Data & Knowledge Engineering 68 (2009) 926–945

Contents lists available at ScienceDirect

Data & Knowledge Engineering

journal homepage: www.elsevier.com/locate/datak

A concurrency control scheme for mobile transactions in broadcast disk environments

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ARTICLE INFO

Article history:
Received 6 November 2007
Received in revised form 12 February 2009
Accepted 12 February 2009
Available online 3 March 2009

Keywords:
Mobile databases
Mobile transactions
Concurrency control
Wireless broadcast channels
Data dissemination
Broadcast data
Broadcast disks
Mobile computing

ABSTRACT

Broadcast disk technique has been often used to disseminate frequently requested data efficiently to a large volume of mobile clients over wireless channels. In broadcast disk environments, a server often broadcasts different data items with differing frequencies to reflect the skewed data access patterns of mobile clients. Previously proposed concurrency control methods for mobile transactions in wireless broadcast environments are focused on the mobile transactions with uniform data access patterns. These protocols perform poorly in broadcast disk environments where the data access patterns of mobile transactions are skewed. In broadcast disk environments, the time length of a broadcast cycle usually becomes large to reflect the skewed data access patterns. This will often cause read-only transactions to access old data items rather than the latest data items. Furthermore, updating mobile transactions will be frequently aborted and restarted in the final validation stage due to the update conflict of the same data items with high access frequencies. This problem will increase the average response time of the update mobile transactions and waste the uplink communication bandwidth. In this paper, we extend the existing FBOCC concurrency control method to efficiently handle mobile transactions with skewed data access patterns in broadcast disk environments. Our method allows read-only transactions to access the more updated data, and reduces the average response time of updating transactions through early aborts and restarts. Our method also reduces the amount of uplink communication bandwidth for the final validation of the update transactions. We present an in-depth experimental analysis of our method by comparing with existing concurrency control protocols. Our performance analysis shows that it significantly decreases the average response time and the amount of uplink bandwidths over existing methods.

1. Introduction

The rapid development of wireless networks and powerful portable computer technologies have accelerated the development of mobile computing technologies, resulting in the increased and widespread use of mobile computing devices. These mobile units will often disconnect for a prolonged period of time to save battery power as well as communication cost in the mobile wireless computing environment. They also may be disconnected due to the node or wireless channel failure. In a wireless mobile network, the server may have a high downstream bandwidth broadcasting capability while the upstream bandwidth for mobile clients to the server is very limited. Organizing massive amount of data on wireless

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doi:10.1016/j.datak.2009.02.008

communication networks to provide fast and low power access to users equipped with mobile devices, is a new challenge to data management and telecommunication communities [8,14].

To cope with this challenge, broadcasting has been studied as a possible solution [13,15,18,19]. Acharya et al. proposed a *broadcast disks* technique for structuring the broadcast in a way that provides an improved performance for data with non-uniform access pattern [1]. The basic idea of broadcast disks is to broadcast data items, that are most likely to be of interest to a larger section of the client community, more frequently than others. Thus, in broadcast disks technique, the broadcast is created by assigning data items to different "disks" of varying sizes and speeds, and then multiplexing the disks on the broadcast channel. Items stored on faster disks are broadcast more often than items on slower disks. A single broadcast cycle consists of all the broadcast data items with different broadcast frequencies.

The broadcasting model is suitable for many application domains where the size of the database is relatively small but the number of clients is very large. These applications include stock trading, mobile auctions, mobile commerce applications, weather information systems, and traffic information systems [4,6,12,31]. The above applications comprise of a large proportion of read-only transactions and a small number of update transactions. For example, the number of stock buyers or bidders (i.e., update transactions) in stock trading and auctions is relatively fewer compared to the number of speculators (i.e., read-only transactions) who read the prices frequently. In these applications, the consistency among data items is likely to be violated by update transactions. Thus, a concurrency control scheme is needed to preserve data currency and consistency for mobile transactions [26,32].

In wireless broadcast environments, conventional concurrency control schemes such as two-phase locking and timestamp ordering are not suitable for the mobile transactions due to the limited bandwidth in the uplink communication channel and the limited battery power of mobile clients [3,7,11,16,17]. There have been many research efforts reported in the literatures that focus on the concurrency control scheme for wireless broadcast environments [2,5,10,20,22,23,25,27,28,33]. Lee et al. proposed a variant of the OCC method called FBOCC (Forward and Backward OCC) that uses forward validation for update transactions and partial backward validations for read-only transactions [24].

However, all the concurrency control methods for wireless broadcast environments including FBOCC method are focused on mobile transactions with uniform data access patterns. Existing methods perform poorly in broadcast disk environments where the data access patterns of mobile transactions are skewed. In broadcast disk environments, compared to a flat broadcast program, a broadcast cycle usually becomes long to reflect the skewed data access patterns. This will often cause read-only transactions to access the old data items rather than the more updated data items. Furthermore, update mobile transactions will be frequently aborted and restarted in the final validation stage due to the update conflict of the same data items with high access frequencies. This problem will increase the average response time of the update mobile transactions and waste the uplink communication bandwidth.

In this paper, we extend FBOCC method so that it can efficiently handle mobile transactions having skewed data access patterns in broadcast disk environments. We call the extension of FBOCC method as OCCBD (Optimistic Concurrency Control for Broadcast Disks). OCCBD method broadcasts the update control information multiple times in a single broadcast cycle. OCCBD method will allow read-only transactions to access the more updated data while reducing the average response time of update transactions through an early abort and restart. Also, the uplink communication bandwidth for the final validation of the update transaction is reduced. OCCBD method uses a backoff technique to avoid the frequent abort and restart of update transactions.

The rest of the paper is organized as follows: In Section 2, we discuss the related works. We describe our proposed OCCBD method in Section 3. Section 4 discusses how to determine the number of minor group cycles in our proposed method. We give the performance analysis of OCCBD method in Section 5. Finally, Section 6 provides concluding remarks.

2. Related works and preliminaries

There have been a lot of researches in wireless broadcast in the last decade. In this section, we discuss previous researches on the concurrency control schemes for mobile transactions in wireless broadcasting environments. We also take a closer look at FBOCC scheme which is the basis of our method.

2.1. Mobile transaction management in wireless broadcast environments

Barbara proposed a modified version of the conventional Optimistic Concurrency Control (OCC) protocol to support both read-only and update transactions at the mobile clients [2]. However, his protocol gives a significant delay to aborted mobile transactions. Shanmugasundaram et al. proposed a weaker correctness criterion called *update consistency* [28]. Update consistency allows read-only transactions to read current and consistent data in wireless broadcast environments without contacting the server. However, the serializability is not maintained which is very important in mobile commerce applications such as mobile stocks trading. Lee et al. proposed a method to reduce the response time of mobile read-only transactions by using a predeclaration technique [20–22]. However, the predeclaration technique does not support update transactions and the predeclaration process is computationally expensive.

Pitoura and Chrysanthis proposed three broadcast methods to guarantee the correctness of read-only transactions [27]. However, their three methods have the following problems. The *multi-version broadcast* method increases the size of the