11ème Atelier en Evaluation de Performances
Toulouse, du 15 au 17 mars 2016

Anticipating Resource Management and QoE Provisioning for Video Streaming

Imen TRIKI, Rachid ELAZOUZI, Majed HADDAD

University of Avignon France
imen.triki/rachid.elazouzi/majed.haddad@univ-avignon.fr

1. Resume

This study provides important insights in the design and optimization of adaptive video streaming by exploiting the knowledge of future capacity variations. We develop a framework that allows to extend the model developed in [1] by balancing system utilization and adaptive video quality. Our main contributions can be summarized as follows

i) We provide a general optimization framework for stored adaptive video delivery that accounts for operators' and clients' preferences
ii) Under the constraint of no rebuffering events, we formally obtained the optimal solution where the transmission schedule is of a threshold type and the coding strategy is of an ascending type
iii) We propose an efficient mechanism that performs close to the optimal solution, and we evaluate its performance and robustness using realistic traces.

2. Problem Formulation

We propose an optimization model in which we minimize an objective function $\mathcal{F}$ in respect of some constraints. The trend of this function depends on a fixed parameter a that adjusts the trade-off between the network utilization cost and the user QoE.

$$\min_{(r,\gamma)} \mathcal{F}(r,\gamma) = \frac{1}{T}\int_0^T \frac{r(t)}{c(t)}dt - a\frac{\sum_{j=1}^{j=L} w_j \int_0^T \gamma_j(t)r(t)dt}{S_L} \tag{1}$$

$$\text{s.t}\begin{cases} \int_0^t \frac{\lambda\, c(t)\gamma_1}{b_L} \geq l(t) & \forall t \leq T \\ \int_0^t \sum_{j=1}^{j=L} \frac{\lambda\, r(t)\gamma_j(t)}{b_L} \geq l(t) & \forall t \leq T \\ \int_0^T \sum_{j=1}^{j=L} \frac{\lambda\, r(t)\gamma_j(t)}{b_L} = l(T) & \end{cases}$$

where :
c : characterizes the network available capacity
r : characterizes the network transmission schedule
b_i designs bitrate level i ; $b_i \leq b_j$ for $i \leq j$
γ_j : characterizes bitrate level j
w_j : a score assigned to bitrate level j
T : the video length in s
S_L : the video size in bits with the highest quality
λ : the video speed lecture
l : the constraint function of the buffer state evolution

3. Problem Resolution

3.1. Threshold strategy

Definition 1. *Giving the network capacity* c*, we define the threshold transmission schedule by*

$$r_{th}(t) = \begin{cases} c(t) & \textit{if } c(t) \geq \alpha \\ 0 & \textit{otherwise,} \end{cases} \tag{2}$$

Proposition 1. *Assume that there exists a feasible solution that satisfies the constraints in (1), then there exists an optimal strategy* $(r_{th}, \gamma_{r_{th}})$ *of optimisation problem (1), where* r_{th} *is a threshold transmission schedule.*

3.2. Ascending coding rate approach

Definition 2. *We say a bitrate level strategy is* **ascending** *if the quality level of segments increases during the session, i.e., for all* $0 \leq t \leq t' \leq T$

$$b(t) \leq b(t') \textit{ i.e., } \gamma(t) \geq \gamma(t')$$

Proposition 2. *Assume that there exists a threshold-based solution* (r_{th}, γ) *that satisfies constraints in (1), then there exists a threshold-based ascending bitrate level solution* (r'_{th}, γ') *that optimizes problem in (1).*

4. Algorithmic approaches

4.1. Principal of optimal solution

(i) We first look at all the possible values of $\alpha \in [\alpha_{min}, \alpha_{max}]$ that satisfy the constraints in (1) while associating to each one the highest possible video quality, (ii) Suppose that we obtain a set of M possible thresholds $\{\alpha_i, i = 1, 2, \ldots, M;\ \alpha_i < \alpha_j\ ,\ i < j\}$. Therefore, for each threshold and its corresponding video quality, we compute the resulting cost function $\mathcal{F}$, (iii) The optimal solution corresponds to the one that minimizes $\mathcal{F}$. The accuracy of this algorithm increases with M at the expand of increasing complexity.

4.2. Heuristic for a near-optimal solution

Let γ_α and $\mathcal{F}_\alpha$ be, respectively, the ascending bitrate level strategy and the cost function under r_α-based transmission schedule. The main steps of the proposed heuristic are described in Algorithm 1, where INVEST represents the approach for generating sub-optimal thresholds and AWARE represents the heuristic for setting sub-optimal ascending bitrate levels.

Algorithm 1: Heuristic for a near-optimal solution

Data: $c, \mathrm{VideoProperties}, L, w, Q$

$\alpha \leftarrow c_{min};\ i \leftarrow 1;$

$[\mathrm{PossibleTransmission}, r_\alpha, \gamma_\alpha] =$ $\textit{AWARE}(c, \alpha, \mathrm{videoProperties}, L)$

while PossibleTransmission **do**

  $\mathcal{F}_\alpha = \mathrm{computeObjFunction}(c, r_\alpha, \gamma_\alpha, w)$

  $i = i + 1$

  $\alpha = \textit{INVEST}(c, i, Q)$

  $[\mathrm{PossibleTransmission}, r_\alpha, \gamma_\alpha] =$ $\textit{AWARE}(c, \alpha, \mathrm{videoProperties}, L)$

end

$\mathcal{F}^*_{\alpha^*} = \min\{\mathcal{F}_\alpha\}$

$\alpha_{th} = \alpha^*$

return $(\alpha_{th}, \gamma_{\alpha_{th}})$

4.2.1. Heuristic for generating thresholds : INcrease with VariablE foot STep (INVEST)

The increase on α is performed by adding a variable footstep at each iteration depending on the dynamic of the network capacity. We fix the amount of data that we wish to abandon at each step (denoted by Q). Then, we adjust the value of α which gives the corresponding variable footstep.

4.2.2. Heuristic for Anticipating qoe With Ascending bitRate lEvels (AWARE)

We start by assigning the lowest level to all video segments. Then, we keep increasing the levels progressively starting by the end of the video as long as the constraints are satisfied. Once a constraint is violated, we choose the previous level of the segment. The number of loops is equal to $L - 1$. To reduce at maximum the startup delay, we set by default the buffering-cache segments to the lowest video quality and use a greedy[1] transmission instead of using a threshold-based transmission. An inherent advantage of this algorithm is that it ensures a progressive increase of the quality levels instead of an aggressive increase as in the optimal solution, which is quite more appreciable for the user's perception.

1. A greedy transmission uses all the available network capacities.

5. Results

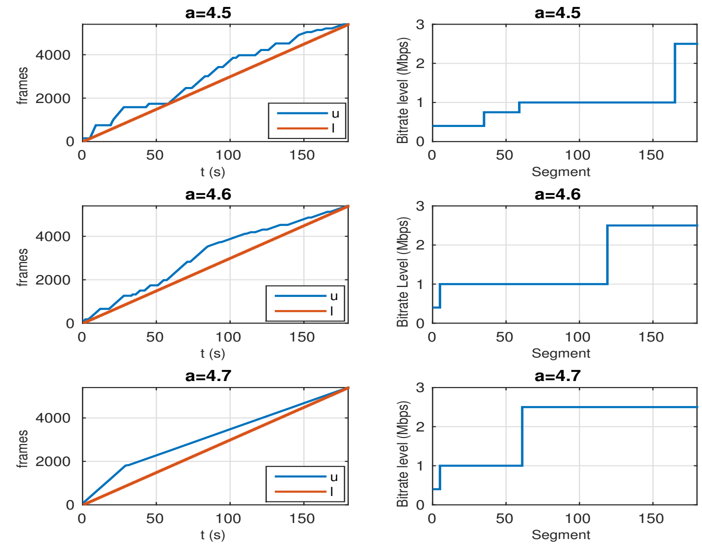

FIGURE 1 – Playback buffer state evolution and corresponding bitrate levels for different a.

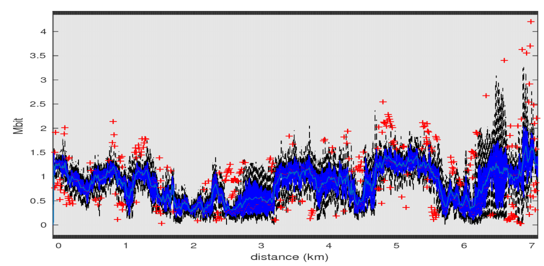

FIGURE 2 – Experimental real spacial variations of the capacity for the tramway Ljabru-Jernbanetorget trajectory.

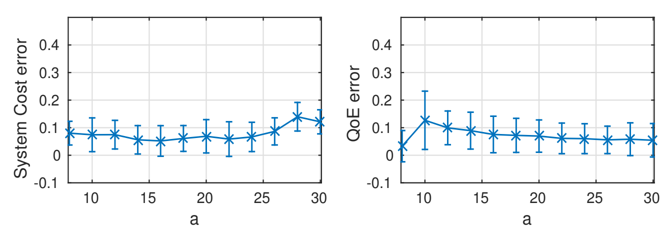

FIGURE 3 – Average error rate on the system performance under throughput prediction errors.

1. Lu, Zheng and de Veciana, Gustavo. – Optimizing stored video delivery for mobile networks : The value of knowing the future. – INFOCOM , 2013.