An Online Primal Dual Approach for inter-ISP Traffic Reduction in P2P VoD Streaming

TABLE I
IMPORTANT NOTATIONS

M	No. of ISPs
$\mathcal{N}_n(d)$	Peer d's total neighbor set in ISP n
$\mathcal{P}_m$	Peers in ISP m
$B(u)$	Peer u's upload bandwidth
R	No. of chunks buffered before the playing positioin
$\mathcal{R}_{u\to d}(t)$	set of chunks peer d can download from peer u at time t
$a_{u\to d}^{(c)}$	indicator of whether peer u transmits chunk c to peer d
v_d^c	valuation for peer d receiving chunk c
$w_{n,m}$	transaction cost for transmitting a chunk from ISP n to ISP m

***Abstract*—sss**

I. ISP-AWARE P2P VOD MODEL

We consider a mesh-based P2P VoD streaming system deployed among M Internet Service Providers (ISPs). We assume the mesh topology is constructed and maintained by an independent module, which is orthogonal to our work. In the mesh construction module, a peer obtains from a tracker a set of neighbors with similar playback progresses upon joining the overlay.

Under the constructed mesh topology, we model the chunk scheduling and bandwidth allocation problem taking the ISP-awareness into consideration. Let $\mathcal{N}_n(d)$ denote the neighbor set of peer $d \in \cup_{m=1}^{M}\mathcal{P}_m$ in ISP n. We use $B(u)$ to denote the upload bandwidth of peer u. We assume the download bandwidth of peers are large enough to receive the playback rate video. The bandwidth bottleneck is at peers' upload bandwidth. When a peer is watching a specific position of a video, the peer does not need to request all its missing chunks of the video. Hence, we assume a peer will request R chunks ahead of its playing position. We consider a discrete time slot model for the system, $t = 0, 1, 2, \ldots, T$. Let $\mathcal{R}_{u\to d}(t)$ denote the set of chunks that peer d does not have among the R chunks ahead of playing position at time t and sends requests to neighbor u at time slot t. Let $a_{u\to d}^{(c)}$ be the indicator of whether peer u transmits chunk c to peer d, i.e., $a_{u\to d}^{(c)} = 1$ means peer u transmits chunk c to peer d, $a_{u\to d}^{(c)} = 0$ means peer u does not transmit chunk c to peer d. Peer d's valuation for receiving chunk $c \in \mathcal{R}_{u\to d}(t)$ is v_d^c. The transaction cost for peer d receiving chunks from peers in ISP n is $w_{n,m}$. The important notations is summarized in table I.

Hence, the total utility for chunk dissemination is,

$$\max \sum_{t=0}^{T} \sum_{d\in\cup_{m=1}^{M}\mathcal{P}_m} \sum_{u\in\cup_{n=1}^{M}\mathcal{N}_n(d)} \sum_{c\in\mathcal{R}_{u\to d}(t)} a_{u\to d}^{(c)}(v_d^{(c)} - w_{n,m}), \tag{1}$$

$$\text{s.t.} \sum_{d\in\cup_{n=1}^{M}\mathcal{N}_n(u)} \sum_{c\in\mathcal{R}_{u\to d}(t)} a_{u\to d}^{(c)} \le B(u), \forall u \in \cup_{m=1}^{M}\mathcal{P}_m, \tag{2}$$

$$\sum_{u\in\cup_{n=1}^{M}\mathcal{N}_n(d)} a_{u\to d}^{(c)} \le 1, d \in \cup_{m=1}^{M}\mathcal{P}_m, c \in \mathcal{R}_{u\to d}(t), \tag{3}$$

$$a_{u,d}^{(c)} \ge 0, d \in \cup_{m=1}^{M}\mathcal{P}_m, u \in \cup_{n=1}^{M}\mathcal{N}_n(d), c \in \mathcal{R}_{u\to d}(t). \tag{4}$$

Constraint (2) shows that peers upload chunks to its neighbors within its upload bandwidth limit. Constraint (3) shows that a peer will not download multiple copies of a chunk. Constraint (4) shows that the indicator is non-negative.

Next, let us see the dual problem of the optimization problem (1). The dual is as follows,

$$\min \sum_{t=0}^{T} [\sum_{u\in\cup_{m=1}^{M}\mathcal{P}_m} \lambda_u(t)B(u) + \sum_{d\in\cup_{m=1}^{M}\mathcal{P}_m} \sum_{c\in\mathcal{R}_{u\to d}(t)} \eta_d^{(c)}(t)], \tag{5}$$

$$\begin{aligned} \text{s.t.}\, & \lambda_u(t) + \eta_d^{(c)}(t) \ge v_d^{(c)} - w_{n,m}, \\ & d \in \cup_{m=1}^{M}\mathcal{P}_m, u \in \cup_{n=1}^{M}\mathcal{N}_n(d), c \in \mathcal{R}_{u\to d}(t). \end{aligned} \tag{6}$$