Dimensioning of a Multi-rate Network Transporting Variable Bit Rate TV Channels

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Abstract—We consider a centralised (client-server) digital TV network with heterogeneous receiver devices of different resolutions, requiring a multi-rate transport system. There exist two main ways to store and transport (streamed) TV channels in such a system: either by providing different single-layer versions of a channel (simulcast transport mode) or by keeping one multi-layered version (encoded e.g. in SVC) with extractable substreams. We propose one approximate analytical and two simulation methods to estimate the capacity demand in such a network with variable bit rate channels and we consider two behaviour models. In some TV distribution networks, the video is delivered in constant bit rate. However, this implies that the video quality is varying. In order to provide better quality of service (QoS), a network operator must deliver the channels in non-constant bit rate aiming in this way at constant video quality. Our models take into account also the correlations between the different resolutions of a channel.

Starting from real experimental data, we obtain the necessary input to our models and explore two realistic TV network scenarios – with bouquets of 50 and 300 channels, respectively. The results by the three approaches correspond well (relative error of 0.5% at most). In the case of 50 channels, SVC outperforms simulcast in terms of required bandwidth, while in the case of 300 channels, SVC is outperformed by simulcast. Therefore, we conclude that it depends on the system parameters which of both transport strategies will be more beneficial to save network resources.

I. INTRODUCTION

The H.264/MPEG-4 AVC [1] codec is already very popular and many applications are employing it. It is already implemented on multimedia devices or in video delivery systems (from video conferencing applications to Blu-ray disc, HD DVD, HDTV applications; streamed TV in mobile TV, terrestrial, satellite, IP-based networks or Internet). Its compression efficiency with respect to the codecs MPEG-2 [2] and MPEG-4 Part 2 [3] is widely recognised. Recently a Scalable Video Coding (SVC) amendment to it has been standardised [4]. It allows a video stream to be encoded in several layers (a base layer backward compatible with AVC and one or more enhancement layers) with temporal, spatial or quality (SNR) scalability (or a combination thereof). There is much excitement about the benefits of deploying SVC since it is a multi-layered codec and could address the problem of receiver screen resolutions diversity in modern heterogeneous systems, avoiding transcoding or possibly reducing the required network resources with respect to simulcasting all the requested versions. Other undeniable benefits about it could be outlined, e.g., the flexibility in organising the layered structure or the possibility to apply unequal FEC (Forward Error Correction) schemes and ensure always reception of at least the basic service (with the base layer being best protected). For example, in [5], SVC is proposed for deployment in a mobile TV network. At the same time, however, it is largely recognised also that encoding in SVC is in general less efficient than single-layer AVC encoding. According to the specification set at the start of the standardisation process, the incurred penalty rate of SVC to achieve a quality, PSNR (Peak Signal-to-Noise Ratio) equivalent to AVC, must be less than 10%. Some recently reported results in [6] indicate that this is achievable. Nevertheless, the implications of this disadvantage (incurred overhead by SVC) on network dimensioning need to be explored. A multi-rate video can be stored and transported in simulcast mode (several versions of the same content) or in the form of a scalable (SVC) stream with embedded substreams (layers). Thus, for example in [7] this question is discussed with respect to CDN (Content Delivery Network) networks. A more general study in the context of caching video objects can be found in [8]. In [9] we proposed and compared several methods to dimension the aggregation network in a centralised (client-server) network. We worked under the assumption that a number of TV channels in multiple resolutions are delivered either in simulcast or scalable mode, encoded with constant bit rate. Additionally, we derived a formula to find the limit overhead till which there is benefit in deploying the SVC transport strategy.

Some of the streamed video content today is in constant bit rate. However, this implies that the video quality is varying. Therefore, an operator wishing to improve the quality of service (QoS) and hence the quality of experience (QoE) of the users must deliver non-constant rate video. As claimed in [10] this could even lead to capacity gain if an appropriate multiplexing scheme is applied (to HDTV channels in this case). This paper extends the Gaussian approximation and the simulation models from [9] to account for the scenario of non-constant video bit rate. We describe the bit rate fluctuation of a channel stochastically by a given distribution based on real
data. The extended model takes into account the fact that the required bit rates for the resolutions of a given channel are content dependent and correlated.

The rest of the paper is structured as follows. In Section II, we describe the system under study. We propose a Gaussian approximation analytic method for capacity demand estimation in Section III. Our simulation approaches are presented in Section IV. Numerical results are discussed in Section V, and finally the paper is concluded in Section VI.

II. System Under Study

We aim at developing models to estimate the capacity demand on the aggregation link in a TV broadcast system of digital (IP-transported) channels, where a bouquet of TV channels is offered to an audience of subscribers. A bouquet of $K$ TV channels are broadcast (multicast) to the (active) subscribers (users) on request. The bit rate of a streamed channel is not constant, since constant quality is aimed for by the operator. Moreover, a system with multi-resolution receiver devices is envisioned, requiring that the content of the streamed channels is encoded in $L$ different resolutions, either by providing independent versions (simulcast scenario) or by encoding them in scalable embedded/multi-layered streams (e.g., in SVC). The bouqet of offered channels is characterised by a given channel popularity distribution from which the probability $\rho_k$ with $k \in \{1, \ldots, K\}$ that a certain channel is requested for watching is drawn. Very often, e.g. in [11] this distribution is approximated by a Zipf law [12]:

$$\rho_k = dk^{-\alpha},$$

where $d$ is a normalisation constant ensuring that the sum of all probabilities $\rho_k$ is 1, and $\alpha$ is the parameter of the Zipf distribution, ranging typically between 0.5 and 1.

We denote the capacity demand $C$ under a simulcast scenario by $C_{\text{SIM}}$, and under the SVC scenario by $C_{\text{SVC}}$. Remark that these are random variables, since there is randomness in a user’s behaviour: a user watches television or not, he selects a TV channel (respectively streamed video content) among $K$ available channels, he is requesting it in a given resolution. We also assume that if the multicast channels are scalably encoded, only the layers up to and including the highest requested one are multicast, since otherwise, it would result in a waste of network resources.

Once a user is tuned in to a particular channel, and in contrast to [9], we assume that the required bit rate of this channel is fluctuating. We only consider fluctuations associated with the succession of scenes of programmes transported over that (selected) channel (because we assume that fluctuations associated with frame type are smoothened by the shaper in the encoder [13]). In the general case, we assume that there are no dependencies between the bit rates of the different channels but there is a dependence between the rates of the different resolutions of one channel: under resolution we mean the different versions under simulcast (SIM) streaming or the different layers in scalable encoding of a channel under SVC streaming. This correlation between the different resolutions accounts for the fact that if a high bit rate is produced in one scene, this is probably the case for all versions/layers of a channel transporting the same content. With this assumption, a multicast channel’s resolution generates with rate $r_\ell$, where $\ell$ stands for the resolution and $\ell \in \{1, \ldots, L\}$. Remark that for simulcast (SIM) each resolution $\ell$ has its own specific bit rate $r_\ell$, while for SVC to subscribe to resolution $\ell$ all layers up to the streamed layer $\ell$ need to be received, i.e., in the SVC case we denote by $r_{\ell_0}$ the total bit rate of all layers 1 to $\ell$. The channel’s versions/layers have a joint distribution $\Pi = \{r_1, \ldots, r_L\}$ with $L$ marginal distributions $\{\pi_{r_\ell}\}$ corresponding to the distribution associated to resolution $\ell$ from which its rate is drawn. In this work, we assume that all the channels behave statistically the same, hence have the same joint distribution (and resulting marginal distributions). In the analytical method we will consider, we will need the vectors of the resolutions’ average rates and the covariance matrices.

Furthermore, we assume that in all offered resolutions the channel popularity distribution (the Zipf distribution) is the same, i.e., given that the user has chosen to watch a certain resolution (through his choice of device) he selects which channel to watch according to the popularity law given in (1) irrespective of his choice of resolution.

A. Capacity Demand under Simulcast

We define the random variables $n_{k,\ell}$, where $1 \leq k \leq K$, $1 \leq \ell \leq L$, as the number of users watching channel $k$ in resolution $\ell$. Because with simulcast every channel is encoded in $L$ independent versions, and a channel is streamed in version $\ell$ if at least one user watches that channel in resolution (version) $\ell$, we can express $C_{\text{SIM}}$ in the following way:

$$C_{\text{SIM}} = \sum_{k=1}^{K} \sum_{\ell=1}^{L} r_\ell 1\{n_{k,\ell}>0\},$$

where $1\{\cdot\}$ is the indicator function of the event $\cdot$, expressing that there is a contribution to $C_{\text{SIM}}$ from a channel $k$ if it is watched by at least one user in resolution $\ell$.

B. Capacity Demand under SVC

With scalable video encoding, in order to watch a channel in resolution $\ell$, all layers 1 until $\ell$ of that channel are needed for decoding, because they are all interrelated (in this paper we do not consider scalable encoding such as e.g., multiple description coding, MDC). Thus, layer 1 until $\ell$ of channel $k$ need to be transported if there is at least one user watching channel $k$ in resolution $\ell$, and if there is no user watching channel $k$ in a higher resolution than $\ell$. Therefore, $C_{\text{SVC}}$ can be expressed as follows:

$$C_{\text{SVC}} = \sum_{k=1}^{K} \sum_{\ell=1}^{L} r_{\ell} 1\{n_{k,L}=0, \ldots, n_{k,\ell+1}=0, n_{k,\ell}>0\}. \tag{3}$$
C. Channel Viewing Probabilities

A number of user behaviour models are possible; one possible scenario is when a user (with his receiving device) is associated only to a given resolution; another possible organisation of the system is that any user can access any resolution (for example different devices for the different resolutions or one device capable of receiving any resolution). We denote the former model as User model I, while the latter as User model II.

Under User model I, the group of $N$ users (subscribers) is divided in $L$ fixed sets. Within a set all clients use a terminal capable of receiving resolution $\ell$, and there are $N_\ell$ users of type $\ell$ so that the sum of all $N_\ell$ over all $L$ resolutions/sets is $N$.

The TV channels are assumed to have independent probabilities $\rho_k$ of being watched, which are proportional to the popularity of the channels, drawn as explained above from a Zipf distribution.

We calculate the following probability generating function for the joint probability of the channels being watched by a given set of users:

$$F(z_{k,\ell};\forall k,\ell) = E\left[\prod_{k=1}^{K} \prod_{\ell=1}^{L} z_{k,\ell}^{n_{k,\ell}}\right], \quad (4)$$

where $\sum_{k=1}^{K} n_{k,\ell} = n_{\ell} \leq N_{\ell}$.

Inside a set of $N_\ell$ users associated to layer $\ell$, a user has an activity grade $a_\ell$, the probability of being active watching a channel, which is the average fraction of the time that a user of type $\ell$ watches television. We then have that the sample space corresponding to the vector of random variables $(n_{1,1}, n_{2,1}, \ldots, n_{K,L})$ is constituted by all tuples $(n_{1,1}, n_{2,1}, \ldots, n_{K,L})$ for which the number of active users is $n = \sum_{k=1}^{K} \sum_{\ell=1}^{L} n_{k,\ell} \leq N$. The formula to calculate the probability that corresponds to a realisation of the variables $(n_{1,1}, n_{2,1}, \ldots, n_{K,L})$ under User model II is:

$$\Pr\left[\begin{array}{c}
n_{1,1} = n_{1,1}, n_{2,1} = n_{2,1}, \ldots, n_{K,1} = n_{K,1}; \\
n_{1,\ell} = n_{1,\ell}, n_{2,\ell} = n_{2,\ell}, \ldots, n_{K,\ell} = n_{K,\ell}; \\
n_{1,L} = n_{1,L}, n_{2,L} = n_{2,L}, \ldots, n_{K,L} = n_{K,L}
\end{array}\right] = \frac{N!}{(N-n)!} (1-a)^{N-n} a^n \prod_{k=1}^{K} \prod_{\ell=1}^{L} \frac{(\rho_k b_\ell)^{n_{k,\ell}}}{n_{k,\ell}!}. \quad (7)$$

The corresponding probability generating function is:

$$F(z_{k,\ell};\forall k,\ell) = \left[1 - a + a \sum_{k=1}^{K} \rho_k \sum_{\ell=1}^{L} b_\ell z_{k,\ell}\right]^{N}. \quad (8)$$

III. CAPACITY DEMAND – A GAUSSIAN APPROXIMATION APPROACH

We assume first that the aggregate capacity demand is a Gaussian variable, thus, provided its average and variance (standard deviation) are known, the distribution can be found. For practical reasons we express it in the form of the complementary cumulative distribution function (CCDF), also referred to as tail distribution function (TDF). This is the probability that the required bandwidth exceeds a certain value $C_{\text{avail}}$, i.e., $\Pr[\{C_{\text{SIM}}, C_{\text{SVC}} > C_{\text{avail}}\}]$.

A. Average of the Aggregate Flow

The average of the aggregate flow $C$ from multicast channels in $L$ resolutions is the sum of the averages of the contributions of all the resolutions in both simulcast (SIM) or scalable encoding (SVC) scenarios.

1) Simulcast: In the simulcast case, the mean of the aggregate traffic $C_{\text{SIM}}$ is:

$$E[C_{\text{SIM}}] = \sum_{\ell=1}^{L} \sum_{k=1}^{K} E[r_{\ell,1}(n_{k,\ell} > 0)]$$

$$= \sum_{\ell=1}^{L} \sum_{k=1}^{K} E[r_{\ell}] E[1(n_{k,\ell} > 0)]$$

$$= \sum_{\ell=1}^{L} E[r_{\ell}] \sum_{k=1}^{K} \Pr[n_{k,\ell} > 0], \quad (9)$$

where $E[r_{\ell}]$ is the average rate of resolution $\ell$. Here we have used the property that the average of an indicator function is the probability of its event. $\Pr[n_{k,\ell} > 0]$ expresses the probability that a given channel $k$ is requested in the given resolution $\ell$ by at least one user (hence the channel is multicast streamed).
2) SVC: In the SVC case, the mean of the aggregate traffic is:

\[ E[C_{SVC}] = \sum_{\ell=1}^{L} \sum_{k=1}^{K} E[r_{\ell}] \sum_{k=1}^{K} E[r_{\ell}] E[1_{\{n_{k,\ell} = 0, \ldots, n_{k,\ell+1} = 0, n_{k,\ell} > 0\}}] \]

\[ = \sum_{\ell=1}^{L} E[r_{\ell}] \sum_{k=1}^{K} \text{Pr}[n_{k}, L = 0, \ldots, n_{k,\ell+1} = 0, n_{k,\ell} > 0], \]

where \( E[r_{\ell}] \) stands for the average contribution of a scalable flow of up to and including layer \( \ell \).

B. Variance of the Aggregate Flow

In order to obtain the variance, first the second-order moments of the aggregate traffic under the SIM and SVC scenarios (respectively of \( C_{SIM} \) and \( C_{SVC} \)) are derived below. With the index \( k \) for the probabilities that a channel \( k \) is watched by a given number of users \( n_{k,\ell} \), we make distinction between the channels, as there is correlation between the rates of the versions/layers of one and the same channel, but there is no correlation between those of different channels.

1) Simulcast: The second-order moment of \( C_{SIM} \) is expressed as follows:

\[ E[C_{SIM}^2] = \sum_{k=1}^{K} \sum_{1=1}^{L} \sum_{k=1}^{K} \sum_{1=1}^{L} E[r_{\ell_1} r_{\ell_2} 1_{\{n_{k,\ell_1} > 0, n_{k,\ell_2} > 0\}}] \]

\[ = \sum_{k=1}^{K} \sum_{1=1}^{L} E[r_{\ell_1}^2] E[1_{\{n_{k,\ell_1} > 0\}}] \]

\[ + \sum_{k=1}^{K} \sum_{1=1}^{L} \sum_{k=1}^{K} \sum_{1=1}^{L} E[r_{\ell_1} r_{\ell_2}] E[1_{\{n_{k,\ell_1} > 0, n_{k,\ell_2} > 0\}}] \]

\[ + \sum_{k=1}^{K} \sum_{1=1}^{L} \sum_{k=1}^{K} \sum_{1=1}^{L} \sum_{k_2 \neq k_1} E[r_{\ell_1}] E[r_{\ell_2}] E[1_{\{n_{k_1,\ell_1} > 0, n_{k_2,\ell_2} > 0\}}] \]

\[ = \sum_{k=1}^{K} \sum_{1=1}^{L} E[r_{\ell_1}^2] \text{Pr}[n_{k,\ell_1} > 0] \]

\[ + \sum_{k=1}^{K} \sum_{1=1}^{L} \sum_{k_2 \neq k_1} E[r_{\ell_1} r_{\ell_2}] \text{Pr}[n_{k,\ell_1} > 0, n_{k,\ell_2} > 0] \]

\[ + \sum_{k=1}^{K} \sum_{1=1}^{L} \sum_{k_2 \neq k_1} E[r_{\ell_1} r_{\ell_2}] \text{Pr}[n_{k_1,\ell_1} > 0, n_{k_2,\ell_2} > 0] \cdot \text{Pr}[n_{k_1,\ell_1} > 0, n_{k_2,\ell_2} > 0]. \]

In (11) we accounted for the fact that the probabilities of the bit rates are independent from the probabilities of requesting a channel, and also for the fact that the rates of the different resolutions of one and the same channel are correlated. The following relation holds for the covariance: \( \text{Cov}[r_{\ell_1}, r_{\ell_2}] = E[r_{\ell_1} r_{\ell_2}] - E[r_{\ell_1}] E[r_{\ell_2}] \). The terms \( E[r_{\ell_1} r_{\ell_2}] \) in (11) are thus directly related to the covariance terms \( \text{Cov}[r_{\ell_1}, r_{\ell_2}] \), which compose a covariance matrix, the main diagonal of which is formed by the variance terms \( \text{Var}[r_{\ell}] \) related to \( E[r_{\ell}^2] \).

The square of the average of \( C_{SIM} \) can also be expressed as three types of terms corresponding to the three types of terms in (11). The variance of the aggregate traffic \( C_{SIM} \) is \( \text{Var}[C_{SIM}] = E[C_{SIM}^2] - E[C_{SIM}]^2 \). Under simulcast, the variance of \( C_{SIM} \) has the following form:

\[ \text{Var}[C_{SIM}] = \sum_{k=1}^{K} \sum_{1=1}^{L} \sum_{k=1}^{K} \sum_{1=1}^{L} \left( E[r_{\ell_1}^2] - E[r_{\ell_1}]^2 \right) \text{Pr}[n_{k,\ell_1} > 0] \]

\[ + \sum_{k=1}^{K} \sum_{1=1}^{L} \sum_{k=1}^{K} \sum_{1=1}^{L} \left( E[r_{\ell_1} r_{\ell_2}] \text{Pr}[n_{k,\ell_1} > 0, n_{k,\ell_2} > 0] \right. \]

\[ - E[r_{\ell_1}] E[r_{\ell_2}] \text{Pr}[n_{k,\ell_1} > 0] \text{Pr}[n_{k,\ell_2} > 0] \]

\[ + \sum_{k=1}^{K} \sum_{1=1}^{L} \sum_{k=1}^{K} \sum_{1=1}^{L} \sum_{k_2 \neq k_1} E[r_{\ell_1}] E[r_{\ell_2}] \]

\[ \cdot \left( \text{Pr}[n_{k_1,\ell_1} > 0, n_{k_2,\ell_2} > 0] - \text{Pr}[n_{k_1,\ell_1} > 0] \text{Pr}[n_{k_2,\ell_2} > 0] \right). \]

2) SVC: The formula for the variance of \( C_{SVC} \) is the same as (12) but with the following substitutions:

\[ \text{Pr}[n_{k,\ell} > 0] \]

\[ \text{Pr}[n_{k_1,\ell_1} > 0, n_{k_2,\ell_2} > 0] \]

\[ \text{Pr}[n_{k_1,\ell_1} > 0, n_{k_2,\ell_2} > 0] \]

\[ \text{Pr}[n_{k_1,\ell_1} > 0] \]

\[ \text{Pr}[n_{k_2,\ell_2} > 0] \]

In (11) we accounted for the fact that the probabilities of the bit rates are independent from the probabilities of requesting a channel, and also for the fact that the rates of the different resolutions of one and the same channel are correlated. The following relation holds for the covariance: \( \text{Cov}[r_{\ell_1}, r_{\ell_2}] = E[r_{\ell_1} r_{\ell_2}] - E[r_{\ell_1}] E[r_{\ell_2}] \). The terms \( E[r_{\ell_1} r_{\ell_2}] \) in (11) are thus directly related to the covariance terms \( \text{Cov}[r_{\ell_1}, r_{\ell_2}] \), which compose a covariance matrix, the main diagonal of which is formed by the variance terms \( \text{Var}[r_{\ell}] \) related to \( E[r_{\ell}^2] \).

The square of the average of \( C_{SIM} \) can also be expressed as three types of terms corresponding to the three types of terms in (11). The variance of the aggregate traffic \( C_{SIM} \) is \( \text{Var}[C_{SIM}] = E[C_{SIM}^2] - E[C_{SIM}]^2 \). Under simulcast, the variance of \( C_{SIM} \) has the following form:

\[ \text{Var}[C_{SIM}] = \sum_{k=1}^{K} \sum_{1=1}^{L} \sum_{k=1}^{K} \sum_{1=1}^{L} \left( E[r_{\ell_1}^2] - E[r_{\ell_1}]^2 \right) \text{Pr}[n_{k,\ell_1} > 0] \]

\[ + \sum_{k=1}^{K} \sum_{1=1}^{L} \sum_{k=1}^{K} \sum_{1=1}^{L} \left( E[r_{\ell_1} r_{\ell_2}] \text{Pr}[n_{k,\ell_1} > 0, n_{k,\ell_2} > 0] \right. \]

\[ - E[r_{\ell_1}] E[r_{\ell_2}] \text{Pr}[n_{k,\ell_1} > 0] \text{Pr}[n_{k,\ell_2} > 0] \]

\[ + \sum_{k=1}^{K} \sum_{1=1}^{L} \sum_{k=1}^{K} \sum_{1=1}^{L} \sum_{k_2 \neq k_1} E[r_{\ell_1}] E[r_{\ell_2}] \]

\[ \cdot \left( \text{Pr}[n_{k_1,\ell_1} > 0, n_{k_2,\ell_2} > 0] - \text{Pr}[n_{k_1,\ell_1} > 0] \text{Pr}[n_{k_2,\ell_2} > 0] \right). \]
Pr[\bar{A}] = 1 − Pr[A],
Pr[\bar{A}_1 \cap \bar{A}_2] = 1 − Pr[A_1] − Pr[A_2] + Pr[A_1 \cap A_2],
Pr[A \cap B] = Pr[B] − Pr[C],
Pr[\bar{A}_1 \cap \bar{A}_2 \cap B_1 \cap B_2] = Pr[B_1 \cap B_2] − Pr[C_1 \cap B_2] − Pr[B_1 \cap C_2] + Pr[C_1 \cap C_2].
(16)

IV. Simulation Approaches

We wrote an event-driven C-based simulator, which can simulate both simulcast and SVC streaming transport modes. This simulator generates a number of realisations of the variable capacity demand C (C_{SIM} under simulcast and C_{SVC} under SVC). For every realisation, a user is either tuned into a given channel k and resolution l or is inactive (governed by the user model and activity grade). According to the selected transport mode (SIM or SVC), the activity grade of the users, and the popularity distribution of the multimedia content (i.e., the Zipf parameter α), we measure the TDF of the variable C, over a sufficiently large number of realisations, depending on the required accuracy. The random number generating function interpreting the activity grade of users follows a uniform distribution.

A multivariate Gaussian variable for the rates of a channel’s resolutions is generated at every simulation step, drawn from a distribution defined by the input average vector and covariance matrix. In this paper, we refer to this simulator as Gaussian simulator.

We also constructed another (C-based) simulator. The difference with the previous one is that the channel’s resolutions rates are drawn randomly from a list of the average rates of real movies. We refer here to this simulator as histogram simulator. Were this list of movies’ average rates long enough (sorted and possibly with assigned probabilities to every rate realisation or in a histogram form), the probability distribution of the rates would have been reasonably well approximated.

V. Results

In this section we will estimate the capacity demand in a realistic TV example by the three approaches described above (an analytical and two simulation ones). In this way we will validate the different approaches and will point out their advantages and their drawbacks. All K channels are encoded in two spatial resolutions (L = 2), every resolution corresponding to a certain spatial/temporal format for all the channels from the bouquet of channels. We start from experimental data for 20 movies encoded in two resolutions (QVGA and VGA), both single-layered in AVC mode and multi-layered in SVC mode. The two resolutions are: base resolution QVGA 320x240@15Hz for some of the movies or 12.5Hz for the other, and its spatial and temporarily scaled resolution VGA 640x480@30Hz for some of the movies or respectively 25Hz for the other. The rates are taken such that delivering a resolution in either of the transport modes (simulcast or SVC) provides the same video quality, approximately a PSNR of 34 dB for both resolutions. Normally, the base layer of an SVC encoded video is AVC-compliant encoded; however in the experimental data set we use, the QVGA resolution in SVC has some 8% higher bit rate (for the same quality) with respect to AVC encoded QVGA. An SVC VGA resolution of a channel has some 21% higher bit rate than the corresponding AVC VGA version, which we refer to as “penalty rate of SVC”. Note that the penalty rate values specified above (8% and 21%) are the averages over all the movies and they differ for each of them. The vectors of the resolutions’ averages and covariance matrices for the two H.264 coding modes (AVC and SVC) are given in Table I. We set the network parameters as follows. Two cases are considered: with K = 50 and K = 300 channels. For the parameter of the Zipf distribution, we choose α = 0.6 as in our previous work [9]. We set the number of users N_k (l = 1; 2) to 500 for every of the two resolutions (QVGA and VGA) in User model I, and N to 1000 in User model II. The activity grade is a_ℓ = 0.8 under User model I, and a = 0.8 and b_1 = b_2 = 0.5 under User model II.

The TDFs of C_{SIM} and C_{SVC} by the analytical and the
Based on the studied cases, we conclude that for non-constant bit rate channels it is not straightforward whether an SVC transport scheme will be beneficial for saving on network resources. This depends on the system environment (parameters). SVC becomes the more efficient transport mode when all resolutions of all channels are actively requested (for which the prerequisites are high activity grade of users, small bouquet of channels), when the SVC overhead is small and when there are more resolutions in the system (actively requested).

### REFERENCES


