Bandwidth-Aware Scheduling in Media Streaming Under Heterogeneous Bandwidth*

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Abstract. Data-driven media streaming has been deployed gradually over the Internet. In such systems, node periodically exchanges media block availability and fetches desirable blocks from neighbors. The issue on optimizing fetching blocks is called block scheduling and receives focus, especially in heterogeneous overlay. In this paper Bandwidth-Aware Scheduling (BAS) formulates such problem by incorporating bandwidth and block deadline, as well as node importance. Simulation results verify that BAS performs much better than existing ones.

Keywords: Peer-to-Peer, Media Streaming, Block Scheduling, BAS.

1 Introduction

Peer-to-peer (P2P) overlay populates in file-sharing, media streaming. The success originates from utilizing each peer's resource. Recently, media streaming applications called as data-driven approaches inspiring from BitTorrent [1] prevail on the Internet. Each peer chooses random node subset as neighbors so that an unstructured overlay is formed. Such gossip-style construction guarantees high system robustness and availability. Without explicitly building and maintaining block propagation path, these data-driven protocols determine block delivery direction based on block availability. The source node encodes media content into block sequence and pushes them to neighbors appropriately. Then, each peer exchanges block availability periodically. Upon such information each peer independently decides from which neighbor each desired block is fetched. And it requests blocks from respective neighbors. Both systematical studies [2] and realistic deployment [3] demonstrate that data-driven approach is better than other deterministic approaches such as tree-based ones, especially when churn is high or bandwidth varies greatly. As block scheduling is core of system, it is imperative to optimize scheduling to enhance system throughput further under heterogeneous network. In addition, steady playback rate requires that fetched blocks should arrive before deadline.

In media streaming application, the most valuable resource is bandwidth. However, existing measurements of overlay network reveal that peer usually exhibits

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extreme heterogeneity on access bandwidth. Furthermore, the bandwidth between two peers is more diverse and tends to be exaggerating under network congestion. To accommodate bandwidth heterogeneity, the source node encodes media content into several layers through layered coding, where each layer is iteratively dependent on lower layers. That means a higher layer can only be decoded if all of lower layers are available. Each layer consists of a sequence of equal-size blocks. Node would adjust receiving number of layers based on available bandwidth. Further, each node has sliding window moving as playback rate. The front portion of the sliding window is called exchanging window. Blocks within exchanging window will be consumed one by one.

In this paper we consider bandwidth constraint and block deadline, as well as node importance, and propose Bandwidth-Aware Scheduling strategy to improve system throughput. The remainder is organized as follows. Section 2 discusses related work. Section 3 first presents potential ineffectiveness of most relevant work, DONLE [4], in an example, then several definitions and problem formulation are proposed. Section 4 evaluates BAS's performance in comparison and concludes in section 5.

2 Related Work

Achieving higher throughput is desirable in media streaming. There are several milestone works. The first is ESM [5] that aims to distribute media content to large population of peers through tree-based topology. It utilizes the peers' bandwidth and greatly increases system throughput. The next is RLM [6], which collects blocks from multiple senders instead of one and greatly stabilizes the receiving block rate. The third is PeerStreaming that [7] steps further, where each node notifies upper streaming nodes the interested partitions of content. By integrating multiple partitions, node recovers original content and adapts to bandwidth variation through regulating partition announcements. The last is CoolStreaming [8], inspiring from BitTorrent [1], and implements fine-grain block scheduling within finite sliding window. Several similar systems such as PPLive [3], GridMedia [9] emerge in the following years.

The techniques [12,13] constructing the overlay according to some specific QoS metrics are perpendicular to block scheduling problem studied in this paper. The common scheduling strategies include *random* strategy in Chainsaw [10], *local rarest first (LRF)* strategy in CoolStreaming [8], *round robin (RR)* strategy, and *DONLE* [4]. DONLE formulates block scheduling as an integer linear programming problem by imposing priority on each desirable block, which is also solved with min-cost network flow algorithm. By maximizing average priority sum of blocks that each node can receive under heterogeneous bandwidth constraints, DONLE strategy achieves better throughput than all others. Since no block deadline considered in DONLE, we are motivated to enhance system throughput further by incorporating block deadline as well as node importance.