Randomized adaptive video on demand*

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Interactive home video entertainment is an actively developing application of technology. Usually the movies are stored in a central video server. The video server is connected via a high-capacity fiber link to local distribution centers from which coax cables are used to broadcast to the households. Major bottlenecks in this architecture are the limited number of broadcast channels and/or the number of movies that the server can transmit concurrently.

In this work we investigate the on-line video on demand problem, namely having to accept or reject a request for a movie without knowing the future requests.

The first attempt to tackle video on demand from an *optimization perspective* was done by [AGH, 95]. In this work [AGH, 95] presented a *competitive* analysis of the problem, and introduced the concept of refusal by choice and showed that this leads to very good performance ratios which assymptotically match the corresponding lower bounds. Refusal by choice was used previously in the problem of Admission Control in fast networks (see [AGLR, 94], [ABFR, 94], [KS, 95]).

Our work presents a randomized scheduling method, that follows the principle of refusal by choice with delayed notification. We assume an underlying distribution of movie requests which is skewed. In fact, a variation of our scheduling algorithm is able to follow slow changes in this distribution, in an adaptive way that has a small transient behaviour. Thus, the exact form of the distribution of requests is not necessary to be known by this variation of our method. We believe that the assumption on a skewed distribution of movie requests is a pragmatic one. The model considered here follows [AGH, 95], as far as the architecture is concerned.

Assume, that the distribution $p()$ of movie requests is known. Our scheduler S divides (initially) the channels according to $p()$, so that channels in partition C_i will be used for movies to be seen by at least i users on average. The goal is to allocate channels in a way which optimizes channel revenue and reduces unused channels.

S puts the arriving requests to the movie queues: When a request for movie m_j is done, it is inserted into Q_j. When a request can wait no more the scheduler decides whether to serve the requests in Q_j. If there is a free channel in a set C_k with $k \leq |Q_j|$ then all movie requests in Q_j are served on that channel by a single transmission. If no such channels is available, then S rejects only those requests that cannot wait anymore.

When a channel is freed it is chosen to be placed to a set C_i with probability $\frac{f'_i}{F}$ where $F = \sum_{i=1}^{k} f'_i$.

The f'_i's and k are estimated as follows: If n users place overlapping requests (that can be served concurrently), then $P_i^m = Prob\{\text{movie } m \text{ will be selected by } i \text{ users}\} = \binom{n}{i} p^i(m)(1-p(m))^{n-i}$. Let $Q_i^m = \sum_{j=i}^{n} P_j^m$, and $f_i = \sum_m Q_i^m$. Let $f'_1 = f_1$, and $f'_2 = \sum_{i=2}^{j_2} f_i$ for a $j_2 \geq 2$ such that $\frac{f_1}{2} \leq f'_2 < f_1$. In general, let $f'_l = \sum_{i=j_{l-1}}^{j_l} f_i$, where j_{l-1} is such that $f'_{l-1} = \sum_{i=j_{l-2}}^{j_{l-1}} f_i$, and j_l is such that $\frac{f_1}{l} \leq f'_l < \frac{f_1}{l-1}$. Finally, let k be such that $f'_k = \sum_{i=j_{k-1}}^{n} f_i$ and $\frac{f_1}{k} \leq f'_k < \frac{f_1}{k-1}$.

The distribution $p()$ is called k-skewed if the cummulative statistic f_i is such that there exist such f'_i, $i = 1, \cdots, k$.

We show that:

Theorem 1 *If $p()$ is k-skewed then the competitive ratio of S is asymptotically bounded above by $5 + 4H_{k-1}$, where H_k is the k^{th} harmonic number (i.e. $H_k = 1 + \frac{1}{2} + \ldots + \frac{1}{k}$)*

We also show that the same theorem holds for a variation of our method where the distribution $p()$ is not known but the scheduler estimates it based on the recent movie requests.

References

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