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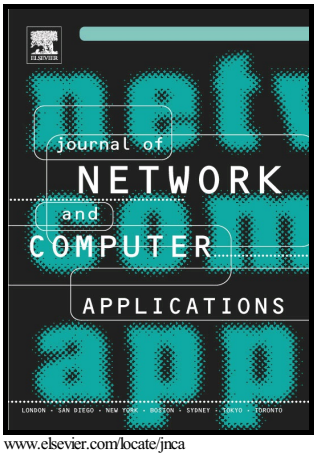

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Fractal: An Advanced Multidimensional Range Query Lookup Protocol on Nested Rings for Distributed Systems

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Abstract

One of the key issues in large-scale distributed systems such as P2P and grids is the capability of efficient multidimensional range query processing. Although several methods have recently been proposed for solving this problem on distributed systems, these methods have not been able to meet the fundamental necessity of a typical method on large-scale distributed systems, i.e., scalability.

This paper presents Fractal, a fully decentralized and highly scalable multidimensional range query lookup protocol for distributed systems. In this work, to organize the available nodes in the system, an n-dimensional space called *Key Space* is utilized. The available nodes on the nested Fractal rings maintain information about only O(logN) other nodes, and the Fractal lookup protocol discovers the destination node through these nested rings with a logarithmic cost. Because of its flexibility, Fractal allows the system to create a concept called *Layering*, which minimizes the probability of the wide-area message transfers (WAMTs) during the lookup process. Using several criteria, Fractal is compared with several successful methods that have recently been presented. Simulation results show the efficiency and performance of Fractal in networks of different sizes.

Keywords: Multidimensional range query, lookup protocol, distributed systems, WAMTs, the nested Fractal rings;

1. Introduction

In recent years, with the increase in the computational and storage needs of users, many researchers have tried to produce a huge processing and data-sharing environment by liking resources distributed geographically as this connections and the underlying infrastructure appear as a single system but powerful in terms of storage capacity and processing capability (Foster and Kesselman, 2003). These loosely coupled distributed platforms, including cyber physical networks, smart city platforms, and P2P networks, are used for a variety of purposes including scientific computation (Kulisch and Miranker, 2014; Jenks and Sutor, 2013; Joly et al., 2005; Balis, 2016) and data sharing (Qiu et al., 2014; Lee et al., 2015; Yu et al., 2014; Raj et al., 2015). Because of the large number of users (participating nodes) that are dynamic and heterogeneous, the participating nodes in such platforms differ widely in their resource capabilities including CPU speed, bandwidth, and memory capacity. Therefore, efficient service/resource discovery in such large-scale systems is one of the largest challenges (Cardosa and Chandra, 2010; Bashir et al., 2015; Ghate et al., 2016; Navimipour et al., 2014).

Recently there have been numerous researches to improve resource discovery in such systems. A lot of resource discovery methods make use of the capability of the whole nodes (decentralized approaches) (Torkestani, 2012; Brocco et al., 2010; Butt et al., 2011; Lee et al., 2010; Kocak and Lacks, 2012; Brunner et al., 2012; Cambronero and Valero, 2013; Ma et al., 2015; Tan et al., 2010; Tan et al., 2012) instead of relying on the capability of some special nodes (centralized approaches) (Foster and Kesselman, 1997; Mutka and Livny, 1987; Liu et al., 2011; Germain et al., 2000; Chien et al., 2003; Berman et al., 2003; Kaur and Sengupta, 2007), which suffer from single point of failure and bottlenecks, in order to improve the scalability of their methods. However, the participating nodes have to exchange a large amount of information in short time span due to the dynamic nature of such systems (Andrew and van Steen, 2007). As a result, this increases the system traffic and decreases the system efficiency. For example, based on a study that has been conducted on Planetlab (Oppenheimer et al., 2006) the node resource capabilities fluctuate on the order of approximately 30 min (Cardosa and Chandra, 2010).

One of the major unsolved problems in distributed systems is the support of efficient multi-attribute range queries. Several methods have attempted to solve this problem in their lookup methods (Souri and Navimipour, 2014; Caminero et al., 2013;