Literature Review and Survey:
Resource Discovery in Computational Grids

Figures

Resource discovery in Computational Grids

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Abstract

Resource discovery is an important aspect of Computational Grids. Locating resources in a Computational Grid is difficult because of the geographic dispersion and dynamic nature of the resources. This survey provides an in-depth overview of the resource discovery in Computational Grids, which is based on ongoing research on this specific area from 1997 to 2003. The report first identifies and defines the concept of resource discovery in a Computational Grid and then different problems of discovering resources in large distributed networks are discussed. Various solutions to different resource discovery algorithms and their effectiveness are reviewed. Several architectures and applications related to resource discovery are also discussed including Web Service Discovery Architecture (WSDA), Monitoring and Discovery Service (MDS, Globus tool), Open Grid Service Architecture (OGSA), Universal Description, Discovery and Integration (UDDI). Different resource discovery protocols are identified as well through this survey.

1 Introduction

1.1 Computational Grid

As stated in (Foster i, 2002) and (Foster a, 1998), the computational grid is “a new class of infrastructure, which provides scalable, secure, high-performance mechanisms for discovering and negotiating access to remote resources, the Grid promises to make it possible for scientific collaborations to share resources on an unprecedented scale, and for geographically distributed groups to work together in ways that were previously impossible”. According to (Foster i, 2002), in 1965, Fernando Corbato and other designers of the Multics operating system from MIT had foreseen a computer system, which is similar to a power grid or a water grid. In 1968, J. C. R. Licklider and Robert W. Taylor predicted a Grid-like infrastructure in their paper “The Computer as a Communications Device”. In (Foster a, 1998), the authors provided details purpose, shape, and architecture of a computational grid. In their paper the authors discussed six main important factors such as why grid computing is needed, for what kind of activities, what kind of applications it is needed, who will be the users, how the infrastructure will be used, how to build the grid and what kind of problems will be faced to design a grid. They gave different directions to design and maintain a heterogeneous large distributed grid. (Foster a, 1998) is identified as the first paper where different implementation strategies to build a complicated grid infrastructure were provided for the first time in detail.

1.2 Resource and Resource Discovery

According to (Iamnitchi a, 2001) resources are computers, cluster of computers, online instruments, storage space, data, application and a resource discovery mechanism returns the identity (may be location address(es)) of matching resources for a given description of desired resources.

1.3 Why Resource Discovery

According to (Iamnitchi a, 2001), large number of users, heterogeneous resources, dynamic status of resources (over time) in a large distributed network make resource discovery difficult than that of traditional network. In a Computational Grid, Different operating systems, different administrative domain, lack of portability between platform dependent applications make resource discovery more difficult. So, appropriate resource discovery mechanism is an important aspect of Grid Computing. Success of Computational Grid mainly depends on locating appropriate resources for a specific task.

1.4 Outline of the survey

This survey will cover resource discovery in Grid Computing in details. This survey consists of 5 sections. Section-1 covers the introduction to the topic, Section-2 covers a general discussion about different component of resource discovery, and Section-3 covers different resource discovery algorithms, protocols and existing solutions. Section-4 gives a brief discussion about discovery mechanisms in topical web and mobile ad-hoc networking. Finally Section-5 presents the concluding remarks. Appendix- i to vi contain bibliography, annotated bibliography, list of researchers, sample e-mail which was sent to researcher, list of upcoming conferences, and a cross-referencing graph respectively.

2 General Discussions

Following terms, components, and theory has been used to conduct this survey.

2.1 Components of Resource Discovery

(Iamnitchi b, 2002), (Iamnitchi c, 2002) identified four different architectural components for a general resource discovery solution, “Membership protocol”, “Overlay construction”, “Preprocessing”, “Request processing”. (Iamnitchi c, 2002) also identified four environment parameter factors, which dominate the performance and design strategies for a resource discovery solution. These four factors are “Resource information distribution and density”, “Resource information dynamism”, “Request popularity distribution”, “Peer participation”.

2.1.1 Architectural Components

According to (Iamnitchi b, 2002) (Iamnitchi c, 2002), following architectural components are identified:

2.1.1.1 Membership Protocol

It refers to how a new node becomes a member of an unstructured network and how a member learns about other members in such network. It is responsible for collecting and updating information about currently active members.

2.1.1.2 Overlay Construction Function

It refers to select the active members from the local membership list. This selected member list depends on bandwidth availability, network load, administrative policies, and topology specifications. It is responsible for searching the best match for a given request.

2.1.1.3 Preprocessing

It refers to off-line preparations for achieving better search performance. An example of preprocessing is an advertisement for a local resource to other networks. It is responsible for efficient searches.

2.1.1.4 Request Processing

It is responsible for searching resources. It has two components:

Local Processing

It facilitates looking up local resource information for a requested resource.

Remote Processing

It refers to send the request to other networks through different mechanism for appropriate resources.

2.1.2 Resource Discovery Modeling

According to (Iamnitchi c, 2002), following four environment parameter factors are identified:

2.1.2.1 Resource Information Distribution and Density

It refers to different load of information sharing on different nodes. As for example, some nodes share a large number of resource information, on the other hand, a home computer shares just a few. Some resources are very common and some are very unique and rare.

2.1.2.2 Resource Information Dynamism

It refers to different attributes of resources, which are dynamic and static in nature. As for example, CPU load, memory availability are two high variant attributes. On the other hand, operating systems, type of CPU are two nearly static attributes.

2.1.2.3 Requests Distribution

It refers to possible closer uniform distribution of popular requests. L. Breslau and others showed in their paper "Web caching and zipf-like distributions: Evidence and implications" that HTTP requests follow zipf distributions.

2.1.2.4 Peer participation

The peer participation depends on different type of networks. As for example, peer participation in p2p networks significantly varies as in Computational Grid.

According to (Iamnitchi c, 2002), these four parameters dominate the performance and design of a general resource discovery mechanism:

2.2 Models for grid resource management

(Buyya c, 2000) discussed three different management models for grid resource management such as hierarchical model, abstract owner model and (computational) market model. Hierarchical model contains different active and passive components for grid computing. As for example “Domain Control Agents” is an active component, which can provide state information through publishing in an information service or through direct query. Abstract owner model refers to an order and delivery and result gathering approach. The (computational) market model refers to mixture of both hierarchical and abstract owner model and it refers to a computational economy development in grid resource management. The authors believed that one or more of discussed model could be mapped with existing or future grid systems.

(Krauter, 2000) identified some key resource management approaches to design a comprehensive resource management system. In this paper, the authors presented resource management system as the core component of a network computing system (NCS). The authors discussed different aspects of resource management such as mainly quality of service (QoS) issue, different heterogeneity issues, different scheduling approaches, resource discovery technique, different resource distribution approaches. The authors suggest that a resource management system can maintain a replicated network directory, which may contain resource information and then resource discovery function queries the “resource dissemination function” for a particular resource.

2.3 Virtual Organization (VO)

As stated in (Foster b, 2001), Virtual organizations refer to "secure, flexible, coordinated resource sharing among dynamic collections of individuals, institutions, and resources."

2.4 Graph Theory

According to the book "Introduction to Algorithms by T.Cormen, C. Leiserson, and R. Rivest":

2.4.1 Directed Graph

A directed graph *G* is a pair *(V, E)*, where *V* is a finite set and E is binary relation on *V*. Set *V* is called the vertex set of *G* and elements of *V* care called vertices. The set *E* is called edge set of *G* and elements of this set are called edges.

2.4.2 Undirected Graph

An undirected graph G is a pair (V, E), where edge set E contains unordered pair of vertices.

2.4.3 Strongly-Connected Graph

A directed graph is strongly connected graph if every two vertices are reachable from each other.

2.4.4 Complete Graph

A complete graph is an undirected graph in which every pair of vertices is adjacent.

2.4.5 Resource discovery and graph theory

According to (Law, 2000), a network can be viewed as a directed graph and if u, v are any two nodes of a network and if u knows v then an edge between u and v is created, $(u, v) \in E$. For any node u, if $(\Gamma(u)$ is the known set of u

$(u,v) \in E$ iff $v \in \Gamma(u)$

According to (Law, 2000) the goal of resource discovery algorithm based on a graph theory is to develop a complete graph from a given directed graph.

3 Design and Implementation

3.1 Algorithms

The following resource discovery algorithms are reviewed in (Harchol-Balter, 1999), (Jun, 2000), (Kutten a, 2002), (Kutten b, 2001), (Ludwig, 2002), (Li-Xu, 2002), (Law, 2000),(Maheswaran a, 2000), and (Huang, 2002):

3.1.1 Flooding Algorithm

According to (Jun, 2000) and (Harchol-Balter, 1999), this algorithm is widely used by internet routers and where every node acts as a transmitter and receiver and every node tries to send every message to every node of its neighbor, a newly added new edge is not used for any communication, direct communication exists only in between initially existing set of neighboring edges of the network. The required number of rounds of this algorithm is equivalent to the diameter of the graph. So (Harchol-Balter, 1999) claimed that this algorithm can be very slow if not started with a graph, which has small diameter.

3.1.2 The Swamping Algorithm

According to (Jun, 2000) and (Harchol-Balter, 1999), swamping algorithm is similar to flooding algorithm except this algorithm allows a node to connect with all of its current neighbors, not only with the set of initial neighbors. (Harchol-Balter, 1999) suggested that the main advantage of this algorithm is this algorithm needs $\mathrm{O}(\log n)$ rounds to converge to a complete graph and which is irrespective to the initial configuration. According to (Harchol-Balter, 1999), the disadvantage is communication complexity of this algorithm grows very quickly.

3.1.3 The Random Pointer Jump Algorithm

In this algorithm, in each round, each node contacts with a random neighbor, and then this random neighbor sends all of its neighbors to the sender node. Finally sender neighbor and random neighbor's neighbors get merged. (Jun, 2000) and (Harchol-Balter, 1999) claimed that a strongly connected graph with n nodes needs $\Omega(n)$ complexity time to converge to a complete graph.

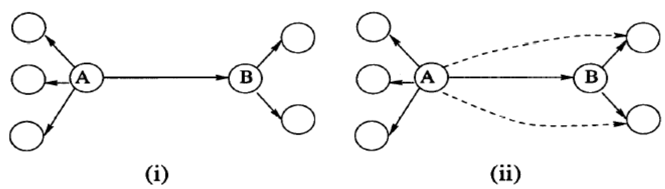

Figure 1: Random Pointer Jump (Harchol-Balter, 1999, page: 232)

(i) Before the Random Pointer Jump. Node A chooses at random one of its neighbors and opens a connection with it. Here B is the chosen neighbor (ii) After the Random Pointer Jump Node B has passed to node A all of its neighbors, and now A also points to them. The dashed lines indicate newly formed edges

3.1.4 The Random Pointer Jump with Back Edge Algorithm

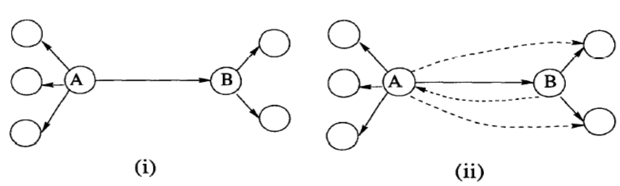

Figure 2: Random Pointer Jump with Back Edge (Harchol-Balter, 1999, page: 233)

(i) Before the Random Pointer Jump with Back Edge. Node A chooses at random one of its neighbors and opens a connection with it. Here B is the chosen neighbor (ii) After the Random Pointer Jump Node B has passed to node A all of its neighbors, and now A also points to them. Node B is also given a pointer to node A. The dashed lines indicate newly formed edges

(Harchol-Balter, 1999) claimed that this algorithm is almost identical to Random Pointer Jump algorithm except every time adding a back edge after performing the pointer jump.

3.1.5 Name Dropper Algorithm

(Harchol-Balter, 1999) proposed a new algorithm for querying resources in a weakly connected network where it is assumed that all machines already know each other. They proposed "Name-Dropper" algorithm for resource discovery, which takes $O(\log^2 n)$ rounds to learn each other, $O(n^2 \log^2 n)$ number of connections and $O(n^2 \log^2 n)$ number of pointers in a network. In (Harchol-Balter, 1999), the authors claimed that this new algorithm is more efficient in terms of required time and total number of network communications compare to four other algorithms, mainly flooding algorithm, swamping algorithm, random pointer jump algorithm, and random pointer jump with back edge algorithm.

(Harchol-Balter, 1999) also claimed that this algorithm achieves "near-optimal performance both with respect to time complexity and with respect to the network communication complexity". This algorithm is almost identical to "Random pointer" algorithm. But according to (Harchol-Balter, 1999), in worst-case $O(\log^2 n)$ rounds of "Name-Dropper" algorithm dominates over $\Omega(n)$ rounds of complexity time of "Random pointer" algorithm, where n is the number of machines.

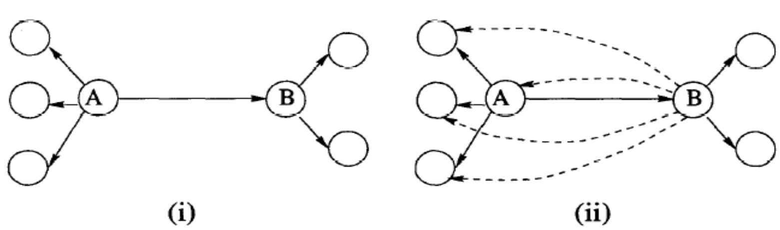

Figure 3: Name Dropper (Harchol-Balter, 1999, page: 235)

(i) Before Name-Dropper. Node A chooses a random neighbor; here B is the chosen neighbor (ii) After one round of the Name-Dropper algorithm. A has passed to B all of its neighbors and B has added edges to these neighbors. In addition, B learns about A. The dashed lines indicate newly formed edges.

3.1.6 Deterministic Resource Discovery Algorithm

(Kutten b, 2001) proposed a better algorithm (deterministic) for resource discovery compare to "Name-Dropper" by (Harchol-Balter, 1999). Compare to the main randomized algorithm of (Harchol-Balter, 1999), time complexity is reduced from $O(\log^2 n)$ to $O(\log n)$, for message complexity this improved algorithm takes $O(n \log n)$ compare to $O(n \log^2 n)$ and this algorithm also takes $O(|E_0| \log^2 n)$ complexity for communication compare to $O(n^2 \log^3 n)$. (Kutten b, 2001) claimed that this work extends the connectivity algorithm of Shiloach-Vishkin (Shiloach, 1982), which describes a "parallel model of computation."

(Kutten a, 2002) proposed an asynchronous solution of (Kutten b, 2001). (Kutten a, 2002) claimed that this algorithm terminates in time $\Delta T + O(\log n)$ and it uses "$O(n \log n)$ message totaling $O(|E_0| \log^2 n)$ bits".

3.1.7 Absorption (Randomized Resource Discovery) Algorithm

(Law, 2000) proposed a randomized resource discovery algorithm called "absorption algorithm" based on a strongly connected graph. According to this paper, this algorithm is developed in two stages. In stage 1, a network of n nodes is partitioned into clusters; each cluster has its leader node and all nodes in a cluster know their leader. In this stage, an ultimate leader is determined in the network. In stage 2, the ultimate leader of the network broadcasts the pointers to the each member of the network in one time step. The authors claimed that this absorption algorithm takes $O(\log n)$ steps time complexity, can send $O(n \log n)$ number of messages, and can pass $O(n^2 \log n)$ number of pointers with high probability.

3.1.8 Distributed Awareness Algorithm

After analyzing different algorithms of (Harchol-Balter, 1999), (Jun, 2000) proposed a new agent-based resource discovery algorithm called “Distributed Awareness Algorithm” and also they proposed a framework for dynamic assembly of agents based on this algorithm. Distributed awareness refers to a learning mechanism by which a node gets awareness about other nodes in a network. According to (Jun, 2000), in this algorithm, each node has an awareness table and each node exchanges the information of this awareness table with other nodes. A typical awareness table entry contains location of the node (IP address), when last heard from the node, when last time the awareness information was sent to the node. The authors claimed that this agent based resource discovery system could provide better discovery services using its agents’ autonomous behavior.

3.1.9 Data Flooding Based Data Dissemination Algorithm

(Maheswaran a, 2000) proposed an algorithm called “Data Dissemination Algorithm” which follows swamping approach (Harchol-Balter, 1999) for message distribution. When a message comes to a node, that message gets validated. This validation process relies on three types of dissemination, universal awareness that permits all incoming messages, neighborhood awareness that allows messages from a certain distance, and distinctive awareness, which discards messages if it finds out that the less Grid potentiality at the local node in remote node, is less than that of the requestor node.

In (Maheswaran a, 2000), the authors also measured the performance of “universal awareness”, “neighborhood awareness”, and “distinctive awareness” dissemination schemes. The authors claimed that universal approach is more expensive in terms of message complexity than that of neighborhood and distinctive approach. The authors also claimed that this new class of dissemination could reduce the communication overhead during the resource discovery.

3.1.10 Discovering Intermittently Available Resources (DIAR) Algorithm

(Huang, 2002) proposed an algorithm to discover the occasionally available resources in multimedia environment. The authors defined different policies for a QoS based resource discovery service for a given graph theoretic approach. They introduced a generalized version of Discovering Intermittently Available Resources (DIAR) algorithm based on occasionally available resources. They evaluated the performance of QoS policies based on different time-map strategies in a centralized system and they claimed that randomized placement strategies and increased server storage can facilitate better performance to discover a particular resource.

3.2 Protocols

Following protocols are identified in (Allen a, 2001), (Czajkowski a, 2001), (Czajkowski a, 2001), (Foster b, 2001), (Foster e, 2002), (Roszkowski, 1998), (Larson, 2001), (Verbeke, 2002):

3.2.1 Grid Information Protocol (GRIP)

According to (Czajkowski a, 2001), Grid Information Protocol (GRIP) is used to retrieve information of entities in VO (Foster b, 2001). According to (Czajkowski a, 2001), this protocol is one of the main fundamental building blocks of VO. (Allen a, 2001) proposed an adaptive resource selection mechanism to facilitate autonomous application migration for better resources due to degradation of resources during the execution and they use Grid Registration Protocol (GRRP) of Globus Monitoring and Discovery Service (MDS)(Foster d, 1997) to discover the resource.

3.2.2 Grid Registration Protocol (GRRP)

According to (Czajkowski a, 2001), Grid Registration Protocol (GRRP) is responsible for notifying aggregate directory services which refer to VO-specific resources, which are found by GRIP protocol. Both GRIP and GGRP are used by Globus metacomputing toolkit (Foster d, 1997). In (Allen a, 2001), they also use GRIP protocol of MDS to discover the resource in proposed adaptive resource selection mechanism. The authors of (Allen a, 2001) claimed that this service queries appropriate aggregate (e.g. GRRP) to discover a “potentially interesting” resource and it uses GRIP to locate that resource during the execution of the application.

3.2.3 Lightweight Directory Access Protocol (LDAP)

LDAP protocol is used for retrieving and updating information in a X.500 (to store information in a directory based on certain regulations) model based directory. According to (Foster b, 2001), a LDAP server speaks LDAP protocol and it also makes response to the query. (Czajkowski b, 1998) showed how Lightweight Directory Access Protocol (LDAP) enabled Globus Monitoring and Discovery Service (MDS) can be used as an information service, which is responsible for providing current availability and capability of resources. “Project Isaac”, which was introduced by (Roszkowski, 1998) also uses Lightweight Directory Access Protocol (LDAP).

3.2.4 Common Indexing Protocol (CIP)

According to (RFC-2651, 1999), Common Indexing Protocol (CIP) is used to pass indexing information from server to server to facilitate query routing or redirecting to a client. Project Isaac also uses common Indexing Protocol (CIP) (Roszkowski, 1998).

3.2.5 Z39.50

According to (Larson, 2001), Z39.59 is an information retrieval protocol, which was developed by American National Information Standards Organization (NISO). (Larson, 2001) presented a development technique of developing a cross-domain resource discovery database using Z39.50 protocol and they used Z39.50 “Explain Database” to select the databases and to search the “Explain Database” to extract the server information using probabilistic algorithm to retrieve and rank the collection of information to the user for selection.

3.2.6 JXTA

As stated in jxta.org[1], "JXTA protocols are a set of protocols, which are designed for ad hoc, pervasive, and multi-hop peer-to-peer (P2P) network computing. Using the JXTA protocols, peers can cooperate to form self-organized and self-configured peer groups independent of their positions in the network (edges, firewalls, network address translators, public vs. private address spaces), and without the need of a centralized management infrastructure." (Verbeke, 2002) presented a framework for large-scale computations for "coarse-grained" parallelization. The components of this proposed framework are based on JXTA protocol, which can facilitate a dynamic and decentralized organization of computation resources. In this framework, JXTA protocol facilitates dynamic aspect of grid through peer discovery where nodes are added or removed during the job execution.

3.2.7 Simple Object Access Protocol (SOAP)

According to (Foster e, 2002), SOAP is an enveloping mechanism for carrying XML payloads. This protocol provides a message passing mechanism to exchange information between service provider and requestor. SOAP payload can be carried HTTP, FTP, JMS (Java Messages Service), etc.

3.2.8 Network-Efficient Vast Resource Lookup At Edge (NEVRLATE)

(Chander, 2002) proposed a protocol called NEVRLATE (Network-Efficient Vast Resource Lookup At Edge) that facilitates a scalable resource discovery service and it is used for vast resource discovery. NEVRLATE organizes directory service mainly in two-dimensional Grids, registration to the resources is stored in one horizontal dimension and lookup is occurred in vertical dimension. The main

[1] http://spec.jxta.org/v1.0/docbook/JXTAProtocols.html

specialty of this protocol is to organize n servers into a flexible structure takes $O\sqrt{n}$ message complexity mainly for registration and discovery of the resource. They claimed that NEVRLATE service could provide a scalable worldwide "semantic" and "extended web" infrastructure.

3.3 Approaches

Following resource discovery mechanisms are identified in (Iamnitchi a, 2001), (Iamnitchi b, 2002), (Iamnitchi c, 2002), (Rana a, 2001), (Jun, 2000), (Ludwig, 2002), (Li-Xu, 2002), (Maheswaran a, 2000), (Huang, 2002), (Wolski, 1999):

3.3.1 Peer-to-Peer Approach

(Iamnitchi a, 2001), (Iamnitchi b, 2002), (Iamnitchi c, 2002) discussed peer-to-peer resource discovery in detail. (Iamnitchi a, 2001) proposed peer-to-peer resource discovery architecture for a large collection of resources. The authors of (Iamnitchi a, 2001) claimed that this decentralized resource discovery architecture could lessen huge administrative burden as well as it can also provide very effective search-performance result. They analyzed this resource discovery mechanism on up to 5000 peers based on the assumption that every peer provides at least one resource.

In (Iamnitchi c, 2002), author discussed different resource discovery problems in a large distributed resource-sharing environment specially in a grid environment. In this document, author identified four different architectural components called "Membership protocol", "Overlay construction", "Preprocessing", and "Request processing". Author also identified four environment parameter factors, which dominate the performance and design strategies for a resource discovery solution. These four factors are "Resource information distribution and density", "Resource information dynamism", "Request popularity distribution", "Peer participation".

In (Iamnitchi b, 2002), the authors gave a brief description of different resource discovery approaches in peer-to-peer networking. The authors claimed that using four axes framework (Iamnitchi c, 2002), it is possible to design any resource discovery architecture in a grid.

(Hoschek a, 2002) proposed a general purpose query support enabled “Unified Peer-to-Peer Database Framework (UPDF)” for large distributed systems. UPDF can be identified as a peer-to-peer database framework for a general purpose query support which is unified because it supports arbitrary query languages, random node topologies, different data types, different query response modes, different neighbor selection policies for expressing specific applications.

3.3.2 De-Centralized approach

(Iamnitchi a, 2001) and (Rana a, 2001) discussed this approach. (Rana a, 2001) described a de-centralized resource management and discovery architecture based on interacting software agents where agents can represent as a service, an application, a resource or a matchmaking service. The authors of (Rana a, 2001) showed that this proposed approach could provide dynamic registration of resources and user task. According to this paper, this approach is basically a matchmaking approach, which can facilitate dynamic resource management and resource discovery in a grid environment, which is based on XML documents, which provide the resource availability, resource capability.

3.3.3 Agent-Based Approach

(Jun, 2000) presented a distributed resource discovery method for a large wide area distributed system. This paper presents different resource discovery algorithms mainly flooding algorithm, swamping algorithm, random pointer jump algorithm, and name dropper algorithm. After analyzing all these algorithms the authors proposed a new agent-based resource discovery algorithm called “Distributed Awareness Algorithm” and they also proposed a framework for dynamic assembly of agents based on this algorithm. Distributed awareness refers to a learning mechanism in which a node gets awareness about other nodes in a network. In this algorithm, each node has an awareness table and each node exchanges the information of this awareness table with other nodes. A typical awareness table entry contains location of the node (IP address), when last heard from that node, when last time the awareness information was sent to the node.

They also claimed that this agent based resource discovery system can provide better discovery services using its agents' autonomous behavior and some other existing technology including "Bond agents", and some existing JPython written resource monitoring software.

3.3.4 Ontology Description- Based Approach

Ontology refers to a description of a service (resource), (Ludwig, 2002) proposed a semantic service discovery framework in a grid environment. They proposed a service matchmaking mechanism based on ontology knowledge and they claimed that this matchmaking framework can provide a better service discovery and also can provide close matches. The main idea behind this approach is the advertisement of the resource. In this approach, service provider registers its service description into the service registry database. When a Grid application sends a request to service directory, matchmaker returns the matches to the service requester. Requester chooses the best resource based on the specific need.

3.3.5 Routing Transferring Model-Based Approach

(Li-Xu, 2002) proposed a resource discovery technique called Routing-Transferring Model. This model consists of three basic components - resource requester, resource router and resource provider. The provider sends the resource information to a router and router stores that information in a router table. After that, when requester sends a request to the router, router checks its routing table for an appropriate resource provider and after finding that entry router forwards that request to the service provider or another router. The authors formalized this model and they analyzed the complexity of Shortest Distance Routing Transferring (SD-RT) algorithm based on this formalization. They claimed that resource discovery time depends on topology and they also showed that SD-RT could locate a resource in the shortest time, if the topology and distribution of resources are explicit. They examined their proposed model in Vega Grid project and their experiment shows that higher frequency and more location of resources can reduce the resource discovery time.

3.3.6 Parameter-Based Approach

(Maheswaran a, 2000) examined different approaches for resource discovery in a grid system. A new concept "Grid potential" is proposed in this paper, which encapsulates the processing capabilities of different resources in a large network. The authors also proposed an algorithm called "Data Dissemination Algorithm". This algorithm follows swamping approach (Harchol-Balter, 1999) for message distribution. When a message comes to a node, that message gets validated. The validation process depends on three types of dissemination, universal awareness that permits all incoming messages, neighborhood awareness that allows messages from a certain distance, and distinctive awareness, which discards messages if it finds out that the less Grid potentiality at the local node in remote node, is less than that of the requestor node. The authors also measured the performance of "universal awareness", "neighborhood awareness", and "distinctive awareness" dissemination schemes. The authors claimed that universal approach is more expensive in terms of message complexity than that of neighborhood and distinctive approach. The authors also claimed that this new class of dissemination could reduce the communication overhead during the resource discovery.

3.3.7 Quality of Service (QoS)-based Approach

(Huang, 2002) proposed an algorithm to discover the occasionally available resources in a multimedia environment. In this paper, the authors defined different policies for a QoS based resource discovery service for a given graph theoretic approach. They introduced a generalized version of Discovering Intermittently Available Resources (DIAR) algorithm based on occasionally available resources. They evaluated the performance of QoS policies based on different time-map strategies in a centralized system. Through the experiment they found out randomized placement strategies and increased server storage can facilitate better performance to discover a particular resource.

3.3.8 Request Forwarding Approach

According to (Iamnitchi b, 2002), (Iamnitchi c, 2002), following four-request forwarding approaches are identified.

3.3.8.1 Random Walk Approach

In this approach, to forward the request, the node is chosen randomly.

3.3.8.2 Learning-Based Approach

As discussed in (Iamnitchi b, 2002), (Iamnitchi c, 2002), a request is forwarded to a node who answered similar request before. If no similar answer is found, the request is forwarded to a randomly chosen node.

3.3.8.3 Best-Neighbor Approach

The number of received answer is recorded without recording the type of requests. The request is forwarded to that node which answered highest number of requests.

3.3.8.4 Learning-Based + Best-Neighbor Approach

This approach to identical to learning-based approach except when no similar answer is found, request is forwarded to the best neighbor.

According to (Iamnitchi a, 2001), (Iamnitchi c, 2002), the authors analyzed this resource discovery mechanism in an “emulated” grid, which is a large grid network (for this case up to 5000 peers) based on the assumption that every peer provides at least one resource. The authors measured performance evaluation of a simple resource discovery technique based on “request propagation”. The authors found that learning-based approach performs better among four request propagation approaches. The authors also claimed that best-neighbor approach works well in an unbalanced distribution, and although random walk approach performs well in equally distributed resources, but it performs satisfactory in all cases.

3.4 Discovery mechanisms on Different Architectures

3.4.1 Globus

(Foster d, 1997) presented a metacomputing infrastructure toolkit called Globus, which was originally developed to integrate geographically distributed resources including supercomputer, cheap desktop, large databases, storages, scientific tools and together they can form distributed virtual supercomputers. In (Foster d, 1997), the authors described data communication, resource discovery, resource allocation, and authentication. In Globus toolkit, basic low level mechanism such as network information, communication, authentication are provided along with high level metacomputing services such as parallel programming tools(MPI) and different schedulers (DUROC). The authors presented this work as an initiative to achieve a large target mainly developing an Adaptive Wide Area Resource Environment (AWARE), which was described as a set of high-level services, an appropriate infrastructure for dynamically changing behavior of metacomputing environments. Globus uses GRRP and GRIP protocols to discover the resources in VO.

3.4.2 Ninja Service Directory Service

(Czerwinski, 1999) presented an architecture and implementation of secure service discovery service (SDS) called Ninja Service Directory Service- a Java-based implementation. SDS is a two-way service where service providers provide complex advertisement of available or currently running resources. On the other hand, client uses SDS to query for locating the resources. In this architecture, the Extensible Markup Language (XML) is used to describe the resource and queries. According to this paper, security is the core component of SDS. They claimed that this service can provide highly available, fault tolerant and intermittently available services and it also can provide effective search result to the client.

3.4.3 Open Grid Service Architecture (OGSA)

(Foster e, 2002) described a web service enabled grid architecture called Open Grid Service Architecture (OGSA), which supports creation, termination, job management and invocation of unpredictable services through standard interfaces and conventions. The authors investigated three main web service standards mainly Simple Object Access protocol (SOAP), Web Services Description Language (WSDL), WS-Inspection. Because of dynamic nature of WSDL specially on “registering and discovering interface definition, endpoint implementation description” and generating proxy dynamically the authors chose WSDL as the main web service standard of OGSA. In OGSA, everything is referred to as a grid service and this grid service is expressed using Web Services Description Language (WSDL) for lifetime management, discovery mechanism and notification, etc. In OGSA, information about a Grid service which is referred as “service data” and facilitates helps

"FindServiceData" to discover a resource. In (Foster e, 2002), the authors represented OGSA as a natural evolution of Globus toolkit (Foster d, 1997) specially version 2. (Foster e, 2002) is also identified as the solution to the question "how grid functionality can be incorporated into a Web services framework "which was raised in (Foster b, 2001).

(Curcin, 2002) proposed a next generation grid-enabled data mining architecture called "Discover Net". According to (Curcin, 2002), (Ghanem, 2002), proposed approach is built on top of OGSA standard. This approach is originated for the ongoing needs of bioinformatics industry where data analysis is very complicated and it uses data-pipelined approach. This approach is developed based on the service model concept that allows any service-based architecture. According to (Curcin, 2002) knowledge discovery service has two main sub-services called computation service and data service. Computation service refers to define and compose the analysis of data according to different data. According to (Ghanem, 2002), this service is used to create and manage "complex knowledge discovery workflows that integrate data and analysis routines provided as remote services". In Discovery Net, Knowledge Discovery Look-up and Registration servers facilitate publication and retrieval of "data analysis services".

3.4.4 Web Service Discovery Architecture (WSDA)

(Hoschek b, 2002) proposed a unified and modular service discovery architecture for Grid computing, called Web Service Discovery Architecture (WSDA), which can be used in run time to discover and adapt appropriate remote services. WSDA facilitates an interoperable web service discovery layer by defining industry standard appropriate services, interfaces, and protocol bindings. The communication primitives facilitate service identification, retrieval of service description in a Grid computing environment. WSDA and OGSA (Foster e, 2002) are proposed for fulfillment of almost same set of targets but they are both independent in nature. The main difference between OGSA and WSDA is

OGSA is restricted to map a Grid Service Handle (GSH) to a Grid Service Reference (GSR) and in OGSA it is not obvious that every legal HTTP URL is a GSH; on the other hand in WSDA every legal HTTP link is a valid service link.

3.4.5 Nimrod/G

(Buyya a, 2000) proposed a “component based architectural design for Nimrod-G” which was implemented using different middleware services. Nimrod/G is a grid-enabled resource management service, which is an extended version of their previous “Nimrod” resource management architecture. This new Nimrod/G uses Globus Resource Allocation Manager (GRAM) to allocate the resource, Monitoring and Discovery (MDS) service to monitor and discover the resource, Grid Directory Information services for resource sharing. The authors of (Buyya a, 2000) claimed that Nimrod/G could make good scheduling decisions.

3.4.6 InfoGram

(Laszewski, 2002) proposed a new Grid service for Globus infrastructure called InfoGram. According to this paper new service can combine two other previously implemented services, information service and job execution service, into one service. They claimed that this new proposed service could simplify the Globus architecture significantly. The authors also believe that it is possible to integrate their proposed information service to existing Globus MDS service. The research work described in this paper is part of Globus project. The authors claimed that it is possible to execute untrusted applications in trusted in this proposed infrastructure.

3.4.7 MapCenter

(Bonnassieux, 2003) proposed a web-based visualization model, called MapCenter for monitoring resources in a grid and currently this model is used for monitoring European DataGrid. This model is a high-level model and it is developed on top of "Grid Information Service" which is described in (Czajkowski a, 2001). This model is designed to graphically display all resources, services running over the system. The basic idea behind this approach is to query MDS to retrieve "Resource Discovery", "Logical Discovery" and "Location Discovery" information. The development of MapCenter approach is still an on going process and according to (Bonnassieux, 2003), more new functionalities will be added over "E-toile" and "the French Grid Project".

3.4.8 XenoServer

According to (Kotsovinos, 2002), XenoServer is a distributed platform for a wide area network. XenoCorp is responsible for locating appropriate XenoServers for a particular job. XenoCorp uses matchmaking technique to locate the resource between clients and XenoServers. According to this paper, any client from anywhere can submit a job for execution on the XenoServer platform and the client has to pay for used resource to the sponsor.

3.4.9 Universal Description, Discovery and Integration (UDDI)

According to (UDDI, 2000), UDDI is a specification for distributed web-based information registers for web services. UDDI is a specification to publish and discover information of "Web services". According to this technical paper, Web service is an internet-based service, which can provide a specific service to another company or a software program to complete a particular task. XML based UDDI business registration service publishes information about a service for other interested party though "white pages", "yellow pages" and "green pages" components.

4 Resource discovery in other areas

4.1 Mobile Ad-hoc Network

(Doval, 2002) proposed a discovery system, which provides resource location in a simple, platform-independent way for mobile networks. In this paper, they presented "Nom", a peer-to-peer protocol based decentralized resource location and discovery system for mobile networks. In Nom architecture, each node has its own Nom code which is responsible for monitoring network traffic of local node to discover resource location queries and "using standard messages to resolve those queries and provide resource location to application-level code".

4.2 Topical Web

(Aggarwal, 2001) proposed an intelligent crawling mechanism using self-learning crawling approach for "topical" resource discovery. This proposed intelligent web crawler uses linking website content, candidate URL structure, or siblings to estimate the probability "that a candidate is useful for a given crawl". Since Conventional topical or query based searching technique needs a good amount of storage, this proposed intelligent crawling mechanism could be an alternative to solve this problem.

5 Concluding Remarks

Resource discovery is one of the most important aspects of ongoing Computational Grid research. Success of Computational Grid depends on locating appropriate resources for a specific task. This survey identified several resource discovery algorithms that can be implemented in Computational Grid. Name-Dropper algorithm achieves near-optimal performance both with respect to time complexity and network communication complexity (Harchol-Balter, 1999). (Iamnitchi a, 2001) tested a decentralized resource discovery mechanism over 5000 peers and they claimed that a decentralized approach can provide promising performance result and they developed a correlation between discovery performance and sharing characteristics. Resource monitoring (current status of the resource) also can ensure the best usages of the resources in a Computational Grid. (Wolski, 1999) discussed the short and medium-term forecasting of CPU availability of time-shared UNIX systems for Grid computing. They suggest that CPU prediction is very useful for process scheduling and resource discovery (selection) in a large distributed network like Computational Grid. (Bonnassieux, 2003) presented a high-level user-friendly resource discovery mechanism, MapCenter approach. Most of the Grid toolkits and infrastructure currently use Monitoring and Discovery service (MDS) of Globus toolkit (Laszewski, 2002), (Allen a, 2001), (Buyya a, 2000). Several promising and efficient algorithms, protocols, resource discovery mechanisms were identified through this survey, which, if implemented, can enhance the performance and effectiveness of Computational Grids. The concept of benchmarking has been used in several other fields; however it may also be implemented in the existing Grid systems for which a “comprehensive software infrastructure” is needed. A good future direction for research would be to measure the overhead of different existing Grid services and to measure their impact of “application performance” (Snavely, 2003).

Appendix-i

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[93]. (Stoica, 2001) I. Stoica, R. Morris, D. Karger, M. Kaashoek, H. Balakrishnan, "Chord: A Scalable Peer-to-peer Lookup Service for Internet Applications," *ACM SIGCOMM 2001*, pp: 149-160, 2001

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[97]. (Swany b, 2002) M. Swany , R. Wolski, "Building performance topologies for computational grids," *Proc. of the LACSI Symposium*, Santa Fe, October 2002

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URL:
http://www.uddi.org/pubs/Iru_UDDI_Technical_White_Paper.pdf

[99]. (Verbeke, 2002) J. Verbeke, N. Nadgir, G. Ruetsch,I. Sharapov, "Framework for Peer-to-Peer Distributed Computing in a Heterogeneous, Decentralized Environment," *Proc of Third International Workshop on Grid Computing – GRID 2002*, Baltimore, MD, USA, , LNCS 2536, pp: 1 ff,Springer-Verlag, 2002

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Appendix-ii

Annotated Bibliography

[1]. (Aggarwal, 2001) C. Aggarwal, F. Al-Garawi, P. Yu, "On the design of a learning crawler for topical resource discovery," *ACM Transactions on Information Systems (TOIS)***,** vol. 19 Issue: 3, pp: 286-309, 2001

Keywords: learning crawler, topical resource discovery, world wide web, web crawler, URL token based learning, link based learning, sibling based learning, intelligent crawler algorithm

In this paper, the authors propose an intelligent crawling mechanism using self-learning crawling approach for "topical" resource discovery. This proposed intelligent web crawler uses linking website content, candidate URL structure, or siblings to estimate the probability "that a candidate is useful for a given crawl". Since Conventional topical or query based searching technique needs a good amount of storage, this proposed intelligent crawling mechanism could be an alternative to solve this problem.

[2]. (Allen a, 2001) G. Allen, D. Angulo, I. Foster, G. Lanfermann, C. Liu, T. Radke, E. Seidel, J. Shalf, "The Cactus Worm: Experiments with Dynamic Resource Discovery and Allocation in a Grid Environment, " *A technical Report: TR-2001-28*,University of Chicago, 2001

Keywords: Cactus, resource discovery, grid environment, adaptive resource selection mechanism, application migration, Globus, contract violation, resource selection, GRAM, GrADS

In this paper, the authors propose an adaptive resource selection mechanism to facilitate autonomous application migration for better resources due to degradation of resources during the execution. The authors use Grid Registration Protocol (GRRP) and Grid Information Protocol (GRIP) of Globus Monitoring and Discovery Service (MDS) to discover the resource. Basically this service queries appropriate aggregate (e.g. GRRP) to discover a "potentially interesting" resource and it uses GRIP to locate that resource during the execution of the application.

The contribution of this paper is migration to better resource due to contract violation and a Grid-enabled application framework to facilitate the better service.

[3]. (Bonnassieux, 2003) F. Bonnassieux, R. Harakaly, P. Primet, "Automatic services discovery, monitoring and visualization of grid environments: the MapCenter approach," *Across Grid conference*, Santiago de Compostela, Spain, 2003

Keywords: MapCenter, Open Grid, Visualization tool, European DataGRID, Grid environment, Grid Information System, heterogeneous environment, Virtual organizations, ubiquity, dynamicity, SNMP

In this paper, the authors propose a web-based visualization model for monitoring resources in a grid and currently this model is used for monitoring European DataGrid. This model is a high-level model and it is developed on top of "Grid Information Service" which is described in (Czajkowski a, 2001). This model is designed to graphically display all resources, services running over the system. The basic idea behind this approach is to query MDS to retrieve "Resource Discovery", "Logical Discovery" and "Location Discovery" information .The development of MapCenter approach is still an on going process and according to this paper more new functionalities will be added over "E-toile" and "the French Grid Project".

[4]. (Buyya a, 2000) R. Buyya, D. Abramson, J. Giddy, "Nimrod/G: An Architecture for a Resource Management and Scheduling System in a Global Computational Grid, " *Proc. of the HPC ASIA'2000, the 4th International Conference on High Performance Computing in Asia-Pacific Region, Beijing, China,* IEEE Computer Society Press, USA, 2000

Keywords: Nimrod, Nimrod/G, resource management, resource scheduling, computational grid, wide-area cluster computing, GUSTO, parametric engine, MDS server, GRAM server, job wrapper, dispatcher

In this paper, the authors propose a "new component based architectural design for Nimrod-G" which is implemented using different middleware services. This proposed Nimrod/G is a grid-enabled resource management service, which is an extended version of their previous "Nimrod" resource management architecture. This new Nimrod/G uses Globus Resource Allocation Manager (GRAM) to allocate the resource, Monitoring and Discovery (MDS) service to monitor and discover the resource, Grid Directory Information services for resource sharing. In this paper, the authors claim that Nimrod/G can make good scheduling decisions.

[5]. (Buyya c, 2000) R. Buyya, S. Chapin, D. DiNucci, "Architectural Models for Resource Management in the Grid," *The First IEEE/ACM International Workshop on Grid Computing (GRID 2000), Springer Verlag LNCS Series*, vol. 1971, pp: 18-35, 2000

Keywords: Architectural model, resource management, Grid, geographically distributed resources, resource management polices, access-and-cost model, hierarchical model, abstract owner model, computational market model

In this paper, the authors discuss three different management models for grid resource management named hierarchical model, abstract owner model and (computational) market model. Hierarchical model contains different active and passive components for grid computing. As for example "Domain Control Agents" is an active component, which can provide state information through publishing in an information service or through direct query. Abstract owner model refers to an order and delivery and result gathering approach. The (computational) market model refers to mixture of both hierarchical and abstract owner model and it refers to a computational economy development in grid resource management. The authors believe that one or more discussed model can be mapped with existing or future grid systems.

[6]. (Chander, 2002) A. Chander, S. Dawson, P. Lincoln, D. Stringer-Calvert, "NEVRLATE: scalable resource discovery," *Cluster Computing and the Grid 2nd IEEE/ACM International Symposium CCGRID2002*, pp: 382, 2002

Keywords: NEVRLATE, scalable resource discovery, peer-to-peer network, resource lookup, JXTA, UUDI, URI, Gnutella, fault tolerance, Freenet's architecture

In this paper, the authors propose a protocol called NEVRLATE (Network-Efficient Vast Resource Lookup At Edge), which facilitates scalable resource discovery service. NEVRLATE organizes directory service mainly in two-dimensional Grids, registration to the resources is stored in one horizontal dimension and lookup is occurred in vertical dimension.

The main contribution of this work is to organize n servers into a flexible structure takes $O\sqrt{n}$ message complexity mainly for registration and discovery of the resource. The authors believe that this NEVRLATE service can provide a scalable worldwide "semantic" and "extended web" infrastructure.

[7]. (Curcin, 2002) V. Ćurčin , M. Ghanem , Y. Guo , M. Köhler , A. Rowe , J. Syed , P. Wendel, "Discovery net: towards a grid of knowledge discovery," *Proc. of the eighth ACM SIGKDD international conference on Knowledge discovery and data mining,* pp: 658-663, 2002

Keywords: Discovery Net, Grid, knowledge discovery, distributed knowledge discovery, virtual organizations, KDD process, KDD algorithm, virtual organization, service registration, service location resolution, resource discovery server, knowledge server

In this paper, the authors propose a next generation grid-enabled data mining architecture called "Discovery Net". This approach is made originated the ongoing needs of bioinformatics industry where data analysis is very complicated and it uses data-pipelined approach. This approach is created based on the service model concept "that allows any service-based architecture of the emerging gird to be used". According to this paper, knowledge discovery service has two main service called computation service and data service. Computation service refers to define and compose the analysis of data according to different data preparation and data mining algorithm. On the other hand data service refers to user-defined "composition of function as discovery processes".

[8]. **(Czajkowski a, 2001) K. Czajkowski, S. Fitzgerald, I. Foster, C.Kesselman, "Grid Information Services for Distributed Resource Sharing," *Proc. of the Tenth IEEE International Symposium on High-Performance Distributed Computing (HPDC-10),* IEEE Press, 2001

Keywords: Grid, Grid information service, distributed resource sharing, virtual organization, Monitoring of resources, dynamic behavior of resources, Grid software infrastructure, registration protocol, MDS, Globus Grid toolkit, GRIS

In this paper, the authors describe a secure, scalable Grid information service architecture which contains simple data models, query protocol for grid services and "supports the creation of a wide variety of specialized information service" as well as other high level service like information-intensive services. Their implemented infrastructure, MDS-2 has already been widely deployed in different configuration as part of Globus v.1.1.3 and higher. In this infrastructure, the authors focus on "efficient delivery of state information from a single source" which refers to accurate local state or consistent global state of resources.

This paper describes a basic resource discovery and resource management in Grid computing and this Grid Information service contains two fundamental components called "distributed information providers" and "aggregate directory service". This paper is a very fundamental paper and based on this paper Grid Information Service is getting effective day by day with the evolution of Globus Grid Toolkit.

[9]. **(Czajkowski b, 1998) K.Czajkowski, I. Foster, N. Karonis, C. Kesselman, S. Martin, W.Smith, S.Tuecke, "A resource management architecture for metacomputing systems," *The 4th Workshop on Job Scheduling Strategies for Parallel Processing*, pp: 62–82.Springer-Verlag LNCS 1459, 1998

Keywords: Resource management architecture, metacomputing system, GUSTO, site autonomy, heterogeneous substrate, policy extensibility, co-allocation, online control, wide-area scheduling system, RSL, GlobusView, GRAM, Resource broker, graphical resource selector

In this paper, the authors describe a resource management architecture for metacomputing infrastructure. The authors mainly concentrate on five complicated resource management issues in large distributed system mainly "site autonomy", "heterogeneous substrates", "policy extensibility", "co-allocation" and "online control". In this paper, the authors describe how these issues have been solved in Globus metacomputing infrastructure and they implemented different resource management strategies based on particular needs.

The authors also present a comparison of Globus with different other existing resource management services and they showed the superiority of Globus. In this paper, the authors also show that how Lightweight Directory Access Protocol (LDAP) enabled Globus tool Monitoring and Discovery Service (MDS) can be used as an information service which is responsible for providing current availability and capability of resources.

[10]. (Czerwinski, 1999) S. Czerwinski, B. Zhao, T. Hodes, A. Joseph, R. Katz, "An architecture for a secure service discovery service," *In Mobicom '99*. ACM Press, pp: 24-35, 1999

Keywords: Service discovery service (SDS), Service description, hybrid access control, service – specific capabilities, Ninja service discovery service, session specification protocol, hierarchical organization, SDS server, certificate authority, capability manager, bootstrapping, XML search

In this paper, the authors present an architecture and implementation of secure service discovery service (SDS). SDS is a two way service where service providers provide complex advertisement of available or currently running resources. On the other hand, client uses SDS to query for locating the resources.

The Extensible Markup Language (XML) is used to describe the resource and queries. According to the authors, security is the core component of SDS. They show that SDS can provide highly available, fault tolerant and intermittently available services and it also can provide effective search result to the client. To get the effective search result the authors implemented a service called "Ninja Service Directory Service", which is developed in Java.

[11]. (Doval, 2002) D. Doval, D. O'Mahony, "Nom: Resource Location and Discovery for Ad Hoc Mobile Networks," *In Proceedings of The First Annual Mediterranean Ad Hoc Networking Workshop*, Med-hoc-Net 2002, Sept 4-6, Sardegna, Italy, 2002,

Keywords: Mobile Ad Hoc Networks, Resource Location and Discovery, Name Resolution, Self-Configuration, Self-Organizing Networks

In this paper, the authors present "Nom", a peer-to-peer protocol based decentralized resource location and discovery system for mobile networks. In Nom architecture, each node has its own Nom code which is responsible for monitoring network traffic of local node to discover resource location queries and "using standard messages to resolve those queries and provide resource location to application-level code". This paper proposed a discovery system, which provides resource location in a simple, platform-independent way for mobile networks.

[12]. **(Foster a, 1998) I. Foster, C. Kesselman (eds.). "Computational Grids," *The Grid: Blueprint for a New Computing Infrastructure*, Ch. 2, Morgan-Kaufman, San Francisco, 1998

Keywords: Computational Grids, electric power grid, distributed supercomputing, high-throughput computing, on-demand computing, data-intensive computing, collaborative computing, clusters, resource management

In this paper, the authors provide details purpose, shape, and architecture of a computational grid. In this paper, the authors present a formal definition of computation grid along with discussing six main important factors like why grid computing is needed, for what kind of activities, what kind of applications is needed, who will be the users, how the infrastructure will be used, how to build the grid and what kind of problems will be faced to design a grid. The authors give different directions to design and maintain a heterogeneous large distributed grid.

This paper is an overview of Computational grids where the authors discuss about different issues, from high level issues like philosophical issue to low level issues like designing a network protocol issue. This paper is identified as the first paper where different implementation strategies to build a complicated grid infrastructure are provided for the first time in details.

[13]. **(Foster b, 2001) I. Foster, C. Kesselman, S. Tuecke, "The Anatomy of the Grid - Enabling Scalable Virtual Organizations," *Proc. of First IEEE/ACM International Symposium on Cluster Computing and the Grid*, pp: 6 -7, 2001

Keywords: Grid computing, anatomy , large-scale resource sharing, virtual organizations, interoperability, virtual private network, distributed computing environment, fabric layer, connectivity layer, resource layer, collective layer, application layer,

In this paper, the authors discuss different resource sharing and resource using issues in dynamic, scalable virtual organizations (VO). The authors also provide requirements and framework to build up a Grid infrastructure to enable virtual organizations. The authors also discuss about how Grid technology is related to other technologies like peer-to-peer computing, virtual private network, etc.

In (Foster a, 1998), the authors discuss possible designing strategies to design a Grid. On the other hand in this paper, the authors concentrate on those issues more specifically. They show development of a detailed architecture and roadmap to design current and future Grid infrastructure.

[14]. **(Foster d, 1997) I. Foster, C. Kesselman, "Globus: A metacomputing infrastructure toolkit," *International Journal of Supercomputer Applications*, 11(2):115-128, 1997

Keywords: Metacomputing,distributed resources, networked virtual supercomputers, higher-level metacomputing service, lower-level metacomputing service, parallel programming, Adaptive Wide Area Resource Environment, I-WAY networking, desktop supercomputing, Globus toolkit

In this paper, the authors present a metacomputing infrastructure toolkit called Globus, which is originally developed to integrate geographically distributed resources including supercomputer, cheap desktop, large databases, storages, scientific tools and together they can form distributed virtual supercomputers. In this toolkit, basic low level mechanism such as network information, communication, authentication are provided along with high level metacmputing services such as parallel programming tools(MPI) and different schedulers (DUROC). The authors present this work as an initiative to achieve a large target mainly developing an Adaptive Wide Area Resource Environment (AWARE), which is described as a set of high-level services, appropriate for dynamically changing behavior of metacomputing environments.

The authors describe Globus toolkit in detail and propose different strategies for future. The authors specially talk about data communication, resource discovery, resource allocation, and authentication. Globus v.3 is currently available which is a quite mature metacomputing toolkit and new technology called Open Grid Service Infrastructure (OGSI) is built on top of Globus.

[15]. **(Foster e, 2002) I. Foster, C. Kesselman, J. Nick, S. Tuecke, “The Physiology of the Grid: An Open Grid Services Architecture for Distributed Systems Integration,” *Open Grid Service Infrastructure WG, Global Grid Forum,* 2002

Keywords: Virtual organization, Open Grid Service Architecture, Web Services Description Language (WSDL), web service framework, quality of services (QoS), Globus Toolkit, enterprise computing, host centric computing, distributed resources, eUtilities

The authors describe a web service enabled grid architecture called Open Grid Service Architecture (OGSA), which supports creation, termination, job management and invocation of unpredictable services through standard interfaces and conventions. They investigate three main web service standards mainly Simple Object Access protocol (SOAP), Web Services Description Language (WSDL), WS-Inspection. Because of dynamic nature of WSDL specially on "registering and discovering interface definition, endpoint implementation description" and generating proxy dynamically the authors choose WSDL as the main web service standard for OGSA.

In OGSA, everything is referred to as a grid service and this grid service is expressed using Web Services Description Language (WSDL) for lifetime management, discovery mechanism and notification, etc. In OGSA, information about a Grid service which is referred as "service data" and facilitates helps "FindServiceData" to discover a resource. In this paper, the authors represent OGSA as a natural evolution of Globus toolkit specially version 2.

This paper can be easily identified as the solution to the question "how grid functionality can be incorporated into a Web services framework "which is raised in (Foster b, 2001).

[16]. (Foster i, 2002) I. Foster, "The Grid: A New Infrastructure for 21st Century Science," *Physics Today*, 55(2):42-47, 2002

Keywords: Grid computing, Large Hadron Collider, Multics operating system, TeraGrid network, Science portals, distributed computing, Large-scale data analysis, Computer-in-the-loop instrumentation, Single sign-on, Community authorization and policy

In this article, the author presents history, on going process, future directions of grid computing in detail. Author provide a definition of grid computing "the Grid is a new class of infrastructure, which provides scalable, secure, high-performance mechanisms for discovering and negotiating access to remote resources, the Grid promises to make it possible for scientific collaborations to share resources on an unprecedented scale, and for geographically distributed groups to work together in ways that were previously impossible". According to this article, in 1965, Fernando Corbato and other designers of Multics operating system from MIT had foreseen a computer system, which is similar to power grid or water grid. In 1968 J. C. R. Licklider and Robert W. Taylor expected a Grid-like infrastructure in their paper "The Computer as a Communications Device".

[17]. (Ghanem, 2002) M. Ghanem, Y. Guo, A. Rowe, P. Wendel, "Grid-Based Knowledge Discovery Services for High Throughput Informatics," *11th IEEE International Symposium on High Performance Distributed Computing HPDC-11 20002 (HPDC'02)*, pp: 416, 2002

Keywords: knowledge discovery, high throughput informatics, Discovery Net, Discovery Process Markup Language (DPML), knowledge server, meta-information server, look-up and registration server, OGSA

In this paper, the authors discuss a new software called "Discovery Net" for Grid-based knowledge discovery services. These services are used to create and manage "complex knowledge discovery workflows that integrate data and analysis routines provided as remote services". In Discovery Net, Knowledge Discovery Look-up and Registration servers facilitate publication and retrieval of "data analysis services" .The low level grid-based resource management of this proposed approach is built based on Open Grid Service Architecture (OGSA) standard (Foster e, 2002).

[18]. (Harchol-Balter, 1999) M. Harchol-Balter, T. Leighton, D. Lewin, "Resource Discovery in Distributed Networks," *18th ACM Symposium on Principles of Distributed Computing*, pp: 229-237, 1999

Keywords: Resource discovery, distributed networks, name-dropper algorithm, flooding algorithm, swamping algorithm, random pointer jump algorithm, random pointer jump with back edge algorithm , clique, bounded Markov argument, large –scale distributed cache

The authors propose a new algorithm for querying resources in a weakly connected network where assumed that all machines already know each other. They propose “Name-Dropper” algorithm for resource discovery, which takes $O(\log^2 n)$ rounds to learn each other, $O(n^2 \log^2 n)$ number of connections and $O(n^2 \log^2 n)$ number of pointers in a network. In this paper, the authors prove that this new algorithm is more efficient in terms of required time and total number of network communications compare to four other algorithms, mainly “Flooding algorithm”, “Swamping algorithm”, “Random pointer jump algorithm”, and “Random pointer jump with back edge algorithm”.

The authors also claim that this algorithm achieves “near-optimal performance both with respect to time complexity and with respect to the network communication complexity”. This new algorithm is almost identical to “Random pointer” algorithm. The authors also claim that in worst-case $O(\log^2 n)$ rounds of “Name-Dropper” algorithm dominates over $\Omega(n)$ rounds of “Random pointer” algorithm, where n is the number of machines.

[19]. (Hoschek a, 2002) W. Hoschek, “A Unified Peer-to-Peer Database Framework for Scalable Service and Resource Discovery,” *Proc. of Third International Workshop on Grid Computing: GRID 2002,* Baltimore, MD. , pp: 126-144, Springer, 2002

Keywords: Data Grid, Unified peer-to-peer database framework (UPDF), XQuery, European Data Grid, Link Topology, peer-to-peer response mode, query processing, neighbor selection query, JXTA, DNS

In this paper, the authors propose a general-purpose query support enabled “Unified Peer-to-Peer Database Framework (UPDF)” for large distributed systems. UPDF can be identified as peer-to-peer database framework for a general purpose query support which is unified because it supports arbitrary query languages, random node topologies, different data types, different query response modes, different neighbor selection policies for expressing specific applications.

[20]. (Hoschek b, 2002) W. Hoschek, "The Web Service Discovery Architecture," *Proc. of the 2002 ACM/IEEE conference on Supercomputing*, pp: 1-15, 2002

Keywords: web service, discovery architecture, replica catalog, replica manager, Web Service Discovery Architecture (WSDA), MinQuery interface, XQuery, Peer Database Protocol (PDP), LDAP, MDS, UDDI

In this paper, the authors propose a unified and modular service discovery architecture for Grid computing, called Web Service Discovery Architecture (WSDA) which can be used in run time to discover and adapt appropriate remote services. WSDA facilitates an interoperable web service discovery layer by defining industry standard appropriate services, interfaces, protocol bindings. The communication primitives facilitate service identification, retrieval of service description in a Grid computing environment. WSDA and OGSA (Foster e, 2002) are proposed for fulfilling almost same set of targets but they are both independent in nature. The main difference between OGSA and WSDA is, OGSA is restricted to map a Grid Service Handle (GSH) to a Grid Service Reference (GSR) but in OGSA it is not obvious that every legal HTTP URL is a GSH; on the other hand in WSDA every legal HTTP link is a valid service link.

[21]. (Huang, 2002) Y. Huang, N. Venkatasubramanian, **"**QoS-based resource discovery in intermittently available environments,**"** *Proc. of 11th IEEE International Symposium on High Performance Distributed Computing,* pp: 50 -59, HPDC-11, 2002

Keywords: Quality of service (QoS), resource discovery, intermittently available environments, Global grid infrastructure, resource providers, time-map scenarios, graph-theoretic approach, network flow analogy, discovering intermittently available resources (DIAR), DIAR policy

In this paper, the authors propose an algorithm to discover the occasionally available resources in a multimedia environment. The authors define different policies for a QoS based resource discovery service for a given graph theoretic approach. They introduce a generalized version of Discovering Intermittently Available Resources (DIAR) algorithm based on occasionally available resources .They evaluate the performance of QoS policies based on different time-map strategies in a centralized system. Through the experiment they find out randomized placement strategies and increased server storage can facilitate better performance to discover a particular resource.

[22]. (Iamnitchi a, 2001) A. Iamnitchi and I. Foster, "On Fully Decentralized Resource Discovery in Grid Environments," *IEEE International Workshop on Grid Computing*, Denver, CO, pp: 51-62, 2001

Keywords: Decentralized resource discovery, computational grid, CPU load, peer-to-peer architecture, heterogeneity, dynamism, resource sharing, virtual organization, remote resource, request-forwarding algorithm

In this paper, the authors define the definition of resource and resource discovery. Resources are computers, cluster of computers, online instruments, storage space, data, application and a resource discovery mechanism returns the identity (may be location address(es)) of matching resources for a given description of desired resources.

In this paper, the authors propose a peer-to-peer resource discovery architecture for a large collection of resources. The authors claim that this decentralized resource discovery architecture can lessen huge administrative burden as well as it can also provide very effective search-performance result.

The authors analyze this resource discovery mechanism on up to 5000 peers based on the assumption that every peer provides at least one resource. The authors examined different request-forwarding algorithm to discover the resource and the authors concluded that "best-neighbor algorithm" works well in an unbalanced distribution, and although "random walk" algorithm performs well in equally distributed resources, but it performs satisfactory in all cases. At the end of this paper the authors give a hint that in near future the authors would design and evaluate different membership protocol and other request forwarding strategies.

[23]. (Iamnitchi b, 2002) A. Iamnitchi, I. Foster, Daniel C. Nurmi, "A Peer-to-Peer Approach to Resource Discovery in Grid Environments," *Proc. of the 11th Symposium on High Performance Distributed Computing,* Edinburgh, UK, 2002

Keywords: Resource discovery, peer-to-peer approach, emulated grid, unstructured networks, request propagation, random walks propagation, learning based propagation, best neighbor approach, Condor, Globus

The main focus of this paper is to give an idea that how peer-to-peer resource discovery approaches can be used in resource discovery in grid computing. The authors give a brief description of different resource discovery approaches in peer-to-peer networking. The authors propose a four axes framework and the authors believed that using this framework it is possible to design any resource discovery architecture in a grid.

This framework is first proposed in (Iamnichi c). In this paper the authors also examine this framework in an "emulated" grid, which is a large grid network and the authors measure performance evaluation of a simple resource discovery technique based on "request propagation" .The authors find that learning-based approach performs better among four request propagation approaches, mainly "random walk approach", "learning-based approach", "best neighbor approach", and "learning and best neighbor approach".

[24]. (Iamnitchi c, 2002) A. Iamnitchi, “Resource Discovery In Large-Scale Distributed Environments,” *Doctoral thesis proposal,* University of Chicago, 2002

Keywords: Resource location, Grid computing, peer-to-peer environments, Grid emulator, Membership protocol, Overlay construction, Preprocessing, Request processing, Distributed hash table, Resource information dynamism

In this proposal, the author discusses different resource discovery problems in a large distributed resource-sharing environment specially in a grid environment. In this document, author identifies four different architectural components in a general resource discovery solution called “Membership protocol”, “Overlay construction”, “Preprocessing”, “Request processing”. Author also identifies four environment parameter factors, which dominate the performance and design strategies for a resource discovery solution. These four factors are “Resource information distribution and density”, “Resource information dynamism”, “Request popularity distribution”, “Peer participation”. Author gives a hint at the end of her proposal that a peer-to-peer approach can be used to discover the resource in a grid environment.

[25]. (Jun, 2000) K. Jun, L. Bolon, K. Palacz, D. Marinescu, **“**Agent-based resource discovery,” *Proc. of IEEE Heterogeneous Computing Workshop, 2000. (HCW 2000),* pp: 43 -52, 2000
Keywords: Software agent, resource discovery, agent factory, monitoring agent, flooding algorithm, network gossiping, swamping algorithm, random pointer jump algorithm, Name-Dropper algorithm, distributed awareness algorithm, Bond

In this paper, the authors present a distributed resource discovery method in a large wide area distributed system. The authors also discuss about different resource discovery algorithms mainly flooding algorithm, swamping algorithm, random pointer jump algorithm, and name-dropper algorithm. After analyzing all these algorithms the authors propose a new agent-based resource discovery algorithm called “Distributed Awareness Algorithm” and also propose a framework for dynamic assembly of agents based on this algorithm. Distributed awareness refers to a learning mechanism by which a node gets awareness about other nodes in a network. In this algorithm, each node has an awareness table and each node exchanges the information of this awareness table with other nodes. A typical awareness table entry contains location of the node (IP address), when last heard from that node, when last time the awareness information was sent to the node.

The authors claim that this agent based resource discovery system can provide better discovery services using its agents' autonomous behavior and some other existing technology including "Bond agents", and some existing JPython written resource monitoring software.

[26]. (Kotsovinos, 2002) E. Kotsovinos, T. Harris, "Distributed resource discovery and management in the XenoServers Platform," *In Proc. of the 7th CaberNet Radicals Workshop, Bertinoro,* Italy, 2002

Keywords: distributed platform, resource discovery, resource management, XenoServers, computational grid, communication latency, network bottlenecks, web service mirroring, quality of service, resource manager

In this paper, the authors describe the goal of XenoServers, which is a distributed platform for a wide area network. According to this paper, any client from anywhere can submit a job for execution on the XenoServer platform and the client has to pay for used resource to the sponsor. XenoCorp is responsible for locating appropriate XenoServers for a particular job. XenoCorp uses matchmaking technique to locate the resource between clients and XenoServers.

[27]. (Krauter, 2000) K. Krauter, R. Buyyaa, and M. Maheswaran, "A Taxonomy and Survey of Grid Resource Management Systems," *Technical Report: Manitoba University (Canada) and Monash University (Australia),* 2000

Keywords: Computational Grid, Grid Resource Management, network computing system, data Grid, machine organization, resource namespace organization, resource information store organization, resource discovery, dissemination, scheduling policy, Condor

In this paper, the authors identify some key resource management approaches to design a comprehensive resource management system. The authors present resource management system as the core component of a network computing system (NCS). The authors discuss about different aspects of resource management, mainly quality of service (QoS) issue, different heterogeneity issues, different scheduling approaches, resource discovery technique, different resource distribution approaches. The authors give a hint about a possible resource discovery system where a resource management system could maintain a replicated network directory which may contain resource information and then resource discovery function query the "resource dissemination function" for a particular resource.

[28]. (Kutten a, 2002) S. Kutten, D. Peleg, "Asynchronous resource discovery in peer to peer networks," *Proc. of 21st IEEE Symposium on Reliable Distributed Systems,* pp: 224 -231, 2002

Keywords: Peer-to-peer, P2P, Topology changes, Topology knowledge loss, distributed algorithm, asynchronous algorithm, Gnutella, JXTA, weakly connected graphs

In this paper, the authors try to solve one problem in peer-to-peer networks, which is how to convey the routing information to each other in a network. The authors propose an asynchronous solution of (Kutten b, 2001). This work is basically continuation of (Harchol-Balter, 1999) and (Kutten b, 2001).

The authors claim that the algorithm terminates in $\Delta T + \mathrm{O}(\log n)$ time and it uses "$\mathrm{O}(n \log n)$ message totaling $\mathrm{O}(|E_0| \log^2 n)$ bits".

[29]. (Kutten b, 2001) S. Kutten, D. Peleg, U. Vishkin, "Deterministic resource discovery in distributed networks," *Proc. of the thirteenth annual ACM symposium on Parallel algorithms and architectures,* pp: 77-83, 2001

Keywords: Deterministic resource discovery, distributed networks, Name-Dropper algorithm, Merging trees, incoming edge, path shortening, hook on smallest, hook on smaller, Lipton's open question

In this paper, the authors propose a better algorithm for resource discovery compare to "Name-Dropper" algorithm (Harchol-Balter 99). In this paper, the authors propose a deterministic algorithm for the same problem described in (Harchol-Balter 99). Compare to the main randomized algorithm (Harchol-Balter 99) time complexity is reduced from $O(\log^2 n)$ to $O(\log n)$, for message complexity this improved algorithm takes $O(n \log n)$ compare to $O(n \log^2 n)$ and this algorithm also takes $O(|E_0| \log^2 n)$ complexity for communication compare to $O(n^2 \log^3 n)$. The authors claim that this work extends the connectivity algorithm of Shiloach-Vishkin, which describes a "parallel model of computation."

[30]. (Larson, 2001) R. Larson, "Distributed resource discovery: using z39.50 to build cross-domain information servers," *Proc. of the first ACM/IEEE-CS joint conference on Digital libraries***,** pp: 52-53, 2001

Keywords: Resource discovery, Cross-domain information server, distributed information retrieval, cross-domain resource discovery, distributed search, Z39.50 information retrieval protocol

In this paper, the authors present a development technique of developing a cross-domain resource discovery database using standard Z39.50 information retrieval protocol, which was developed by American National Information Standards Organization (NISO). In this system, the authors use Z39.50 "Explain Database" to select the databases and search the explain database to extract the server information. Probabilistic algorithm is used to retrieve and rank the collection of information to the user for selection.

[31]. (Law, 2000) C. Law, Kai-Yeung Siu, "An O(log n) randomized resource discovery algorithm," The14th International Symposium on Distributed Computing, Technical Report, Technical University of Madrid, pp: 5-8, Oct. 2000

Keywords: Distributed algorithm, resource discovery, randomized algorithm, graph-theoretic model, Name-Dropper algorithm, deterministic resource discovery algorithm, directed graph

In this paper, the authors view a network as a directed graph. If u, v are any two nodes of a network and if u knows v then an edge between u and v is created, $(u,v) \in E$. For any node u, if $(\Gamma(u)$ is the known set of u, then

$$(u,v) \in E \text{ iff } v \in \Gamma(u)$$

The authors suggest that goal of resource discovery algorithm based on a graph theory is to develop a complete graph from a given directed graph.

In this paper, the authors propose a randomized resource discovery algorithm called "absorption algorithm" based on a strongly connected graph. This algorithm is developed in two stages. In stage 1, a network of n nodes is partitioned into clusters; each cluster has its leader node and all nodes in a cluster know their leader. In this stage an ultimate leader is determined in the network. In stage 2, the ultimate leader of the network broadcasts the pointers to the each member of the network in one time step. The authors claimed that this absorption algorithm takes $\mathrm{O}(\log n)$ steps time complexity, can send $\mathrm{O}(n \log n)$ number of messages, and can pass $\mathrm{O}(n^2 \log n)$ number of pointers with high probability.

[32]. (Laszewski, 2002) G. Laszewski, I. Foster, J. Gawor, A. Schreiber, C. Pena, "InfoGram: A Grid Service that Supports Both Information Queries and Job Execution," *Proc. of the 11th IEEE International Symposium on High-Performance Distributed Computing (HPDC-11),* IEEE Press, pp: 333-342, 2002

Keywords: InfoGram, grid service, GRAM, MDS, information queries, job execution, caching, info degradation, xRSL, extensible information model

In this paper, the authors propose a new Grid service for Globus infrastructure called InfoGram. According to this paper this is a new service, which can combine two other previously implemented services, information service and job execution service, into one service. They claim that this new proposed service can simplify the Globus architecture significantly. The authors also claim that it is possible to integrate their proposed information service to existing Globus MDS service.

The research work is described in this paper is part of Globus project. One of the important contribution of this paper is in this service it is possible to execute untrusted applications.

[33]. (Li-Xu, 2002) W. Li, Z. Xu, F. Dong, J. Zhang, “Grid Resource Discovery Based on a Routing-Transferring Model,” *Proc. of Third International Workshop on Grid Computing: GRID 2002,* Baltimore, MD. , pp: 145-156, Springer, 2002

Keywords: Grid, Resource Discovery, Routing-Transferring model, resource requester, resource router, resource provider, Shortest Distance Routing Transferring algorithm (SD-RT), longest path, distribution of resource, Vega Grid project, dynamical resource

In this paper, the authors propose a resource discovery technique called Routing-Transferring Model. In short, this model consists of three basic component-resource requestor, resource router and resource provider. The service provider sends the resource information to a router and router stores that information in a router table. After that, when requestor sends a request to the router, router checks its routing table for an appropriate resource provider and after finding that entry router forwards that request to the service provider or another router. The authors formalized this model and they analyzed the complexity of Shortest Distance Routing Transferring algorithm based on this formalization.

They claim that resource discovery time depends on topology and they also show that SD-RT can locate a resource in the shortest time, if the topology and distribution of resources are explicit. They also show that higher frequency and more location of resources can reduce the resource discovery time. They prototype their proposed model in Vega Grid project.

[34]. (Ludwig, 2002) S. Ludwig, P. Santen, "A Grid Service Discovery Matchmaker based on Ontology Description," *Euroweb 2002 — The Web and the GRID: from e-science to e-business*, 2002
Keywords: Grid service, matchmaking, ontology description, service discovery service, open grid service architecture, resource description framework, ontology interface layer, DARPA's agent markup language, service discovery matchmaker, LARKS matchmaker

In this paper, the author shows that why an otology description for customized service discovery is useful. The authors propose a semantic service discovery framework in a grid environment. Author also proposes for a service matchmaking mechanism based on ontology knowledge and author claims that this matchmaking framework can provide a better service discovery and also can provide close matches.

[35]. (Maheswaran a, 2000) M. Maheswaran and K. Krauter, "A Parameter-based approach to resource discovery in Grid computing systems," *1st IEEE/ACM International Workshop on Grid Computing (Grid 2000)*, pp: 181-190, 2000
Keywords: Resource discovery, parameter-based approach, grid system, dissemination of resource statues, Grid potential, data dissemination algorithm, universal awareness, neighborhood awareness, distinctive awareness, flooding based data dissemination, swamping approach

In this paper, the authors examine different approaches for resource discovery in a grid system. A new concept "Grid potential" is proposed in this paper, which encapsulates the processing capabilities of different resources in a large network. The authors also propose an algorithm called "Data Dissemination Algorithm". This algorithm follows swamping approach (Harchol-Balter, 1999) for message distribution. When a message comes to a node, that message gets validated. This validation process relies on three types of dissemination, universal awareness that permits all incoming messages, neighborhood awareness that allows messages from a certain distance, and distinctive awareness, which discards messages if it finds out that the less Grid potentiality at the local node in remote node, is less than that of the requestor node.

In this paper, the authors also measure the performance of these three types of dissemination. The authors claim that universal approach is more expensive in terms of message complexity than that of neighborhood and distinctive approach. The authors also claim that this new class of dissemination can reduce the communication overhead during the resource discovery.

[36]. (Rana a, 2001) O. Rana, D. Bunford-Jones, D. Walker, M. Addis, M. Surridge, K. Hawick, "Resource discovery for dynamic clusters in computational grids," *IEEE Proc. of 15th International Parallel and Distributed Processing Symposium,* pp: 759 -767, 2001

Keywords: Resource discovery, computational grids, de-centralized approach, software agents, community interactions, matchmaking service, lookup service, Jini, TSpace, resource specification language, device ontology

In this paper, the authors describe a de-centralized resource management and discovery architecture based on interacting software agents where agents can represent as a service, an application, a resource or a matchmaking service. The authors claim that this proposed approach can provide dynamic registration of resources and user tasks. In this paper, the authors also provide a comparison between Jini and TSpace based on discovery and lookup services.

According to this paper, this approach is basically a matchmaking approach, which can facilitate dynamic resource management and resource discovery in a grid environment which is based on XML documents and which provides the resource availability, resource capability.

[37]. (Roszkowski, 1998) M. Roszkowski and C. Lukas, "A Distributed Architecture for Resource Discovery Using Metadata," *D-Lib Magazine: ISSN 1082-9873*, Internet Scout Project, Computer Sciences Department, University of Wisconsin-Madison, 1998

Keywords: Distributed computing, resource discovery, metadata, Lightweight Directory Access Protocol (LDAP), Common Indexing Protocol (CIP), Online Public Access Protocol (OPAC), Project Isaac

In this paper, the authors present an approach to connect geographically distributed collections of metadata to facilitate searching them as a single source of collections. This proposed architecture, "Project Isaac" uses standard internet protocol like Lightweight Directory Access Protocol (LDAP), Common Indexing Protocol (CIP) to query, and to get result and to exchange required indexing information. This proposed linked collection of metadata approach is an alternative to keyword indexing search for resource discovery. The authors present a comparison between "Project Isaac" and other similar metadata for resource discovery architecture mainly Dienst/NCSTRL, the AHDS HTTP/Z39.50 (Larson, 2001), ROADS approach and present some evidence why this approach is better than others.

[38]. (Snavely, 2003) A. Snavely, G. Chun, H. Casanova, R. Wijngaart, M. Frumkin, "Benchmarks for grid computing: a review of ongoing efforts and future directions" *Special section on grid computing, ACM SIGMETRICS Performance Evaluation Review*, vol. 30, Issue 4, 2003

Keywords: Benchmarks, Grid Computing, Global Grid Forum (GGF), high-performance computing, Informational Power Grid

In this paper, the authors discuss different ongoing efforts and future directions of benchmark for different aspects of Grid Computing including Grid applications, resource management, and different grid services. The authors make a comment that a "comprehensive software infrastructure" is needed, because different resource discovery approaches, security mechanism were already identified in (Foster b, 2001). The authors believe that this is the time now to measure the overhead of different existing services and to measure their impact of "application performance".

[39]. (UDDI, 2000) Universal Description, Discovery and Integration (UDDI): *Technical White Paper,* 2000
URL: http://www.uddi.org/pubs/Iru_UDDI_Technical_White_Paper.pdf
Keywords: web service, distributed web-based information, UDDI, UDDI business registry, UDDI discovery layer

In this technical paper, what is UDDI, what is a web service, different components of UDDI specification, and a technical overview of UDDI are given. According to this technical paper, UDDI is a specification for distributed web-based information registers for web services. UDDI is a specification to publish and discover information about "Web services". Web service is an internet-based service, which can provide a specific service to another company or a software program to complete a particular task. XML based UDDI business registration service publishes information about a service for other interested party though "white pages", "yellow pages" and "green pages" components.

[40]. (Verbeke, 2002) J. Verbeke, N. Nadgir, G. Ruetsch,I. Sharapov, "Framework for Peer-to-Peer Distributed Computing in a Heterogeneous, Decentralized Environment," *Proc of Third International Workshop on Grid Computing – GRID 2002*, Baltimore, MD, USA, , LNCS 2536, pp: 1-12, Springer-Verlag, 2002
Keywords: peer-to-peer computing distributed computing, heterogeneous environment, decentralized environment, JXTA protocol, code repository, distribution of task, result retrieval, peer redirection

In this paper, the authors present a framework for large-scale computations for "coarse-grained" parallelization. The components of this proposed framework are based on java based JXTA protocol, which can facilitate a dynamic and decentralized organization of computation resources. In this proposed framework, JXTA protocol facilitates dynamic aspect of grid through peer discovery where nodes are added or removed during the job execution.

[41]. (Wolski, 1999) R. Wolski, N. Spring, J. Hayes, "Predicting the CPU availability of time-shared Unix systems on the computational grid," *Proc of IEEE Eighth International Symposium on High Performance Distributed Computing*, pp: 105 -112, 1999

Keywords: CPU availability, Computational Grid, Time-shared UNIX Systems, vmstat, Network Weather Service (NWS), UNIX load average, Globus, forecasting, CPU monitoring

In this paper, the authors emphasize on the short and medium term forecasting of CPU availability of time-shared UNIX systems for Grid computing. The authors also measure the accuracy of measured CPU availability using vmstat, and Network Weather Service (NWS) utilities. CPU prediction is very useful for process scheduling in a large distributed network like Computational Grids.

Appendix-iii

List of researchers

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Appendix-iv

E-mail sent to researchers

From: "Adriana Iamnitchi" <anda@cs.uchicago.edu>
Subject: Re: Seeking an opinion about "Resource discovery in Grid computing"
Date: Fri, 30 May 2003 21:06:11 -0500
To: "Aktaruzzaman M" <aktaruz@uwindsor.ca>

Dear M (?),

I attach a document on resource discovery -- it's a more readable version of
my thesis proposal. It has a section on previous work with a lot of
references. Also, this paper might be of interest:
http://webmail1.uwindsor.ca/Redirect/www-unix.mcs.anl.gov/~schopf/Pubs/xuehaijeff-hpdc2003-submited.pdf

Regards,
-Adriana

----- Original Message -----
From: "Aktaruzzaman M" <aktaruz@uwindsor.ca>
To: <anda@cs.uchicago.edu>
Sent: Friday, May 30, 2003 7:21 PM
Subject: Seeking an opinion about "Resource discovery in Grid computing"

> Dear Ms. Adriana Iamnitchi,
> I am a masters student at University of Windsor, Windsor,
> Ontario, Canada. I am doing a survey on "Dynamic Resource
> Discovery in Grid Computing". When I started collecting
> papers on this topic, I found out you are doing your PHD on
> almost the same topic as me.I also collected your PHD
> thesis proposal from "Citeseer".Since you are doing your
> PHD, and you are almost done, I am just wondering could you
> suggest me some publication on this "Resource Discovery"
> issue and if you could give me a brief idea idea about the
> future research prospective on this issue.
> I really appreciate your time you spent on to read this
> e-mail.
>
> Regards
> M Aktaruzzaman
> University of Windsor
> Canada
>
>
>
>

File: iamnitchi-proof2.pdf (247Kbytes)

Appendix-v

Forthcoming Conferences

APAC'03
The APAC Conference and Exhibition on Advanced Computing, Grid Applications and eResearch
Royal Pines Resort
Gold Coast, Queensland
Australia
Date: 29 September - 2 October, 2003
URL: http://www.apac.edu.au/APAC03/Announcement/announcement.htm

Grid2003
4th International Workshop on Grid Computing
To be held in conjunction with SuperComputing 2003)
Phoenix, Arizona, USA
Date: 17 November 2003
URL: http://www.npaci.edu/online/v7.10/grid2003.html

P2P2003
3rd IEEE International Conference on Peer-to-Peer Computing
Use of Computers at the Edge of Networks (P2P, Grid, Clusters)
Department of Computer Science and Information Science, Linkopings Universitet
Linkoping, Sweden
Date: 1-3 September 2003
URL: http://www.ida.liu.se/conferences/p2p/p2p2003/

AGridM2003
1st Workshop on Adaptive Grid Middleware (AGridM2003),
In conjunction with the 12th International Conference on Parallel Architectures and Compiler Techniques,
New Orleans, Louisiana, USA
Date: 27 September 2003
URL: http://mayaweb.upr.clu.edu/agridm2003/

SC2003
SuperComputing 2003 (SC2003),
Phoenix, Arizona, USA
Date: 15-21 November 2003
URL: http://www.sc-conference.org/sc2003/

Appendix-vi

Cross referencing graph (next page)

How to read the graph:

a	**x**
Referred By	**b**

This means **a** was referred by **b**

The cross referencing graph indicates following:

- The papers by Ian Foster and Karl Czajkowski are milestone papers, referred by many articles.
- It does not appear to be in any other survey papers except this current survey.