it should be noted that absence of sufficient accuracy and speed in each of the processes can reduce the efficiency and authenticity of the final decisions to a considerable degree. Network centric war (NCW) attempts to inject the concepts of information era into the war environment. It must be regarded that the purpose of NCW is not to exploit computer networks or to utilize automatic weapons; it is intended to exploit the smallest available weapons capitals and gaining benefits from such instruments by synergetic processes to reach the possible usage in other to satisfy the organization purposes. NCW consider the war environment a distributed, heterogeneous, and interactive environment that consist of cognitive and responsive agents in which using a common understanding and a situational understanding move toward the determined purposes. This society interacts in an environment based on reliance for an acceptable level of sensation and finally convergence toward the intention of commanding[2]. According to the great importance of providing information in NCW, it should be noted that providing and distributing incorrect information could be destructive to the same extent.

One of the most important assumptions of modern war is sharing and sending information to existences of the system, without considering geographical and logical intervals. So, every legal existence should be able to access necessary information in everywhere in the network in any given time. As transparency, agility, weak connections, high accessibility and conformity are of the features of environments related to the modern wars, it is visible that architectures and common ancient approaches are not to satisfy such needs[3].

For increasing the capacity of flexibility and defining pre-conventions before hand service description and their relationship will be expressed by added semantic to the under analysis environment. The emphasis of semantic service on 'meaning and content' for adding semantic to the service is for creating understandable machines. Deducing semantic cause concurring on unsuitable time delays lead from environmental complexities like NCW.

In this paper at first we propose a semantic service brokering model for NCW, then for service discovery in the service layer of the model we will introduce the semantic similarity of domain ontology and use a heuristic algorithm for finding neighboring service agents in a decentralization manner for the discovery of services, without the overhead of negotiation, a service agent only needs to know neighbor nodes he is connecting with and what the semantic descriptions of neighboring service agents are. The method of using semantic similarity provides a flexibility to allow individual service agents to perform flexible semantic matches.

Because the algorithm allows individual service agents to only query neighbor nodes without the need of global knowledge, the strategy of the algorithm can let individual service agents have a self-adapting capability to different network structures. With low diameter and low average degree, small world networks have been found important in many fields such as road maps, electric power grids, metabolite processing networks, neural networks, and social influence networks etc. In this study, the description of the proposed algorithm in finding neighbors is within a small world network structure. The algorithm can adapt its connectivity within the small world network structure. Similarly, the algorithm can also be applied to other network structures by the self adapting policy.

## 2. Related works

various works have been done in the realm of service brokering and recourse discovery in the service-oriented systems that some of them will be discussed here.

In the presented architecture in [4] a method suggested whose quality service parameters are analyzed by a function for discovering service suitability rate and the broking operation will be performed by this function. In suggested architecture of this article service requests will be presented to the broker and according to the suitability functions decide a service that maximize the amount of this function.

Article [5] devoted to the suggestion of a system whose broker according to the quality of service insurability dynamically monitor the network services and determine the best services for presenting to the those who request. suggested broker in this article is able to replace users connections with services when access is not achievable and provide an environment highly fault tolerance. In this article a light software broker for benefiting in the distributed environments is presented. In the presented strategy service quality of software (Qos) is centric that set on distributed service suppliers.

Authors of article[6] by classifying system services have considered a dynamic method based on service quality parameters that considered variant features of Qos in the system .on the other hand various works have been done in the realm of working with service-oriented environments considering mental models that are. two software broker of reliability and performance. reliability software broker can discover a software service dynamically that can provide the best efficacy according the effective and operational needs of clients of services. Software performance broker can supply service error tolerance for clients of the services by migration of service supplies of clients of the cervices between multiple software services.

In article [7] a service-oriented environment for distributed multimedia operations is presented those cervices composition in this environment will be performed considering predetermined anthology according to the current system capabilities.

In the presented methods meaning features for discovering services are considered .also service brokers from centralized methods to discover the service are used. we propose a flexible approach to discover services semantically by using a decentralized fashion. We employ ontology driven semantic description to describe services. The algorithm defines service agents as service carriers , allows individual agents to manage their connectivity based on local knowledge by using semantic similarity (e.g., who is connecting with him and what service the neighbor is carrying, conveyed by the semantic description?), and dynamically forms service chains to complete tasks or jobs.

## 3. The proposed Service Brokering Model for NCW

Our proposed service brokering model is an ontology-based five layered model as shown in Fig.3.1. As shown in the figure, system ontology has a pivot role from bottom to the top. From the NCW point of view, the application layer will be the NCW platform through which NCW is presented to the user. This layer is based on the NCW ontology to understand the conceptual structure on how to generate a common operational picture. User requirements and requests are injected into the other layers through the application layer.

Goal based layer is responsible for translating the received requests into goals[8]. This process is done using the corresponding ontology from the ontology pyramid. In this process each goal may also be broken down into smaller goals for further distributions through the brokering layer.

The brokering layer receives the generated goals from the upper layer and distributes the goals (some or all of them) among the brokering services. The brokering layer may be implemented as a brokering grid involving different services each one for a particular attribute. Our proposed brokering grid takes advantage of five independent services according to five important attributes of availability, maintainability, performance, policy, and reliability[3].

The service layer contains the floating services on the overall system infrastructure. Web service is an appropriate technology for exploiting the SOA tenets, so this layer may also be called as web service layer. This layer includes all the web service containers and the web service cores, negotiating according to web service standards as WSDL, and SOAP protocols. Brokering services in the brokering grid conceptually can also be considered as a part of the service layer.

Communication layer refers to the underlying communication network. It is implemented as an IP network with varieties of protocols. The ontology pyramid also interferes the function of this layer to adjust communication protocols, routing strategies, etc.

Although the paper focuses on service discovery, the proposed model shown in Fig.3.1 can be applied for other NCW aspects as well.

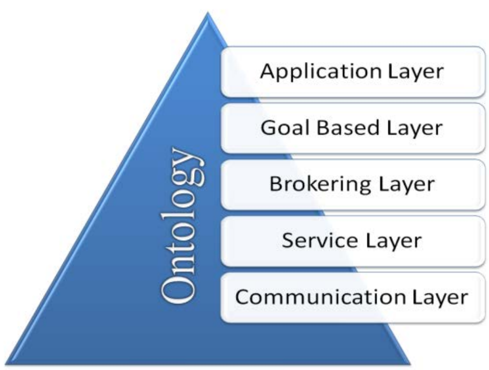


Fig.3.1 The proposed service brokering model for NCW.

## 4. Ontology and semantic similarity

Ontology is a formal structure that contains information about semantic description data. This structure contains a set of concepts and their connections. It can be used in the recovery of information that deals with users inquiries [9, 10]. Ontology O is defined as

$$O = \{C, \le_C, R, \le_R, A\},$$

Where C is a set of concepts, R is a set of relationships, $\le_C$ is a partial order on C and $\le_R$ is a partial order on R. Also, A is defined as a set of axioms [11, 12].

Semantic similarity function is used for computing similarity between two concepts. Similarity between concepts shows degree of their common. Similarity function is defined as sim(x, y): C*C → [0, 1]. The output of this function is a real number in interval [0, 1] that shows the degree of similarity between two concepts x and y. The zero output means lack of sharing and output one shows complete similarity between two concepts [13-17]. The semantic similarity as follows:

$$\mathrm{sim}(x,y) = \rho\frac{|\alpha(x)\cap\alpha(y)|}{|\alpha(x)|} + (1-\rho)\frac{|\alpha(x)\cap\alpha(y)|}{|\alpha(y)|} \tag{4.1}$$

In this function $p \in [0,1]$ determines the degree of influence of generalizations. α(x) is the set of nodes upwards reachable from x, and α(x) ∩ α(y) as the reachable nodes shared by x and y. For more information refer to [18,19].

For example, an ontology with hierarchical structure graph, as shown in Fig. 4.1, has 5 concepts and has 'is a' relationships. we define Weapon as a root node, and which has sub nodes including Air_weapon, Sea-weapon and Ground-weapon. Air_weapon also includes sub-nodes Bomber_weapon, Helicopter_weapon and Missile_weapon.

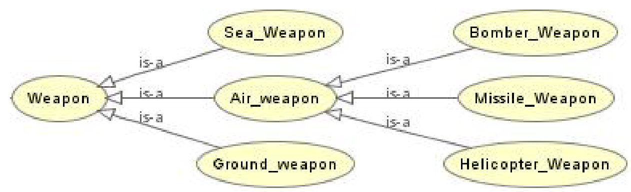


Fig.4.1 An ontology example graph of weapon

In terms of Eq. (4.1), the concepts Bomber_weapon, Helicopter_weapon have 3 reachable nodes from themselves, namely,

α(Bomber_weapon) = 3, α(Missile _weapon) = 3, α(Air_weapon) = 2, α(Helicopter_weapon) =3, α(sea_weapon) = 2, α(Bomber_weapon) ∩ α(Air_weapon) = 2, α(Bomber_weapon) ∩ α(Helicopter_weapon) =2 α(Ground-weapon) ∩ α(Sea-weapon) = 1.

## 5. Description model for service discovery in service layer

In this present article, NCW is modeled as a graph each of the nodes of which defines a service agent and each of the agents carries a specific service type. We assume k different service types existing in the system, which are displayed as $\{S_1,\ldots,S_K\}$. It is noteworthy that service agents have the capability to find their neighboring nodes to form service chains needed for tasks. Tasks are distributed with a certain rate μ in the network and each of them needs m different types of services ( $m \le k$). Supposing that p tasks are distributed in the network, the tasks can be displayed as a p×m matrix, in which every row represents a task and every column the type of the required service. As stated in [20], each node (service agent) may be in one of the three states "inactive", "committed" and "active", which can represented as $ST_k$ = 0, 1 or 2. Inactive state means the node is a free node and not working on any task. Committed state indicates that the node is working on a task but the service chain has not been completed. Active state means that the node is working on a task and the service chain has been completed. Here, we can define semantic similarity matrix as a n×n matrix whose elements represent the degree of similarity between service type needed for the task and service type of the service agent. Regarding the assumption that semantic similarity threshold is 1, the elements of semantic similarity matrix are 0 and 1, in which 1 represents total similarity of service types and 0 indicates dissimilarity of the service type required from that of the service agent. The above model corresponds to the model presented in [20].

## 6. Proposed algorithm

In this method at first a node will be chosen randomly. If this node be free and has one of the different types of services and also have a free neighbor capable providing another type of service in the task ,then this node will be set in the state of committed (ST=1) therefore this node send a "ready" massage to its free neighbor. until fully satisfaction services required for the task, every neighbor with receiving the message of "ready" from its neighbor make itself in the state of committed, and if having another free neighbor that can provide other types of services required for the task, it will send the "ready" message to that neighbor .in the follow, the pseudo code related to the algorithm is represented.

In this part we give an example for better understanding of the algorithm. suppose that we have a network with 8 nodes that are numbered from 1 to 8. also 4 types of services by numbers from 1 to 4 are distributed in this network. Now we suppose that a task that require four type of services {1,2,3,4}is distributed in this network. as the fig.5.2(a) shows at first the node number 5 that has the service type 2 has chosen randomly ,because in the neighbor of this node (3,7)at least there is one node that can supply another type of task, therefore this node will be set in the state of committed (nodes that are set in the state of committed are shown by red color )then the node 5 send ready message to one of its neighbors (node7) and node 7 after receiving this message set itself in the state of committed (fig.5.2(b)). regarding the services required for remained task {1,4}node number 5 to its neighbor (3) that has the service type 4 , send the ready message to this node and node number 3 will be set in the state of committed with receiving the message (fig.5.2(c)). node number 7 based on the reminded service of task {1} analyze its neighbor and because the node 2 is free and has the service type 1, thus node 7 send the node 2 the ready message. This node also with receiving this message set in the state of committed and a chain with nodes of 2, 3,7,and 5 will be formed for the task(fig.5.2(d)).

**INPUT** task
**OUTPUT** services chain for task requires
**ASSUME** $N_K$ is a node that selected at first randomly
**ASSUME** $ST_i$ is state of node ith and $ST_i$ can be 0, 1 or 2
**ASSUME** $S_i$ is the service type of node ith
**ASSUME** L is size of task requires( length of task)
**ASSUME** A is a threshold for similarity function
**ASSUME** $TR_m$ is a service type in task requires
**Begin Algorithm**
Select randomly a free node ($N_K$)
**If** sim($S_k$, $TR_K$)> A **Then**
**If** $N_K$ has a free neighbor ($N_j$) and sim ($S_j$, $TR_j$) > A **Then**
$ST_k$ = 1
$N_K$ send message "ready" to $N_j$
**End If**
**End If**
**While** L > 1
**If** $N_j$ receive the message "ready" from it's neighbor **Then**
$ST_j$ = 1
L = L -1
**End If**
**If** $N_j$ has free neighbor ($N_i$) and sim($S_i$, $TR_i$)> A **Then**
$N_j$ send message "ready" to $N_i$
**End If**
**End While**
**End Algorithm**

Fig.5.1 The pseudo code of algorithm for service discovery

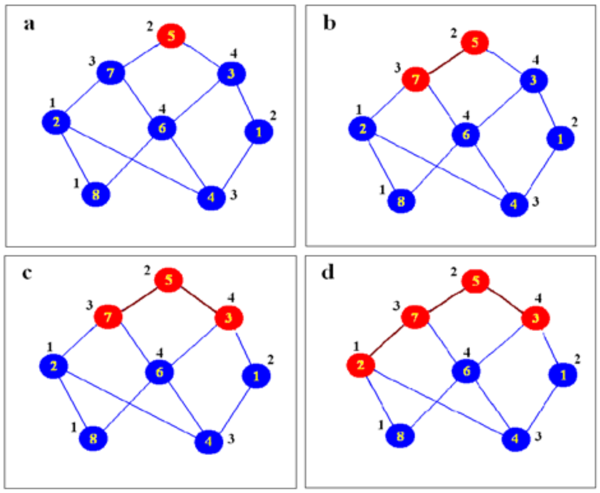

Fig.5.2 The scheme of the algorithm for forming a service chain

## 6. The Results of Simulation

In this section we will show the simulation results of represented model. In this simulation, first we consider a network with 64 nodes and 16 various service types that are uniformly distributed over the network. Also we assumed that each of the tasks needs 16 service types, the represented algorithm is applicable on every network structure and here we used small world network for applying our algorithm we create small world network graph with 64 nodes based on available methods in [21,22].in every experiment 10 different rate of task creation that is between intervals of [0.05,1] and load in every rate, 1000 tasks in the time step that is two times of required services(32).

We analyze the relation of task success probability under different task loading rate along with network scale with consideration of semantic similarity threshold one.

We define task success probability as the ratio of number of tasks completion and total tasks published.

We consider the task complexity as the ratio of required services for the task and the variety of services are in the network. Here we assume that task complexity is 0.5.

### 6.1 The relationship between task success probability and task load rates

Here we analyze the task in different lengths of 4, 8, 12, 16 and evaluate the success probability in similarity threshold of one. The results of these experiments are shown in the fig 6.1.

As you see X-axis is task loading rate and Y-axis show the success probability. From the figures we conclude that with increasing task load rate, success probability will decrease.

### 6.2 the relationship between success probability and increasing the number of nodes

Here we model nodes with the number of 64,128 and 256 that contains 16 various service types that are uniformly distributed and in every time step we send 1000 tasks to them.

We considered success probability of task with regard to three different network scales and suppose task complexity has the fixed amount of 0.5 .the experiment results in the figure 6.1 show that X-axis is task loading rate and Y-axis show task success probability. As observed, when network scale increase, success probability will increase.

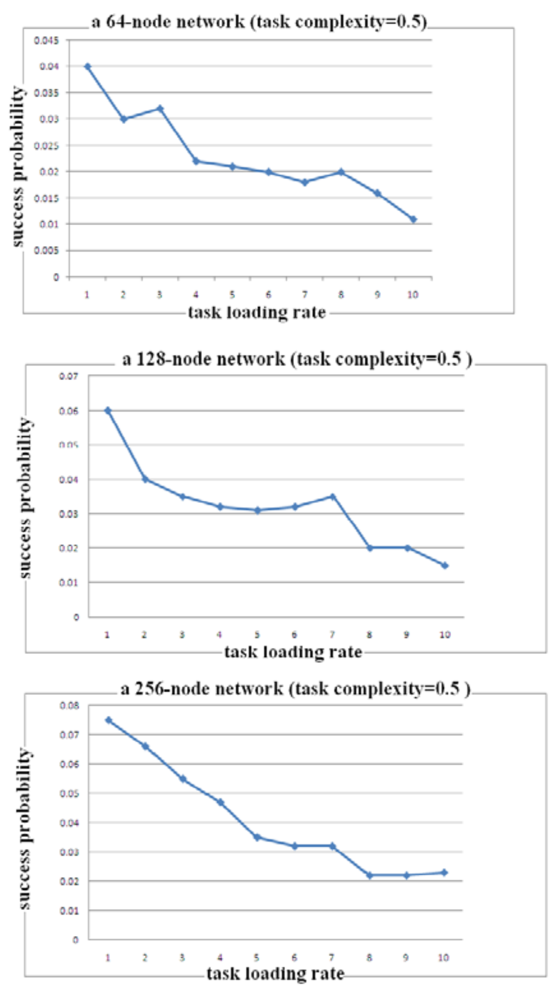


Fig.6.1 The relationship between success probability and different network scale

## 7. Conclusions and future work

service discovery is one of the challenges in service oriented environments. We obviated this challenge with using a perfect semantic model and a heuristic service discovery algorithm for forming a service chain for a specific task. The simulation results shown that with increasing the nodes number or decreasing task loading rates, the success probability of task completing is increasing.

The future work will focus on how to increase the security aspects in the proposed model and how to increase fault tolerance when a service in the service chain confronted with failure.

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