Physical Communication 20 (2016) 1–16

Contents lists available at ScienceDirect

Physical Communication

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

Full length article

On-demand multimedia data broadcast in MIMO wireless networks

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ARTICLE INFO

Article history:
Received 11 May 2015
Received in revised form 23 March 2016
Accepted 15 April 2016
Available online 2 May 2016

Keywords:
Mobile computing
Multimedia
On-demand data broadcast
Channel allocation

ABSTRACT

Given a set of multiple requests from clients equipped with M antennae and a wireless network of m channels, on-demand data broadcast requires to find an optimal schedule of broadcasting (placing) all requested data items of R on a set of channels C as evenly as possible under the constraint that each client may use at most M channels. Such a schedule is important for overcoming the shortcomings of wireless networks such as asymmetric bandwidth between uplink and downlink, and limited battery life of mobile devices. Existing schemes for data broadcast assume single-antenna clients and will result in significant bandwidth wastage and client's data download time increase. To overcome these problems, we propose a novel approach for disseminating multimedia data in a MIMO wireless network by converting it to the multiprocessor scheduling problem where requests and antennae are regarded as tasks and processors respectively. We present three schemes (LFOS, BFOS and BBOS) under this approach: LFOS scheduling data items of largest sizes, BFOS adopting the best matching between data items and channels, and BBOS partitioning data items properly to balance the broadcast cycles of all channels. In comparison with the existing schemes based on single-antenna broadcast, our schemes improve access latency and channel bandwidth usage significantly. This has been verified through extensive experimental results.

1. Introduction

With the advances in wireless technology and mobile communication, wireless data broadcast is an effective solution to increase the bandwidth available for propagating public information to mobile devices. The reasonable utilization of bandwidth tends to highlight the ability of wireless communication and make data propagation more efficient. Recall that a typical wireless data broadcast system contains a base station, multiple channels and a large number of mobile devices. The base station is in charge of disseminating public information in a limited area whose size is determined by the disseminating capacity of base station, while mobile devices download these information from broadcast channels in an ad hoc way. Therefore, it is critical how to broadcast (place) data items to the channels in such a way that enables mobile devices to access public information most efficiently. Data scheduling is also important for minimizing the broadcast cycle and saving battery energy of mobile devices.

Existing schemes designed for data scheduling problem are exploited mainly from two aspects: push-based and pull-based. In push-based approach, according to the knowledge of access probability of requested data items sent by previous clients, the server is only responsible for periodically disseminating some pre-selected data items

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http://dx.doi.org/10.1016/j.phycom.2016.04.003
1874-4907/

at multiple channels. While mobile devices listen to these channels and download the requested data items when they appear in the channels. These characteristics of push-based approach are that the broadcast data items are fixed and do not change in each broadcast cycle of the broadcast process. Although this approach costs shorter time for preparing these data items broadcast at the channels, it cannot meet all requirements of all clients when the requests are often changed in real time. So a new pull-based approach is proposed to solve the above problem, which is also called on-demand data broadcast. According to the requests of clients in a real time system, the server adjusts the broadcast order of data items in multiple channels in each broadcast cycle such that the downloading time of all requested data items of a client and the broadcast cycle of wireless data broadcast system are minimized. Therefore, the characteristic of this pull-based approach is that the broadcast data items are different in each broadcast cycle such that all requirements of clients can be satisfied. However, the preparing time of broadcast data items is obviously increased. From both of these approaches, the need of reducing the access time and satisfying the requirements of clients arises as the main challenge for wireless data scheduling.

As the rapid development of multimedia data communication, many types of multimedia information are disseminated by a server, such as image, audio and video, so the server needs to propagate these abundant knowledge by using the limited bandwidth. In general, multimedia data can be either homogeneous (same size) or heterogeneous (different sizes). Compared to scheduling homogeneous multimedia data to place at the multiple channels, scheduling heterogeneous multimedia data is a more popular but complicated problem. This is because many factors of heterogeneous multimedia data (such as different sizes, different types as well as complicated input and output) make the scheduling process cost more energy and waste more bandwidth. Currently, many existing schemes derived from pull-based and push-based data broadcast are proposed to solve data scheduling problem when mobile device is equipped with one antenna. However, these schemes are not suitable for solving on-demand multimedia data broadcast problem in a MIMO wireless network, because they result in significant bandwidth wastage and client's data downloading time increase. To overcome these problems, we propose a novel approach for disseminating multimedia data in a MIMO wireless network. The central idea is to convert the on-demand multimedia data broadcast problem to multiprocessor scheduling problem where requests and antennae are regarded as tasks and processors respectively and to apply appropriate strategies according to scheduling objectives. Under this approach, we propose a new pull-based scheme which schedules M multimedia data with largest sizes on at most M channels in MIMO wireless networks, called as LFOS. It makes the clients fully use all antennae at the same time and download their requested data items at a minimum time under the constraint of no switches among channels. To achieve an optimal (minimum) broadcast cycle, we propose the second scheme, called BFOS, that balances the shortest broadcast time and the longest broadcast time of broadcast channels. The scheme adopts the best matching strategy between the channels and data items using a bipartite graph to minimize the broadcast cycle of each channel and reduce the bandwidth wastage. Finally, for placing the data items of significantly different sizes, we propose the third scheme, called BBOS, that partitions long data items at M selected channels such that the difference of broadcast cycles among all channels is minimized.

The rest of this paper is organized as follows: In Section 2, we describe some related works about data propagation in wireless data broadcast. In Section 3, we define the on-demand multimedia data broadcast problem and prove it NP-hard. In Section 4, we present three data scheduling algorithms to efficiently place data items at multiple channels under different placement strategies. In Section 5, we analyze the time complexity of the proposed algorithms, and the lower and upper bound of broadcast cycle of the proposed algorithms. In Section 6, we show our experimental results to evaluate the proposed algorithms. Section 7 concludes the paper.

2. Related work

We investigate that wireless data broadcast has been an efficient scheme for propagating information in wireless networks, and works better in many mobile applications. Many fields have been deeply studied, such as indexing, data scheduling and data retrieval. From the perspective of indexing, many approaches are proposed for rapidly determining the locations of requested data items at the channels, for example B^+-tree [1], Huffman tree [2], Hash table [3], Exponential index [4] and Signature index [5]. For efficiently downloading the required information of clients, researchers designed many data retrieval schemes to find the optimal access pattern of requested data items in multiple channels environment for minimizing access latency and energy consumption, for example, minimum cost data retrieval problem [6], minimum constraint data retrieval problem [7], minimum switch data retrieval problem [8], largest number data retrieval problem and largest weight data retrieval problem. [9] proposed efficient algorithms form two views: single antenna and multiple antennae. The algorithms adopt a novel approach that wireless data broadcast system is converted to DAG and apply set cover to solve data retrieval problem. [10] proposed a novelty scheme to apply topological sorting to address the DRMR problem. [11] proposed two algorithms (EDFS and UR) to retrieve the requested data items in their deadlines. [12] proposed a data retrieval scheme that converts a wireless data broadcast system to a special tree. Moreover, this problem is also studied in multiple antennae environment [13,9].

Traditionally, data scheduling scheme is designed to determine the placing sequence of data items at single channel and multiple channels. In push-based wireless data broadcast, Acharya [14] proposed a scheme for assigning data items at single channel, and the broadcast location of this scheme is also decided by the access probability of data items. With the development of infrastructure in wireless networks, [15] proposed a method to allocate data items at