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HET-NETs '04

2ND INTERNATIONAL WORKING CONFERENCE
ON
PERFORMANCE MODELLING AND EVALUATION OF HETEROGENEOUS NETWORKS

Craiglands Hotel
Ilkley, West Yorkshire, UK

26th – 28th July 2004

TECHNICAL PROCEEDINGS

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Measurement, Modelling and Simulation of Videoconference Traffic from VBR Video Encoders

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Abstract

In this manuscript, we present a generic and simple method to model conservatively – with respect to queuing – videoconference traffic from VBR video encoders over IP Networks. The analysis of extensive data compressed by the encoders of the Videoconferencing Tool ViC: NV, NVDCT, H.261, H.263, H.263+, BVC and CELLB (which, to the best knowledge of these authors, haven't been studied in their entirety) suggests that although the fit of the empirical distribution with the MOM method is not satisfactory, a careful choice of the autocorrelation coefficient using the ''compound exponential fit'' model used in [1] and the modulation of the simulated data with a random variable of a uniform distribution, as in [8], can lead to a steady generalization of the DAR model. Simulation results using the ns-2 simulator confirm our claims.

Key-words**:** videoconference, VBR encoders, traffic modelling, queuing, simulation

Introduction

Videoconference traffic modelling has been extensively studied in literature and as a result a wide range of modelling methods can be found. Results of earlier studies as [2], [3], [9], [10], [12], concerning variable bit-rate video streams in ATM networks, indicate that the histogram of the vbr video frame sizes exhibits an asymmetric Gamma-like shape and that the autocorrelation function decays quickly (approximately exponentially) to zero. An important body of knowledge in vbr traffic modelling is the approach in [7] where the DAR [6] model is introduced. Several other models have been proposed for vbr video traffic modelling such as GBAR [4] and SCENIC model [5] which are generalized forms of DAR. The GBAR model could be a solution for traffic modelling of these encoders, as it was especially designed for videoconference. On the contrary, SCENIC is oriented to full motion video and not to a typical videoconference content.

Newer studies of vbr video traffic modelling reinforce the general conclusions obtained by the above earlier studies by evaluating and extending the existing models and also proposing new methods for successful and accurate modelling. In [11], a 'stuffing' method was used for grouping frames into variable frame periods. In this study, the use of movies (like Starwars), as visual content, led to frames generation with an approximate Gamma PDF (more complex when target rate was imposed) and ACF quickly decaying to zero. A final study is [8] where authors proposed a new generalized model called MMB-DAR that combines a marginal matching technique and a variable of uniform distribution.

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The above methods certainly constitute a valuable body of knowledge. However, these methods haven't been applied to the traffic generated by the entirety of the encoders used in the global videoconference market[†]. Many of the encoders supported by ViC like NV, BVC, CELLB are widely used by the academic community while others are used in palmtops thanks to their effective performance and cheap processing needs. Under these circumstances, this study proposes a generic and simple method for conservative modelling of videoconference traffic encoded by the reported existing videoconference coding methods.

The rest of the paper is structured as follows: section 1 describes the characteristics of the experiments and presents some basic statistical information of the measured data. Section 2 contributes modelling results with the DAR model and discusses appropriate methods (per encoder) for – with respect to queuing – successful traffic modelling. The simulation results of section 3 confirm the accuracy and conservativeness of the proposed methods. Finally, section 4 culminates with conclusions and pointers to further research.

1. Description of the Videoconference Experiments

The study reported in this paper undertook measurements of the IP traffic generated by different VBR encoders. To do this, we used the videoconference software package ViC and measured the traffic generated by all the encoders currently supported by the program. These are: NV [17], NVDCT [17], H.261 [13], H.263 [13], H.263+ [13], BVC[‡] and CELLB [15]. The JPEG encoder was not examined as it produces very high Video Bit Rate. This is due to the fact that in its coding algorithm, the entire frames are coded via the JPEG still image standard (does not utilize a block-based conditional replenishment algorithm). The PVH encoder was not studied as it utilizes a video compression algorithm that produces multiple layers in a progressively refinable format and tolerates packet loss [19]. The RAW standard produces uncompressed data and as a result is out of interest in the current study.

Our experiments methodology is the following: importing a created content (a person speaking with mild movement and no abrupt scene changes) through a video camera input, we configured ViC to transmit the encoded data to the IP number of a Network Sniffer (a pc running the Ethereal program). The duration of each experiment was 1 hour and from the ViC menu the Video Bit Rate was configured at 320 Kbps and the Video Frame Rate at 15 fps (parameters required for a qualitative talking heads communication). For comparison reasons, the same content was inputted in all the experiments. In each case, the UDP packets were captured by the traffic monitoring software. The collected data were further post-processed at the frame level by tracing a common packet timestamp. The produced frame size (bytes) sequences were used for further analysis.

Some first conclusions, as supported by the experiments' results (see Table 1), arise concerning the statistical trends of each encoder's traffic. First of all, we observe that the encoders tend to reach the video frame rate threshold specified in the experiment's scenario (except H.263+). Moreover, NVDCT produces lower Video Bit Rate than NV does. This is also observed at the h.26x series. Specifically, h.263+ produces lower Video Bit Rate than h.263 and h.261 do. This was expected, since the earlier encoder versions have improved compression algorithms than the prior ones. Finally,

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[†] Although a newer encoder, namely, H.264, exists, most videoconference clients do not support it.

[‡] Although an extensive research has been made, no information was found for the BVC (Berkeley Video Codec) standard.

despite the fact that the h.261 (Intra-h.261) and NV encoders are both transform coders and are in fact quite similar, the former produces lower Video Bit Rate because it uses a discrete cosine transform (DCT) instead of a Haar transform; it uses a linear quantizer instead of dead-zone only quantizer; and it applies Huffman coding to the run-length encoded symbols (for more information see [13], [15], [16], [17], [18]).

2. Statistical Analysis of the Video Traffic and Presentation of the Simulation Method

Analysis of the traffic, for all experiments, confirms the general body of knowledge that literature has formed concerning videoconference traffic. In brief, the sequence of the frame sizes can be represented as a stationary stochastic process, with an AutoCorrelation Function (ACF) quickly decaying to zero and a marginal frame-size distribution of approximately Gamma form.

The above context makes the DAR model directly applicable for full modelling and analytic treatment of the traffic. This model produces a sequence of frame sizes according to the transitions of a discrete time Markov Chain, of the form:

$$P = \rho \mathrm{I} + (1-\rho)Q \tag{1}$$

where ρ is the autocorrelation coefficient at lag-1, Q is a rank-one stochastic matrix with all rows equal to the probabilities resulting from the negative binomial density corresponding to the Gamma fit for the frame size distribution and I is the identity matrix (with the same dimension as Q).

After extensive analysis of the empirical data with different generalizations of the DAR model in literature and extensive simulations tests using the ns-2 simulator, we concluded to a generic and simple proposal for conservative simulation of the videoconference traffic for each encoder. Our proposal includes the following modelling and simulation steps (for each step we reason our claims):

1. To fit the empirical frame sizes distribution use the MOM method. Why?

- It is simple. All you need is the mean frame size and the variance of the frame sizes sequence given by table 1, and not the entire sequence (only a small part of the sequence is enough as the sequence is stationary).
- It captures accurately the mean video bit rate of the actual data.
- It tends to capture the tail of the frame sizes distribution (that corresponds to the peak rates of the traffic).

In actuality, all density distributions seem to fit a gamma-like shape with a very heavy tail and asymmetry (see figure 1). According to the method of moments when the mean, m, and the variance, v, of the data sample are known, this method produces estimates for the shape and scale parameters of the Gamma distribution: $p = \frac{m^2}{v}$ and $\mu = \frac{v}{m}$ (Numerical values of p and μ parameters of all encoders appear in Table 2).

Although the MOM method did not provide a satisfactory fit in most cases (see figure 1), it can still capture the mean video bit rate (what matters in queuing).

2. Choose the correlation coefficient not at lag-1 by taking into account the long-term trend of the ACF.

Taking into account that the long-term decay rate is the most important factor for queuing, it is evident that a proper model for fitting the autocorrelation function of videoconference traffic is the Compound Exponential Fit (CEF) proposed in [1]. This method is a weighted sum of two geometric terms:

$$\rho_\kappa = w\lambda_1^{\kappa} + (1-w)\lambda_2^{\kappa}, \text{ with } |\lambda_2| < |\lambda_1| < 1 \qquad (2)$$

This method was tested with a least squares fit to the autocorrelation samples for the first 1000 lags[§] for each encoder. Numerical values for the results appear in Table 2, while the graphs of the fitted models are compared to the sample ACFs in figure 2.

What matters in (2) is the autocorrelation coefficient λ_1 as it tends to capture the long-term behavior of the autocorrelation function. The retention of this model is further verified by previous studies [1], [7] for videoconference traffic where values of λ_1 were found to be near 0.998. This being the case, further study towards new models is of no point.

3. Create a 30-state Markov Chain from (1) (using the data set of Table 1 and 2) and assure to modulate the simulated data by a random variable of uniform distribution.

Extensive simulation tests showed that a 30-state markov chain can simulate steadily the actual data.

The 30 states can be easily chosen by dividing the interval between the maximum and the minimum frame size into 30 frame sizes states. So, if x_{min} is the min frame size and x_{max} the max frame size from Table 1 then the step *s* of the states should be $s = integer[(x_{max} - x_{min})/30]$.

To make the simulated data more realistic, the introduction of a random variable Y_n of a uniform distribution in the interval of $[-s/2, s/2]$ is a direct solution (similarly used in [14] but without any suggestion on the selection of the interval).

4. Initialize your Markov Chain with the mean state (which is 15 in our case).

This is a realistic initialization choice as the first frame of the encoder is more probable to be in the mean.

3. Validation of the Simulation Results with ns-2

In this section, we apply trace-driven simulation tests with ns-2 to validate the simulation method proposed in the previous section.

Consider we have a typical M/D/1 queuing system with an incoming vbr source with mean video bit rate equal to C Kbits/sec (containing the actual data or the simulated data), a queue with infinite buffer B (Bytes) and a server with capacity D=1.1*C Kbits/sec (10% higher than the client).

Deploying the above trace-driven simulation system in ns-2, we monitor the queue buffer size every 0.1 sec. The complementary distribution of the monitored buffer frame sizes gives buffer overflow estimation. The comparison of the distribution

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[§] Fitting at 500 and 5000 lags found to be too optimistic and conservative correspondingly (always regarding queuing).

given by the sample data and the simulated data is used for validation of the simulation model.

After extensive simulations, we concluded that the proposed model is steady and provides conservative estimations in all cases. However, a careful choice of the correlation coefficient is needed to assure that the model will remain conservative in future cases of burstier sources. A fit of the autocorrelation function at 1000 lags lead to conservative results for all the encoders. Most ρ values are near 0.98 besides the case of H.263+ (equal to 0.83).

As depicted in figure 3, the buffer overflow estimation given by the simulated data with the DAR model (always with the value of ρ being equal to the correspondent value of Table 2) is more conservative than the actual data estimation. The conservativeness of our method assures the applicability of the simulation method in cases of lower or higher motion videoconference contents.

4. Conclusions

The current study is a contribution of modelling and simulation results for a variety of existing videoconference encoders for talking heads communication. After extensive analysis and simulation tests, we concluded that a careful but simple generalization of the DAR model can simulate steadily and accurately the measured videoconference data. Finally, Tables 1 and 2 constitute a valuable data set for administrators of computer networks interested in queuing studies on videoconferencing applications.

Future work includes: validation of our model with different videoconference contents (low motion and high motion), study of different statistical models for fitting the empirical distribution (besides the MOM method) and the realization of our model using the Continuous version of the DAR model, namely, C-DAR model (proposed in [14]).

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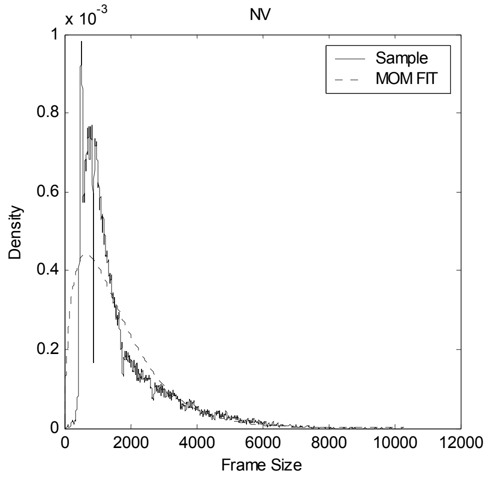
Table 1. Some first statistical characteristics of the generated frame sequences (at 320 KBits/sec and 15 frames/sec)

Encoder	**NV**	**NVDCT**	**H261**	**H263**	**H263+**	**CELLB**	**BVC**
Experiment Duration (sec)	3600						
# of Frames	50113	53336	53937	53453	17921	53749	53855
Mean Video Bit Rate (Kbits/Sec)	182	121	63	54	13	93	92
Mean Frame Rate	14	15	15	15	5	15	15
Mean Frame Size (Bytes)	1638	1023	527	457	331	779	766
Variance (bytes^2)	1589100	678870	174130	24588	401060	407130	467460
Min Frame Size (bytes)	24	24	78	196	80	77	40
Max Frame Size (bytes)	10284	6468	2718	2122	5343	5959	4658

Table 2. MOM and CEF parameters per encoder

	NV	**NVDCT**	**H261**	**H263**	**H263+**	**CELLB**	**BVC**
Parameters of the MOM model							
p	1,68902	1,54127	1,59437	8,50609	0,27242	1,49142	1,25564
μ	969,96887	663,67191	330,47803	53,76463	1213,3365	522,47651	610,1546
Autocorrelation Coefficient $\lambda_1 = \rho$ derived from the CEF model							
λ_1	0,9984	0,99815	0,9987	0,9959	0,83	0,9983	0,9985


NV
x 10^-3
Sample
MOM FIT
Density
Frame Size
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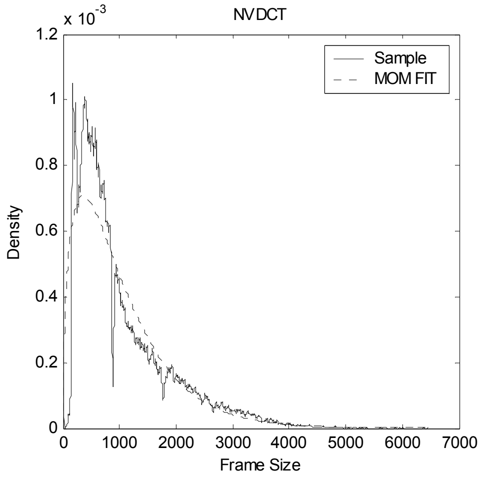
0.4
0.6
0.8
1
0
2000
4000
6000
8000
10000
12000


NVDCT
x 10^-3
Sample
MOM FIT
Density
Frame Size
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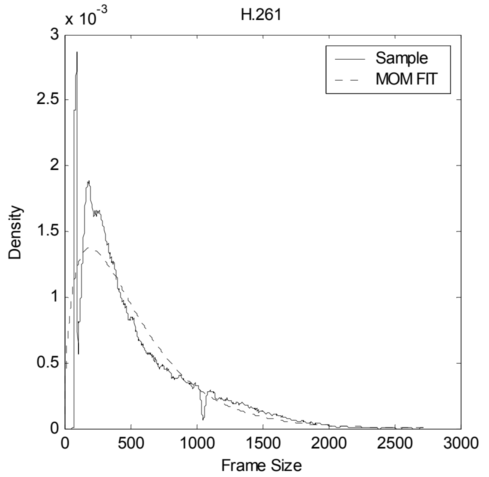
0.4
0.6
0.8
1
1.2
0
1000
2000
3000
4000
5000
6000
7000


H.261
x 10^-3
Sample
MOM FIT
Density
Frame Size
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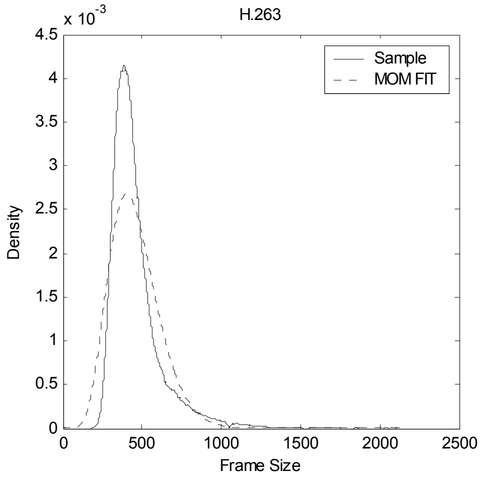
0.5
1
1.5
2
2.5
3
0
500
1000
1500
2000
2500
3000


H.263
x 10^-3
Sample
MOM FIT
Density
Frame Size
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1.5
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2.5
3
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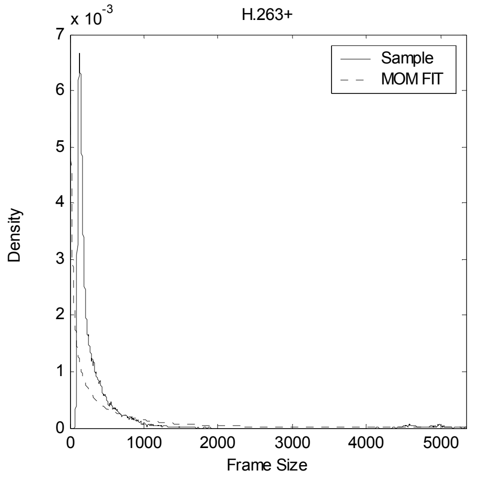
4
4.5
0
500
1000
1500
2000
2500


H.263+
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Sample
MOM FIT
Density
Frame Size
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4
5
6
7
0
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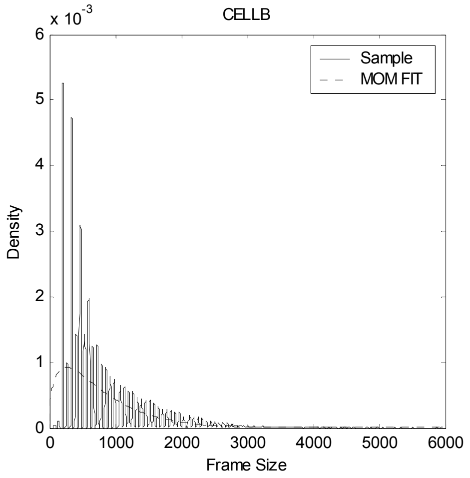
2000
3000
4000
5000


CELLB
x 10^-3
Sample
MOM FIT
Density
Frame Size
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1
2
3
4
5
6
0
1000
2000
3000
4000
5000
6000

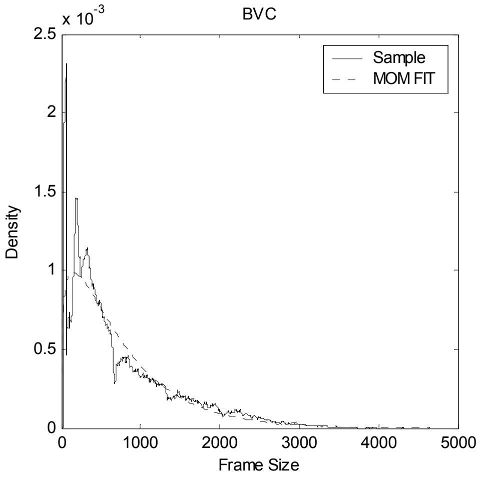
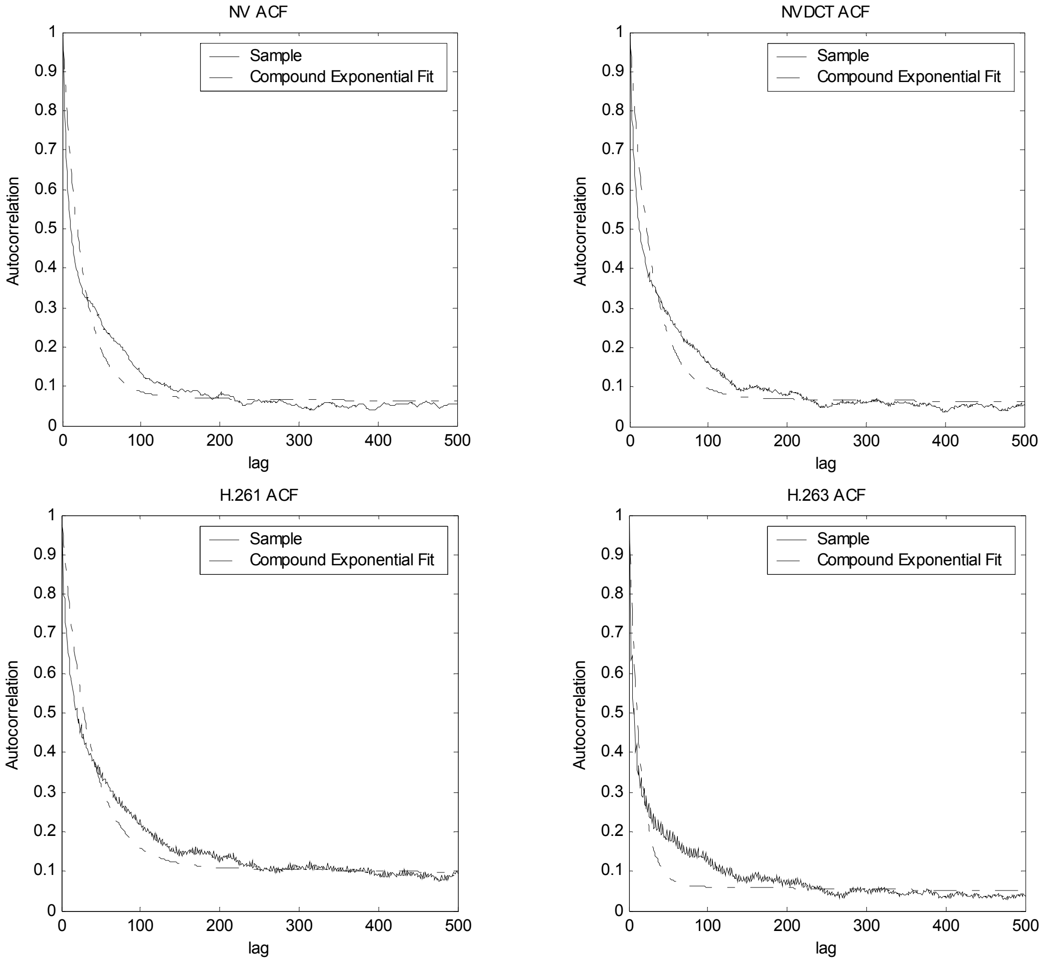


Figure 1. Frame size empirical distributions (smoothed with a typical ''box'' method) and MOM fits per encoder



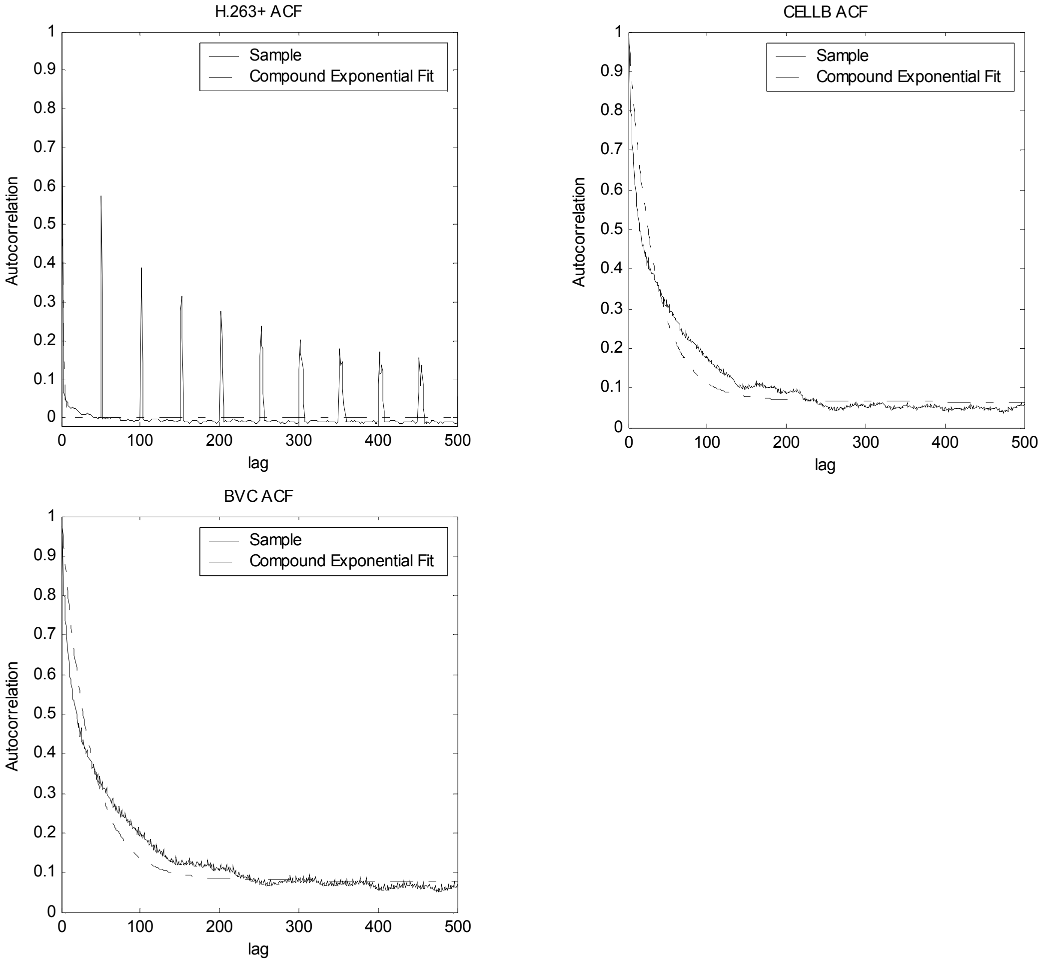
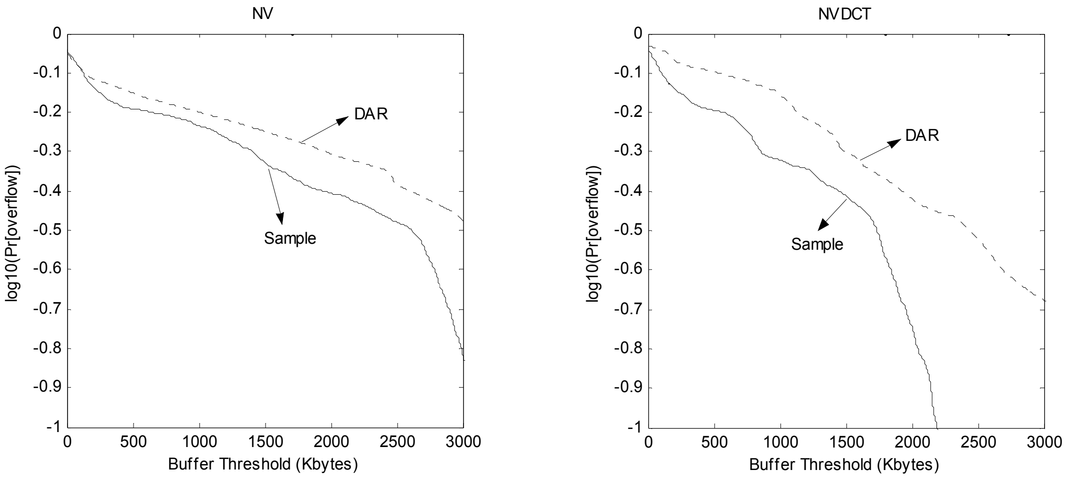


Figure 2. Autocorrelation Graphs and fitted model per encoder



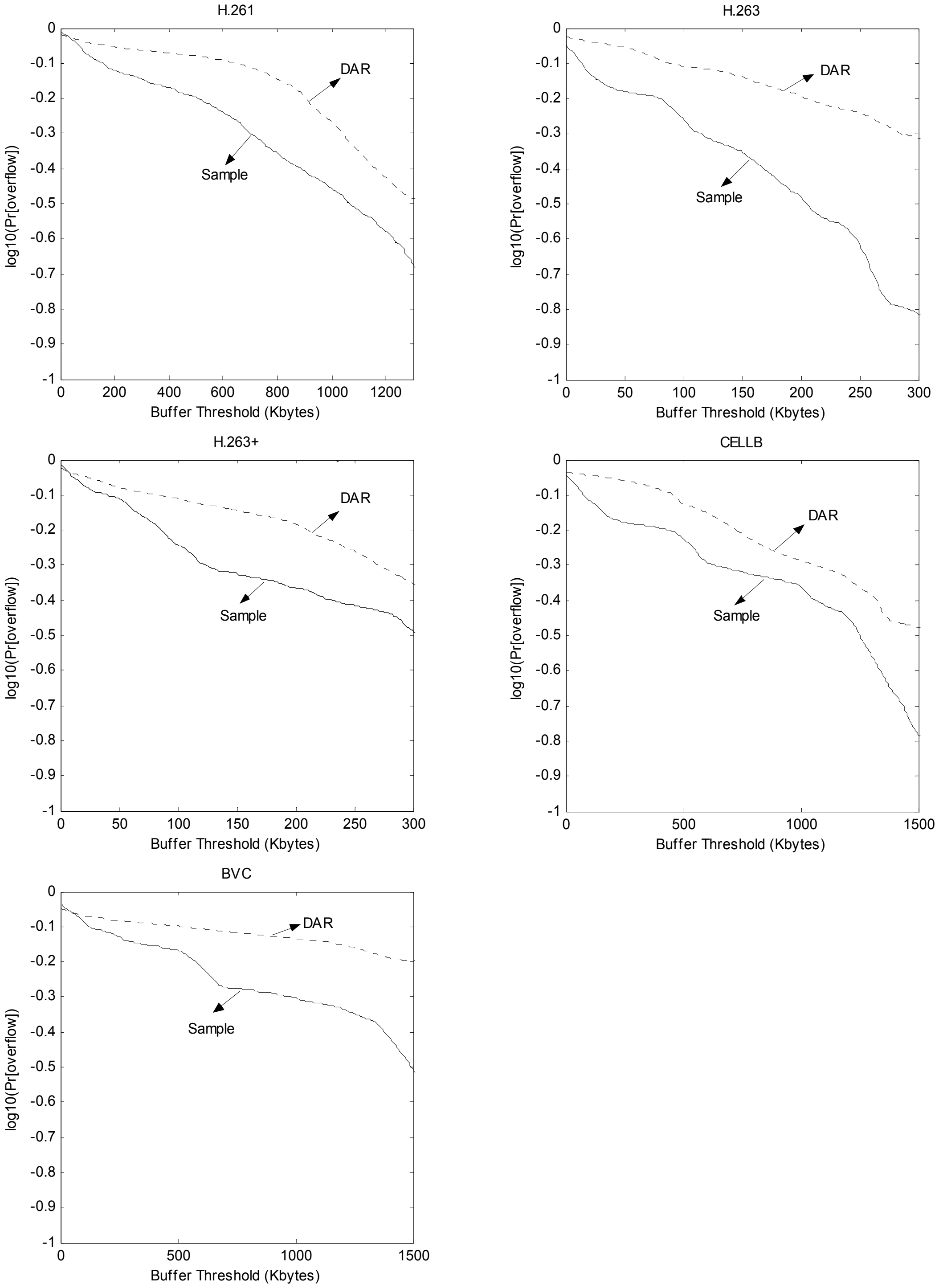


Figure 3. Complementary Distributions of Queue Buffer Size – Overflow Estimation