A Novel Pipeline Approach for Efficient Big Data Broadcasting

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Abstract—Big-data computing is a new critical challenge for the ICT industry. Engineers and researchers are dealing with data sets of petabyte scale in the cloud computing paradigm. Thus, the demand for building a service stack to distribute, manage, and process massive data sets has risen drastically. In this paper, we investigate the Big Data Broadcasting problem for a single source node to broadcast a big chunk of data to a set of nodes with the objective of minimizing the maximum completion time. These nodes may locate in the same datacenter or across geo-distributed datacenters. This problem is one of the fundamental problems in distributed computing and is known to be NP-hard in heterogeneous environments. We model the Big-data broadcasting problem into a LockStep Broadcast Tree (LSBT) problem. The main idea of the LSBT model is to define a basic unit of upload bandwidth, r, such that a node with capacity c broadcasts data to a set of $\lfloor c/r \rfloor$ children at the rate r. Note that r is a parameter to be optimized as part of the LSBT problem. We further divide the broadcast data into m chunks. These data chunks can then be broadcast down the LSBT in a pipeline manner. In a homogeneous network environment in which each node has the same upload capacity c, we show that the optimal uplink rate r^* of LSBT is either $c/2$ or $c/3$, whichever gives the smaller maximum completion time. For heterogeneous environments, we present an $O(n\log^2 n)$ algorithm to select an optimal uplink rate r^* and to construct an optimal LSBT. Numerical results show that our approach performs well with less maximum completion time and lower computational complexity than other efficient solutions in literature.

Index Terms—Big data computing, data delivery algorithm, cloud computing, distributed computing, big data management

1 Introduction

Big-data computing is a new critical challenge that has sparked major research efforts to reshape ICT industry and scientific computing in the past few years [1]. The rapid advances in ICT technologies, such as computation, communication and storage have resulted in enormous data sets in business, science and society being generated and analyzed to explore the value of those data. Currently, both ICT industry engineers and scientific researchers are dealing with petabytes of data sets in the cloud computing paradigm [2]. For instance, in industry, Google, Yahoo!, and Amazon collect huge amount of data every day for providing information services freely to people in useful ways. In science, the Large Hadron Collider (LHC) can generate about fifteen petabytes of data annually, and thousands of scientists around the world need to access and analyze those big data sets [3]. Thus the demand for building a distributed service stack to efficiently distribute, manage and to process massive data sets has risen drastically.

In the past decade, several efficient techniques are proposed to manipulate huge amount of data, ranging from terabytes to petabytes, on as many as tens of thousands of machines. For example, Google presented a distributed computing framework, namely MapReduce [4], to process large-scale data effectively, and also proposed Bigtable [5] for storing structured data on thousands of machines. These techniques allows users to realize data-parallelism [6]. There are many significant issues in developing MapReduce applications, such as, designing the effective strategy for data decomposition, load balancing, and exchanging data among a large set of nodes [7]. In particular, for big-data computing, data transmission overhead is a significant factor of the job completion time. For instance, it is shown that the total amount of data transmission time occupies approximately one-third of the jobs' running time in the Hadoop tracing logs of Facebook [8].

In this paper, we focus on the big data broadcasting operation that is one of the most essential communication mechanisms in distributed systems. There are a lot of application domains that widely apply broadcasting operations, such as scientific data distributions [9], database transaction logs backups, the latest security patches, multimedia streaming applications, and data replica or virtual appliance deployment [10] among distributed data centers. Since the size of data becomes so enormous, the impact of broadcasting operation also becomes increasingly significant.

We consider the big data broadcasting problem in a heterogeneous network where nodes may have different uploading capacities. The big data broadcasting problem is about how the nodes may obtain a given big data

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