Peer-to-Peer Overlay Network Based on Swarm Intelligence

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Abstract. As the number of information in the Internet constantly increases and the complexity of systems rapidly grows, locating and manipulating complex data has become a difficult task. We propose a self-organizing approach that combines purely decentralized unstructured peer-to-peer (P2P) with space based computing in order to effectively locate and retrieve information from a network. The approach is inspired by swarm intelligence, is distributive and autonomous. As the scalability is a common open issue both for unstructured P2P networks and for coordination models, our approach successfully copes with that by using a biologically inspired multi-agent system. Benchmarks demonstrate powerful query capabilities with a good scalability.

Keywords: swarm intelligence, unstructured P2P, space based computing, lookup mechanisms.

1 Introduction

The highly dynamic nature of the Internet, characterized by a huge number of information often expressed as complex data, imposes the necessity for new and advanced ways for locating and retrieving of information. We propose a self-organizing architecture as a combination of unstructured P2P [1] and space based computing ([4], [9]) for searching and retrieving data concurrently. It intends to use the benefits of both paradigms. The lookup mechanism is inspired by swarm intelligence ([6], [8], [12]).

2 Architecture and Design

In our approach, a space-based architecture, called XVSM (extensible virtual shared memory)[1], based on a formal model [7], is used . It generalizes Linda tuple space communication ([4], [9]) by introducing customizable, shared data structures (*shared containers* [10]). A container stores *entries* that generalize tuples. Each container possesses so-called *coordinators* (e.g. fifo, random, template matching, key, label), and can be located and accessed via a URL. All operations on it (*read, take, write*) use this URL to refer to the container. When a container is created, it can be made publicly accessible by a name. [2] combines a structured P2P system with XVSM. In contrast, in this paper, we propose the creation of an overlay network that consists of

[1] Project and open source download site: www.xvsm.org

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lookup containers. A container can be published under one or more public names. The discovery of data is performed by means of swarm intelligence. For the *structure of the overlay network,* we use the scale-free network approach [3] for an initial construction. Software agents realize the *algorithms of the overlay network* acting in swarms and performing the role of artificial ants. The multi-agent system is inspired by ant colony that is distributed, self-organizing, with a high level of autonomy.

Writing of information. An ant can put the content (i) *randomly* (no need for swarm intelligence algorithms), or (ii) using *brood sorting* [5]: entries are distributed on the basis of their type (similar entries stay closer to each other). In this case, the similarity function δ is based on spatial locality. **Retrieving of information.** We implemented two different ant algorithms, an adaptation of MMAS that is combined with Local Search (2.5-Opt) and an adaptation of AntNet. We introduced the following changes: In the *ConstructSolution* procedure [8], heuristic values from the random proportional rule are interpreted as a quality of the used links, expressed in time needed to traverse a particular path from lookup container A to lookup container B by using a particular link. The possible resulting situations of ants' search for the particular data are: *no data* found, *exact data* found, and *acceptable data* found with the accuracy/error rate $< \varepsilon$, where ε is a parameter given in advance, connected to the definition of δ. The *DepositPheromone* procedure [8] is changed as follows: If an ant on its trip *) found exact data, it deposits pheromone; *) found acceptable data, it deposits less amount of pheromone, *) did not find data, then skip depositing pheromones on its trip (i.e., the values on arcs it traversed will be the same as the values on the rest of unvisited arcs in the network). String comparison (representing URLs) uses a similarity function δ, based on a spatial locality. A different amount of pheromones is deposited according to the quality of solution found. The general form δ is: $\delta = \delta$ (currentSolution, exactSolution), that describes how good (acceptable) the found solution is, $\delta \in [0,1]$. In case of changing the type of δ, its value can be scaled into the same segment [0,1]. *DepositPheromone* procedure is changed: 1) for MMAS algorithm: $\Delta\tau = 1/MC^{best}$ where $M=1/\delta$; 2) for AntNet algorithm: $\tau := r\cdot(1-\tau)\cdot\delta$.

3 Simulation Results

We implemented two ways respectively of writing data into containers and of performing lookup and retrieval of data from containers on a cluster of 4 computers (2*Quad AMD 2,0 GHz, 16 GB RAM). A first group of benchmarks investigates the behavior of the algorithms in different combinations (Table 1) and different parameter settings [8] while trying to find the best possible combination of parameters. When comparing the two kinds of lookup, AntNet supplies the best performance in case of retrieving only one query (Fig. 1). A second group of benchmarks investigates the query capability of our system and compares it with Gnutella's lookup mechanism [1]. We can conclude that the adapted intelligent algorithms cope successfully with an increasing number of queries, compounded of several simple queries. We used the possibility of increasing the number of concurrently working ants. Our approach outperformed the Gnutella lookup by means of the obtained performance. Fig. 1 represents one test case using 80 containers.