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THESIS

Scene Change Detection-Based Markov Chain Models for Improved Video Traffic Modeling

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ABSTRACT

With more than 16 billion videos streamed on YouTube during last May and recent estimates by Cisco that mobile video traffic will increase 25-fold between 2011 and 2016, there is a pressing need to adequately serve large numbers of simultaneous online video transmissions. Network providers need to be able to guarantee the strict Quality-of-Service (QoS) requirements of real-time variable bit rate (VBR) video users, and a good statistical model for multiplexed video traffic can help significantly to evaluate and enhance network performance under various video loads.

This work proposes and evaluates a new hybrid video traffic model.

The video traces examined are MPEG-4 sequences and their genre fluctuates between lectures and cartoons, talk shows and action movies, sci-fi and sports. We first build a Discrete Autoregressive model of order one (DAR(1)) and discuss its efficiency on capturing the behavior of actual traces.

We then proceed to build and evaluate our hybrid model, which combines the DAR(1) model with scene change detection and scene classification techniques. A scene typically consists of a few tens or hundreds of video frames that depict a particular real-world scene and can also be interpreted as a collection of related Groups-of-Pictures (GoPs). The classification is performed based on the average number of bits generated during the scenes and the scene activity is modeled by a Markov chain where each state represents the degree of activity (high/low).

Finally, we compare the results of the two models and discuss the contribution of our proposed model.

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1. INTRODUCTION

The continuous growth of the popularity of online Web video streaming is an undeniable fact. Video streaming websites, such as Youtube.com and Veoh.com, are among the most popular websites throughout the world, with hundreds of new subscribers per day. Subsequently, the imperative need for designing wired and wireless networks able to guarantee the strict Quality-of-Service (QoS) requirements of video traffic has risen. Two of the main video QoS requirements regarding the maximum allowable video packet delay and the maximum allowable video packet dropping, are equally strict. Delays in video streaming can be annoying to viewers and whenever the delay experienced by a video packet exceeds the corresponding maximum delay restriction, the packet is dropped.

Thus, it is only natural for the problem of video traffic modeling to have been extensively studied in known literature. In this thesis, our work is focused on modeling MPEG-4 encoded video traffic. Therefore, we had to choose among the already proposed Variable Bit Rate (VBR) video models, including first-order autoregressive (AR) models, discrete AR (DAR) models, Markov renewal processes (MRP),MRP transform-expand-sample (TES), finite-state Markov chains, Gamma-beta-auto-regression (GBAR) models and more. In our approaches, we have used the DAR(1) model and a Markov chain model.

Some background on MPEG-4 follows (found in [2]). MPEG stands for Moving Picture Experts Group. MPEG-4 is a method of defining compression of audio and visual (AV) digital data and it was introduced in late 1998. Standard MPEG encoders generate three types of video frames: I (intracoded), P (predictive) and B (bidirectionally predictive). As their name dictates, I frames are intra-coded while the generation of P and B frames involves the use of motion prediction and interpolation techniques, along with intra-coding. An I frame uses only transform coding and provides a point of access to the compressed video data. On the other hand, a P frame uses motion-compensated prediction from the most recent previous I or P frame. I and P frames are called anchor frames because they are used to predict other frames. In terms of size, as P frames use information already transmitted in previous anchor frames, their size (number of bits required for representation) can be significantly smaller than that of I frames. B frames are coded based on both past and future I or P frames, thus offering the greatest opportunity for data compression. More specifically, the size of a B frame is typically about an order of magnitude smaller than that of an I frame. To sum up, I frames are usually the largest in size, followed by P and then B frames.

A very important feature of common MPEG encoders (both hardware and software) is the manner in which frame types are generated. Typical encoders use a fixed Group-of-Pictures (GoP) pattern when compressing a video sequence. The

GoP pattern specifies the number and temporal order of P and B frames between two successive I frames. A GoP pattern is defined by the distance N between I frames and the distance M between P frames. In practice, the most frequent values of N are 6, 12 and 15, while the most frequent value of M is 3. In our work, the structure of the examined video traces was that of a GoP pattern with M=3 and N=12.

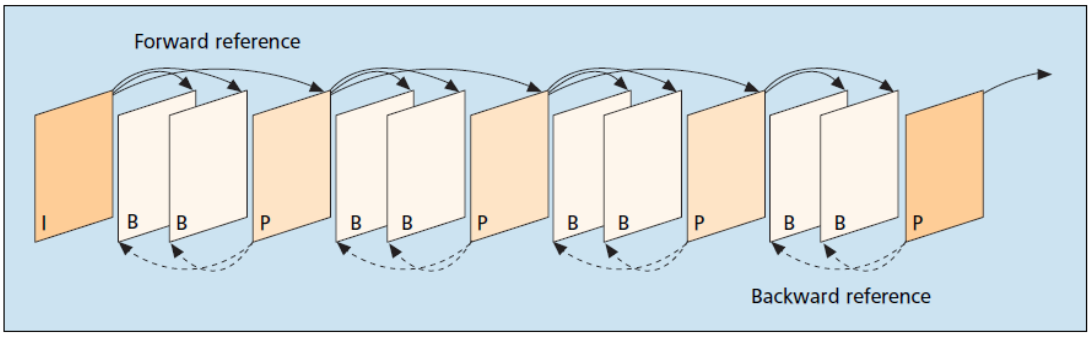

Figure 1.1 *Typical MPEG Group-of-Pictures (GoP) pattern with references used for predictive coding of P and B frames.*

Providing details on the characteristics of previous video encoding standards, such as H.261, H.263, MPEG-1 and MPEG-2, is out of the scope of this thesis. However, we are going to briefly point out the most important differences of MPEG-4 with the aforementioned standards.

H.261 was targeted for teleconferencing applications where motion is naturally more limited and therefore, the accuracy of H.261 motion vectors is reduced in comparison to MPEG. Furthermore, H.261 encoding does not use B frames. The coding algorithm of H.263 is similar to that used by H.261, with certain improvements on performance and error recovery.

MPEG-1 is basically a standard for storing and playing video on a single computer at low bit rates, whereas MPEG-2 is a standard for digital TV. The most significant addition to these standards, which was introduced by MPEG-4, was the ability to represent a scene as a set of audiovisual objects. Also, the MPEG-4 standard is not optimized for a particular application, but instead integrates the encoding, multiplexing and presentation tools required to support a wide range of multimedia information and applications.

In this work, we studied 21 MPEG-4 traces, each in 3 different versions, bringing to 63 the total number of MPEG-4 encoded video traces whose traffic we attempt to model. The list of the video traces used is given below:

1. Die Hard One
2. Citizen Kane
3. Silence of the Lambs
4. Star Wars IV
5. Terminator One
6. Aladdin
7. Cinderella
8. Tonight Show with Commercials
9. Tonight Show without Commercials
10. Lecture-Reisslein
11. Lecture HQ - Reisslein
12. Lecture - Gupta
13. Baseball with Commercials
14. Friends vol. 4 DVD
15. Tokyo Olympics DVD
16. O Brother DVD
17. Die Another Day DVD
18. The Transporter DVD
19. Charlie's Angels DVD
20. Ice Age DVD
21. Oprah without commercials

TABLE 1.1 VIDEO TRACES UNDER STUDY

The first goal of this work was to attempt to model various MPEG-4 movie traces of different genres (drama, action, sci-fi, cartoon, lecture, talk show and sports) with a well-known model, such as the Discrete Autoregressive model of order one (DAR(1) model). The results helped us draw meaningful conclusions on the suitability of the model for generic MPEG-4 traces, and directed our work to a new path, as we investigated the possibility of improving video traffic modeling results by combining the DAR(1) model with scene-detection techniques.

2. MPEG-4 VIDEO TRAFFIC MODELING

2.1 Single-Source MPEG-4 Traffic Modeling

Similarly to [2], our first main concern here is to capture the statistical behavior of the 63 aforementioned single-source MPEG-4 video traces. This can be achieved by finding the distribution providing the best fitting results for the real data. In order to derive which distribution that is, we perform three types of statistical tests.

The set of the distributions examined comprises of the following:

1. Exponential
2. Gamma
3. Lognormal
4. Weibull
5. Pearson V
6. Geometric
7. Negative Binomial

TABLE 2.1 DISTRIBUTIONS UNDER STUDY

The above distributions were chosen as fitting candidates, since almost all of them (with the exception of the exponential distribution) have often been used in video traffic modeling studies in the known literature.

2.1.1 Distributions

The seven distributions presented earlier were selected as fitting candidates for the real data of the 63 movies under study. In other words, we generated distribution data for the respective real data of each such trace. This was done by using the given mean and/or variance of every distribution in order to calculate the distribution's parameters based on the trace statistics. In this section, we present the Probability Density/Mass Function (PDF/PMF), the mean and the variance of all distributions examined.

1. Exponential Distribution: expo(b), b>0
   - PDF: $f(x) = \frac{1}{b} e^{-x/b}$ for all x≥0 and zero otherwise
   - Mean: $Mean = b$
   - Variance: $Variance = b^2$ (not used)

2. Gamma Distribution: gamma(a,b), a>0 and b>0
   - PDF: $f(x) = \frac{b^{-a} x^{a-1} e^{-x/b}}{\Gamma(a)}$ for all x≥0 and zero otherwise
   - Mean: $Mean = ab$
   - Variance: $Variance = ab^2$

3. Lognormal Distribution: LN(μ, σ^2), $\mu>0$ and $\sigma>0$
   - PDF: $f(x)=\frac{1}{x\sqrt{2\pi\sigma^2}}\exp\left(\frac{-(lnx-\mu)^2}{2\sigma^2}\right)$ for all x≥0 and zero otherwise
   - Mean: $Mean=e^{\mu+\frac{\sigma^2}{2}}$
   - Variance: $Variance=e^{2\mu+\sigma^2}(e^{\sigma^2}-1)$

4. Weibull Distribution: Weibull(a,b), a>0 and b>0
   - PDF: $f(x)=ab^{-a}x^{a-1}e^{-(x/b)^a}$ for all x≥0 and zero otherwise
   - Mean: $Mean=\frac{b}{a}\Gamma\left(\frac{1}{\alpha}\right)$
   - Variance: $Variance=\frac{b^2}{\alpha}\left\{2\Gamma\left(\frac{2}{\alpha}\right)-\frac{1}{\alpha}\left[\Gamma\left(\frac{1}{\alpha}\right)\right]^2\right\}$

5. Pearson V Distribution: PT5(a,b), a>0 and b>0
   - PDF: $f(x)=\frac{x^{-(a+1)}e^{-\frac{b}{x}}}{b^{-a}\Gamma(\alpha)}$ for all x≥0 and zero otherwise
   - Mean: $Mean=\frac{b}{a-1}$ for a>1
   - Variance: $Variance=\frac{b^2}{(a-1)^2(a-2)}$ for a>2

6. Geometric Distribution: geom(p), $p\in(0,1)$
   - PMF: $p(x)=p(1-p)^x$ for all x in {0,1, . . .} and zero otherwise
   - Mean: $Mean=\frac{1-p}{p}$
   - Variance: $Variance=\frac{1-p}{p^2}$ (not used)

7. Negative Binomial Distribution: negbin(s, p), s is a positive integer and p ϵ (0,1)
   - PMF: $p(x) = \binom{s+x-1}{x} p^s (1-p)^x$ for all x in {0,1, . . .} and zero otherwise
   - Mean: $Mean = \frac{s(1-p)}{p}$
   - Variance: $Variance = \frac{s(1-p)}{p^2}$

2.1.2 File Format

The real video data, taken from [1], was included in two types of files, the 'terse' and the 'verbose' ones. By presenting the format of those files, the reader will be introduced to the information that we had access to during our work.

- Terse file format

Frame size (bits)	Q_Y (dB)
2248	92.169601
64	92.169601
64	92.169601
160	92.169601
….	….
….	….
….	….

TABLE 2.2 TERSE FILE FORMAT

- Verbose file format

Frame number	Tn (secs)	Frame type	Frame size (bits)	Q_Y(dB)	Q_U(dB)	Q_V(dB)
0	0.000000	I	2248	92.169601	55.271099	55.271099
3	0.100000	P	160	92.169601	55.271099	55.271099
1	0.033333	B	64	92.169601	55.271099	55.271099
2	0.066667	B	64	92.169601	55.271099	55.271099
….	….	….	….	….	….	….
….	….	….	….	….	….	….
….	….	….	….	….	….	….
….	….	….	….	….	….	….

TABLE 2.3 VERBOSE FILE FORMAT

Above, Tn stands for the cumulative display time of the specific frame, whereas Q_Y, Q_U and Q_V represent the quality of the luminance, of the hue and of the saturation component of the encoded video frame. The three quality variables were not used in our work. In order to avoid confusion, we should clarify that frames inside the verbose files are ordered in the codec sequence, while frames inside the terse files are ordered in their display sequence.

In the next three subsections, we analyze the types of statistical tests used in our study. Those can be split into two categories: the qualitative ones, like the Q-Q plots, and the quantitative ones, like the Kolmogorov-Smirnov and the Kullback-Leibler tests.

2.1.3 First Statistical Test: Q-Q plot

In statistics, a Q-Q plot -'Q' stands for quantile- is a probability plot, in that it is a graphical method for comparing two probability distributions by plotting their quantiles against each other. A point (x, y) on the plot corresponds to one of the quantiles of the second distribution (y-coordinate) plotted against the same quantile of the first distribution (x-coordinate).

In other words, the Q-Q plot is a powerful goodness-of-fit test, which graphically compares two data sets in order to determine whether the data sets come from populations with a common distribution. If they do, the points of the plot should fall approximately along a 45-degree reference line [4].

In our case, a Q-Q plot is a plot of the quantiles of the real data versus the quantiles of the fitted distribution (statistical data). A z-quantile of X is any value x such that $P\big((X \leq x) = z\big)$.

In our work, all Q-Q plots produced make use of the 1% quantiles of the two data sets mentioned. To elaborate, we first sorted both the real and the statistical data into ascending order and we then sampled 100 elements of those vectors $(sampling\ step = \frac{number\ of\ frames}{100})$.

2.1.4 Second Statistical Test: Kullback-Leibler Test

The Kullback-Leibler divergence or information divergence was originally introduced by Solomon Kullback and Richard Leibler in 1951. The Kullback-Leibler divergence test (KL-test) is a measure of the difference between two probability distributions *f* and *g* and is defined as follows [5]:

$$I(f,g)=\sum_{i=1}^{k} p_i \log\left(\frac{p_i}{\pi_i}\right)$$

- log: natural logarithm
- k: number of possible outcomes of the underlying random variable
- pi: the true probability of the i^{th} outcome
- $\pi_1,\ldots, \pi_k$: the approximating probability distribution (i.e., the approximating model)

  In this case, the following apply:

- $0 < p_i < 1$
- $0 < \pi_i < 1$
- $\sum p_i = \sum \pi_i = 1$

Hence, *f* and *g* here correspond to the p_i and π_i, respectively. The notation *I(f, g)* denotes the information lost when *g* is used to approximate *f* or the distance from *g* to *f*. If the quantity 0log0 appears in the formula, it is interpreted as zero.

As far as this test is concerned, the lesser the value of $I(f,g)$, the better the fitting attempt. In our implementation, we calculated pi by dividing each source element by the sum of all source elements (probabilities of real data) and we then computed π_i by dividing each distribution data element by the sum of all such elements (probabilities of distribution data).

2.1.5 Third Statistical Test: Kolmogorov-Smirnov Test

The Kolmogorov-Smirnov test (KS-test) tries to determine if two datasets differ significantly. The KS-test has the advantage of making no assumption about the distribution of data, i.e., it is non-parametric and distribution free. The KS-test uses the maximum vertical deviation between the two curves as its statistic D. The formula calculating D is [4]:

$$D = \sup_x \{|F(x) - G(x)|\}$$

- sup: supremum or least upper bound
- F(x): empirical distribution function of the original data
- G(x): cumulative distribution function (cdf) of the model

The more the value of D approaches zero, the better the fitting attempt.

Even though the KS-test is a good statistical tool, one cannot overlook the fact that KS-tests give the same weight to the difference between the actual data and the fitted distribution for all values of data, whereas many compared distributions differ primarily in their tails.

This test was performed by using the Matlab function 'kstest2(X1, X2)', where X1 was the real data vector and X2 the distribution data vector.

2.1.6 Determining Best Fit

Initially, when handling traces of whole movies, our efforts focused on whether a best fit existed or not. More specifically, if the Q-Q plots were unable to indicate a distribution that could serve as a best fit, the corresponding traces were split into their respective I, P and B frames and each sequence of frame types was modeled separately, and tested with the same statistical tests, in order for us to finally decide upon the best fit in each case. If, on the other hand, the Q-Q plots indicated a best fit for the whole trace, we then took the results of the KL and the KS tests into consideration, in the way described in the next paragraph.

In the cases where all three statistical tests or two out of the three tests denoted the same distribution as the best fit, we considered that distribution to provide the best fitting result. However, in the cases where each out of the three tests denoted a different distribution as the best fit, we compared the result of the KL-test with the result of the respective Q-Q plot. If the distribution being the best fit according to the KL test was a close second best according to the Q-Q plot, that distribution was eventually considered to be the best fit for the real data. Throughout our work, we encountered this in several of the traces under study. Still, the most frequent case was that of two statistical tests denoting the same distribution as the best fit. Finally, if all tests offered different results and the KL-test best fit did not happen to be a Q-Q plot good fit, then the specific trace was not later included in our DAR(1) modeling.

2.1.7 Observations – Test Comparison

Our statistical tests' results showed that, in the majority of cases, the three tests used (Q-Q plots, KS-tests and KL-tests) **did not** agree on which distribution provided the best fit. This is intuitively expected, because of the different nature of the tests. More specifically, the Q-Q plot is of a qualitative nature and is based on observation; therefore, in the case where different distributions provide similar fitting results, the Q-Q plot cannot provide a definite or objective conclusion on which one is the best fit. On the other hand, the KS-test does provide a quantitative result, but this refers to the maximum vertical deviation between two curves; therefore, it is clear which distribution has the minimum maximum distance from the real data curve, but this is not conclusive in terms of whether this distribution also constitutes the closest fit throughout the curve length. This is where the KL-test comes in; this quantitative test, as described in section 2.1.4, provides the information lost during a fitting attempt, by comparing the probabilities of every respective element of the real and the distribution

data. In other words, its conclusion is based on all elements of both data sets. Taking the above into consideration, it could be argued that, among the three tests, KL is the one to provide the most accurate results on the goodness-of-fit of a distribution.

The differences in the conclusions of the three tests can be attributed not only to the very different nature of the three statistical tests used, as well as the lower autocorrelation of most of the examined MPEG-4 traces, as opposed to the high autocorrelation of the MPEG-4 videoconference traffic studied in [2]. This lower autocorrelation is responsible for the larger difference in size between successive frames, and hence makes the behavior of traces more unpredictable (i.e., more outliers in the tests). Hence, we had to split 57 out of the 63 traces in I, P and B frames to test each frame type separately.

2.2 Multiplexed MPEG-4 Traffic Modeling

Similarly to [2], our goal is to build a model for multiplexed sources based only on parameters which are either known at call set-up time or can be measured without introducing much complexity in the network. Subsequently, we build a Discrete Autoregressive model of order 1, denoted as DAR(1), in order to capture the behavior of now multiplexed (previously single-source) MPEG-4 traces. The reasons why the DAR(1) model constitutes a good choice for this job will be clarified later on.

2.2.1 The DAR(1) Model

Historically speaking, autoregressive models have been used in the past to model the output bit-rate of VBR encoders. As stated in [6] and [7], a Discrete Autoregressive model of order p, denoted as DAR(p), generates a stationary sequence of discrete random variables with an arbitrary probability distribution and with an autocorrelation structure similar to that of an Autoregressive model. DAR(1) is a special case of a DAR(p) process and is defined as follows:

Let {Vn} and {Yn} be two sequences of independent random variables. The random variable Vn can take two values, 0 and 1, with probabilities 1-ρ and ρ, respectively. The random variable Yn has a discrete state space S and P{Yn=i}=π(i). The sequence of random variables {Xn} which is formed according to the linear model:

$$X_n = V_n X_{n-1} + (1 - V_n) Y_n$$

is a DAR(1) process.

A DAR(1) process is a Markov chain with discrete state space S and transition matrix:

$$\mathbf{P} = \rho \mathbf{I} + (1 - \rho)\mathbf{Q} \quad (1)$$

where ρ is the autocorrelation coefficient, **I** is the identity matrix and **Q** is a matrix with $Q_{ij} = \pi(j)$ for $i, j \in S$.

Autocorrelations are usually plotted for a range W of lags. The term 'lag' is used to refer to the distance between the frames examined. For instance, 'lag-1' means that the computation of the autocorrelation coefficient takes into account frames that are successive. Throughout this thesis, we consider W=1. The autocorrelation can be calculated by the following formula:

$$\rho(W) = E[(X_i - \mu)(X_{i+w} - \mu)]/\sigma^2 \quad (2)$$

where μ is the mean and σ^2 the variance of the frame size for a specific video trace.

The advantages of this model are the easy and practical method of computing the transition matrix and the fact that it is based on only four physically meaningful parameters, i.e., the mean, the peak, the variance and the lag-1 autocorrelation coefficient ρ (keeping it real). For the sake of clarity, the peak is used to determine the number of states in the model. Furthermore, as shown in literature, the DAR(1) model can be used with any marginal distribution.

A more detailed analysis of how we built the DAR(1) model for each one of the traces under study is given below. In each case, the rows of the **Q** matrix, which appears in equation (1), consist of the probabilities of the distribution found to be the best fit $(f_0, f_1, \dots f_k, F_K)$, where $F_K = \sum_{k>K} f_k$, and K is the peak rate. Each k, for $k < K$, corresponds to possible source rates less than the peak rate of K.

From the transition matrix in (1), it is evident that if the current frame has, for example, i cells, then the next frame will have i cells with probability $\rho + (1-\rho) * f_i$, and will have k cells, $k \neq i$, with probability $(1-\rho) * f_k$. Therefore, the number of cells per video frame stays constant from one video frame (I, P or B) to the next (I, P or B), respectively, with a probability slightly larger than ρ.

The DAR(1) model generates a Markov chain resembling the one presented in Figure 2.1. States are represented as circles, while transitions are represented as arrows. Transition probabilities are portrayed as arrow labels. For every state reached during the transition process, a new video frame is generated. The number of a state is the number of video packets a frame consists of. Consequently, the maximum number of packets (or states) that can be generated from the model is calculated by dividing the maximum frame size of the actual trace by the packet size used.

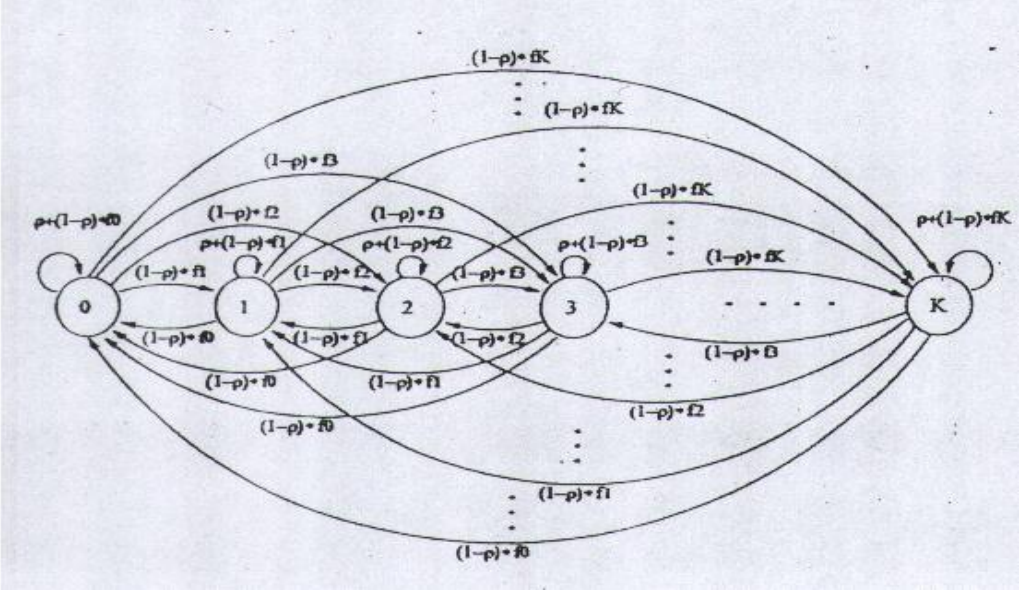

Figure 2.1 *Markov chain generated from the DAR(1) model*

In our implementation, each packet contains 48 [2] or 200 Bytes [8], depending on the case. More specifically, all 30-30-30 traces are modeled with 48 Byte packets whereas all 04-04-04 traces are modeled with 200 Byte packets. Our choice regarding the former lies on the fact that, by using 200 Byte packets, the number of DAR(1) states for the 30-30-30 traces was too small. In the same spirit, the 10-14-16 traces, for which the 200 Byte packets had produced less than 25 states, were chosen to be modeled with 48 Byte packets.

After the statistical data has been generated, we proceed to test whether our model captures the behavior of the real data or not. Therefore, we obtain 5 (or 10 or 15) identical instances of the real source and the statistical source, we shuffle them, by randomly choosing a starting point, we compute their superposition and finally, we graphically represent the quantiles of the two superposed vectors in a Q-Q plot.

2.3 Results/Conclusions

In this section, we first present the statistical data corresponding to the part of our work focusing on finding the best distribution fit. A discussion on the results of this part, as well as the DAR(1) modeling part, follows.

2.3.1 Single-Source MPEG-4 Traffic Modeling

Treated as whole movies	9.52%
Split into I, P and B frames	90.48%

TABLE 2.4 – MOVIES SPLIT INTO THEIR RESPECTIVE I, P AND B FRAMES

Distribution	Corresponding Percentage
Exponential	1.70%
Gamma	35.03%
Lognormal	28.81%
Weibull	18.64%
Pearson V	15.25%
Geometric	0.57%
Negative Binomial	0.00%

TABLE 2.5 - Q-Q PLOTS' CUMULATIVE RESULTS FOR BEST FIT

Distribution	Percentage for *whole movies*	Percentage for *I frames*	Percentage for *P frames*	Percentage for *B frames*
Exponential	0.00%	0.00%	0.00%	5.26%
Gamma	50.00%	40.35%	26.32%	36.84%
Lognormal	16.67%	17.55%	45.61%	24.56%
Weibull	0.00%	24.56%	10.53%	22.81%
Pearson V	33.33%	17.55%	15.79%	10.53%
Geometric	0.00%	0.00%	1.75%	0.00%
Negative Binomial	0.00%	0.00%	0.00%	0.00%

TABLE 2.6 - Q-Q PLOTS' DETAILED RESULTS FOR BEST FIT

Distribution	Corresponding Percentage
Exponential	0.00%
Gamma	0.00%
Lognormal	67.23%
Weibull	0.00%
Pearson V	0.00%
Geometric	0.00%
Negative Binomial	32.77%

TABLE 2.7 – KL TESTS' CUMULATIVE RESULTS FOR BEST FIT

Distribution	Percentage for *whole movies*	Percentage for *I frames*	Percentage for *P frames*	Percentage for *B frames*
Exponential	0.00%	0.00%	0.00%	0.00%
Gamma	0.00%	0.00%	0.00%	0.00%
Lognormal	83.33%	66.67%	66.67%	66.67%
Weibull	0.00%	0.00%	0.00%	0.00%
Pearson V	0.00%	0.00%	0.00%	0.00%
Geometric	0.00%	0.00%	0.00%	0.00%
Negative Binomial	16.67%	33.33%	33.33%	33.33%

TABLE 2.8 – KL TESTS' DETAILED RESULTS FOR BEST FIT

Distribution	Corresponding Percentage
Exponential	1.13%
Gamma	33.90%
Lognormal	20.90%
Weibull	20.90%
Pearson V	15.25%
Geometric	2.83%
Negative Binomial	5.09%

TABLE 2.9 – KS TESTS' CUMULATIVE RESULTS FOR BEST FIT

Distribution	Percentage for *whole movies*	Percentage for *I frames*	Percentage for *P frames*	Percentage for *B frames*
Exponential	0.00%	0.00%	1.75%	1.75%
Gamma	16.67%	38.60%	33.33%	31.58%
Lognormal	50.00%	10.53%	28.07%	21.05%
Weibull	16.67%	24.56%	12.28%	26.32%
Pearson V	16.67%	21.05%	14.04%	10.53%
Geometric	0.00%	0.00%	3.51%	5.26%
Negative Binomial	0.00%	5.26%	7.02%	3.51%

TABLE 2.10 – KS TESTS' DETAILED RESULTS FOR BEST FIT

Distribution	Percentage for *whole movies*	Percentage for *I frames*	Percentage for *P frames*	Percentage for *B frames*	Cumulative Percentage
Exponential	0.00%	0.00%	0.00%	1.75%	0.57%
Gamma	16.67%	33.33%	24.56%	28.07%	28.25%
Lognormal	66.67%	22.81%	45.61%	31.59%	34.46%
Weibull	0.00%	22.81%	5.26%	19.30%	15.25%
Pearson V	16.67%	15.79%	12.28%	8.77%	12.43%
Geometric	0.00%	0.00%	0.00%	0.00%	0.00%
Negative Binomial	0.00%	1.75%	1.75%	0.00%	1.13%

TABLE 2.11 – BEST DISTRIBUTION FIT PERCENTAGES PER TRACE TYPE

Percentage for *whole movies*	Percentage for *I frames*	Percentage for *P frames*	Percentage for *B frames*	Cumulative Percentage
0.00%	3.51%	10.53%	10.53%	7.91%

TABLE 2.12 – PERCENTAGE PER TRACE TYPE OF MOVIES EXCLUDED FROM DAR(1) MODELING

We need to mention that the exponential and the geometric distribution present the worst behavior among all distributions used. That is the case not only here, but also when treating the I, P and B frames of the traces under study separately. The reason justifying such a behavior is that the data of those distributions was generated based on just one parameter, whose calculation made sole use of the mean of the traces and not also their variance. The six traces presented in Table 2.13 are the only ones, among all the traces studied, that can be well-modeled as a whole (i.e., without splitting them into I, P and B frames).

Terminator One, 04-04-04
Cinderella, 04-04-04
Tonight Show with Commercials, 04-04-04
Baseball with Commercials, 04-04-04
Tokyo Olympics DVD, 30-30-30
The Transporter DVD, 30-30-30

TABLE 2.13 – TRACES MODELED AS A WHOLE

As far as the I frames are concerned, we found that among all Q-Q plots produced, there are good and bad fittings. The worst fittings correspond to the traces Tonight Show without Commercials, Lecture Reisslein, Lecture Reisslein HQ and Lecture Gupta for all 3 quantization parameter groups. In other words, the movies with the worst behavior here include a talk show and three lectures. These traces happen to have the highest lag-1 autocorrelation coefficient values among all I frames (see Tables 2.14 and 2.15) and also, some of the highest values among all traces examined. An example of a good fitting, a mediocre fitting and a bad fitting are shown in Figures 2.2, 2.3 and 2.4.

I Frames	Lag-1 Autocorrelation Coefficient, ρ
Tonight Show without Commercials, 30-30-30	0.9768
Tonight Show without Commercials, 10-14-16	0.9875
Tonight Show without Commercials, 04-04-04	0.9917
Lecture – Reisslein, 30-30-30	0.9883
Lecture – Reisslein, 10-14-16	0.9905
Lecture – Reisslein, 04-04-04	0.9926
Lecture HQ – Reisslein, 30-30-30	0.9891
Lecture HQ – Reisslein, 10-14-16	0.9863
Lecture HQ – Reisslein, 04-04-04	0.9856
Lecture – Gupta, 30-30-30	0.9794
Lecture – Gupta, 10-14-16	0.9805
Lecture – Gupta, 04-04-04	0.9789

TABLE 2.14 – AUTOCORRELATION OF I TRACES WITH THE WORST FITTINGS

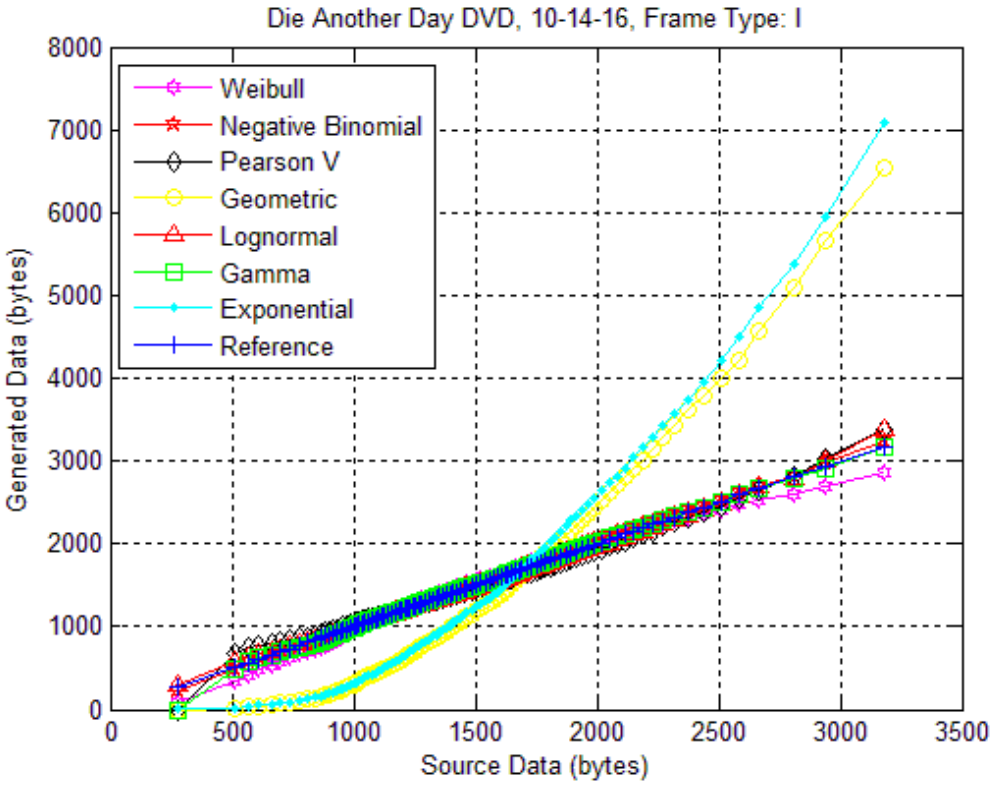

Figure 2.2 *Good fitting, I frames*

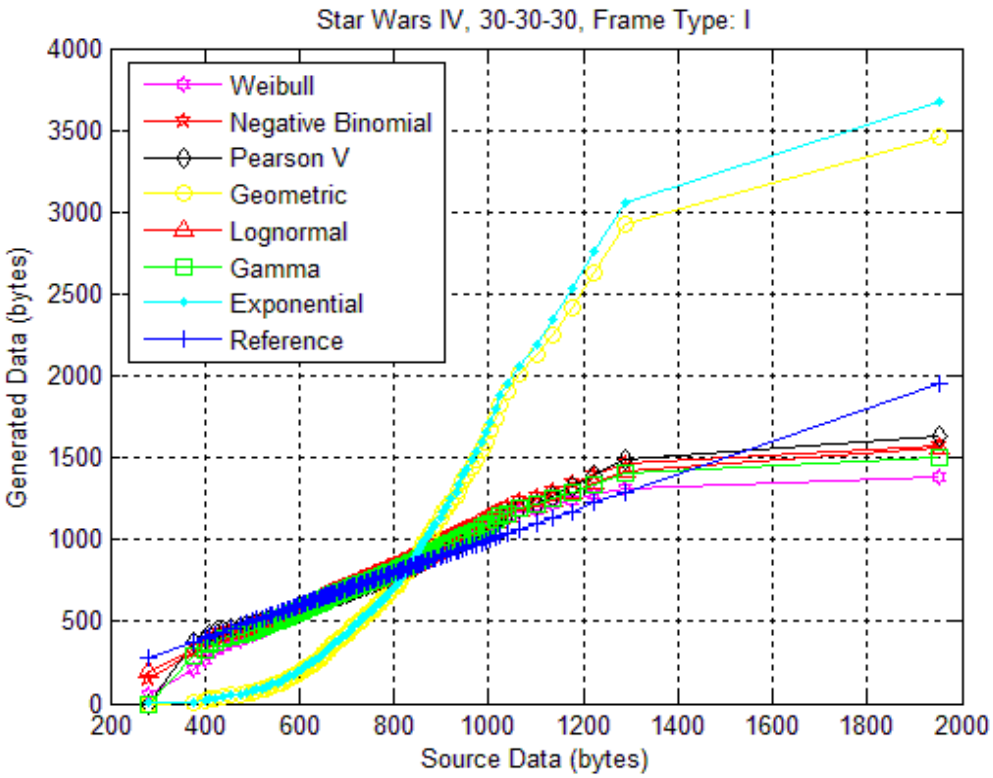

Figure 2.3 *Mediocre fitting, I frames*

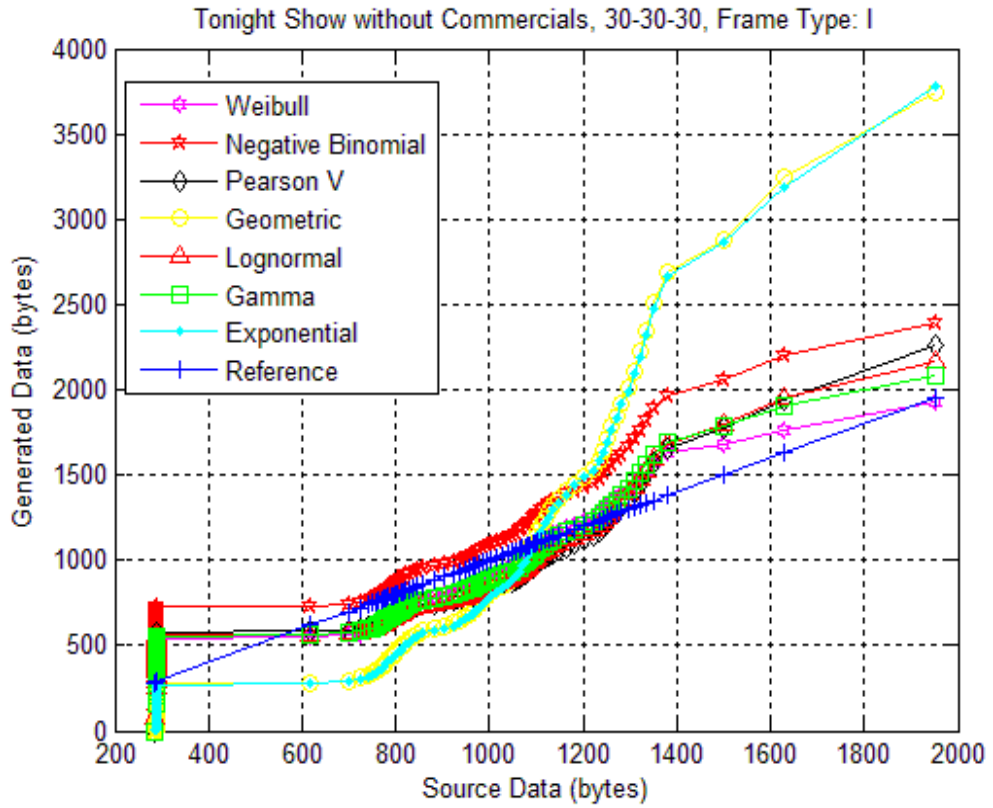

Figure 2.4 *Bad fitting, I frames*

In most of the cases, as the movie quality increases, the accuracy of the fittings increases, too (examples: Citizen Kane I frames, Silence of the Lambs I frames, Star Wars IV I frames). To avoid confusion, the 30-30-30 movies are of the lower and the 04-04-04 movies are of the higher quality. In the cases where fittings are bad for all three qualities of a movie, the aforementioned improvement with quality is hard to observe (example: Lecture Reisslein HQ I frames). On the other hand, one can sometimes observe the opposite, meaning that the accuracy of the fittings diminishes as quality increases (example: Tonight Show without Commercials I frames).

As far as the P and B frames are concerned, our observations are similar to the ones corresponding to the I frames.

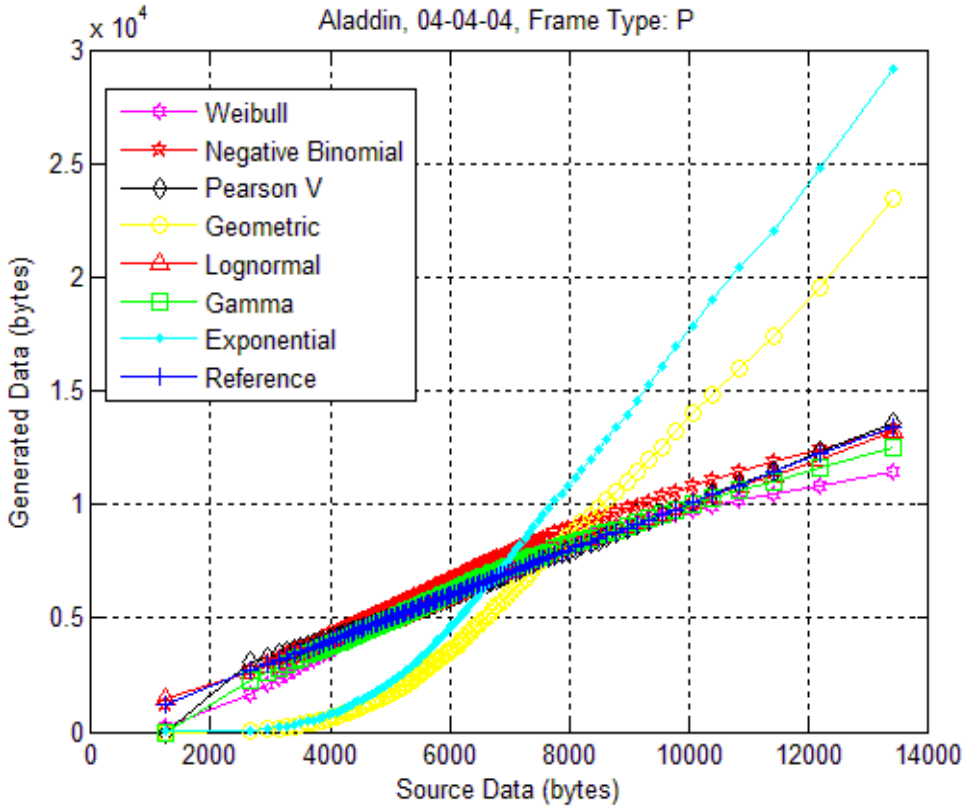

Figure 2.5 *Good fitting, P frames*

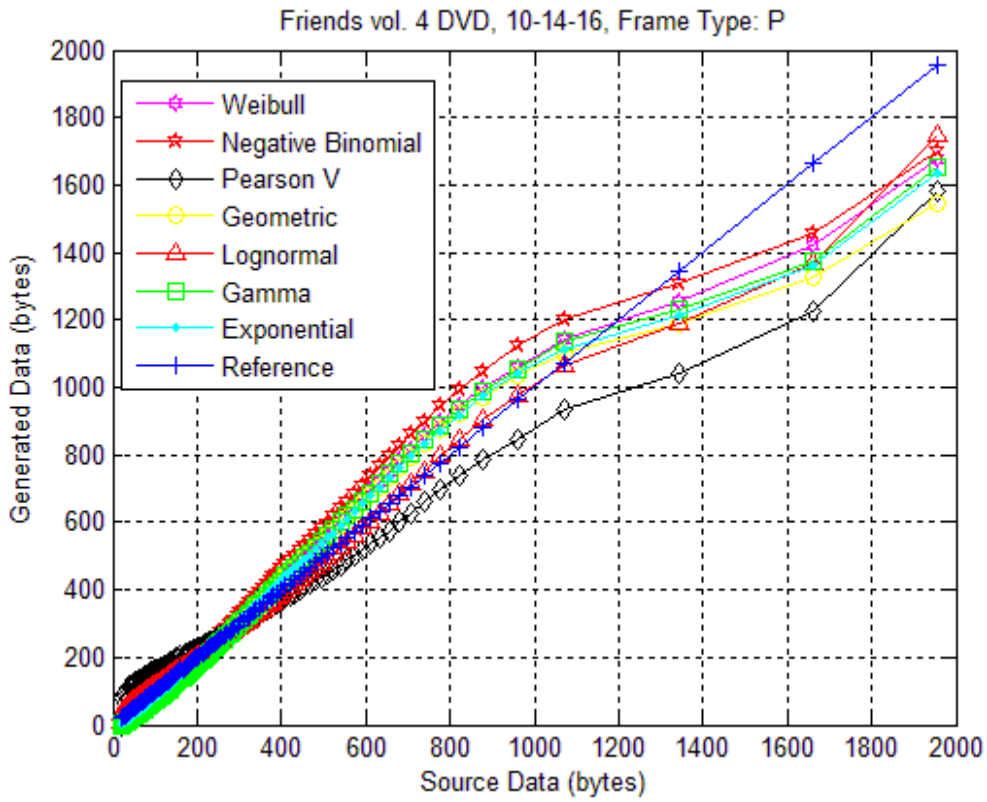

Figure 2.6 *Mediocre fitting, P frames*

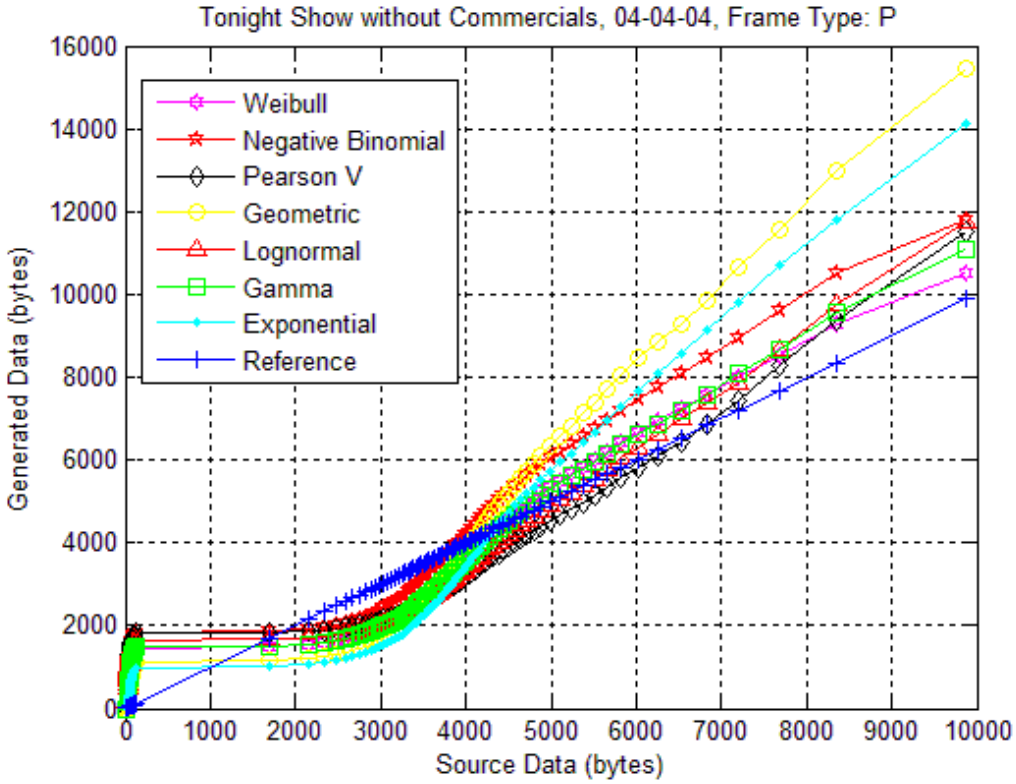

Figure 2.7 *Bad fitting, P frames*

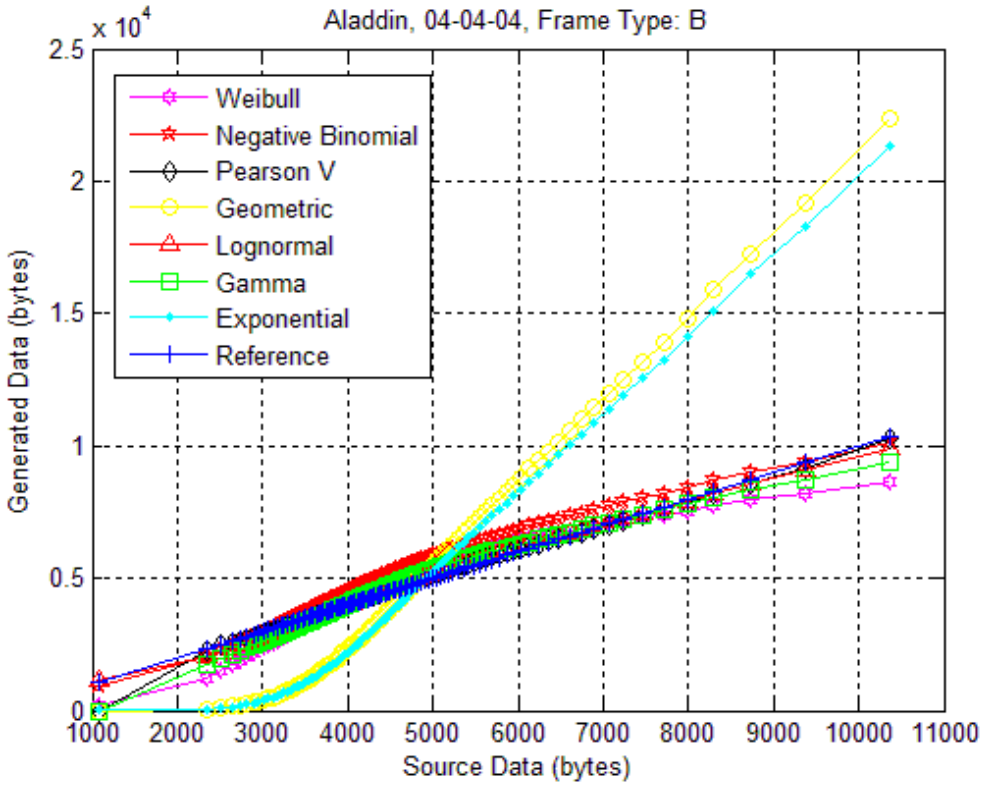

Figure 2.8 *Good fitting, B frames*

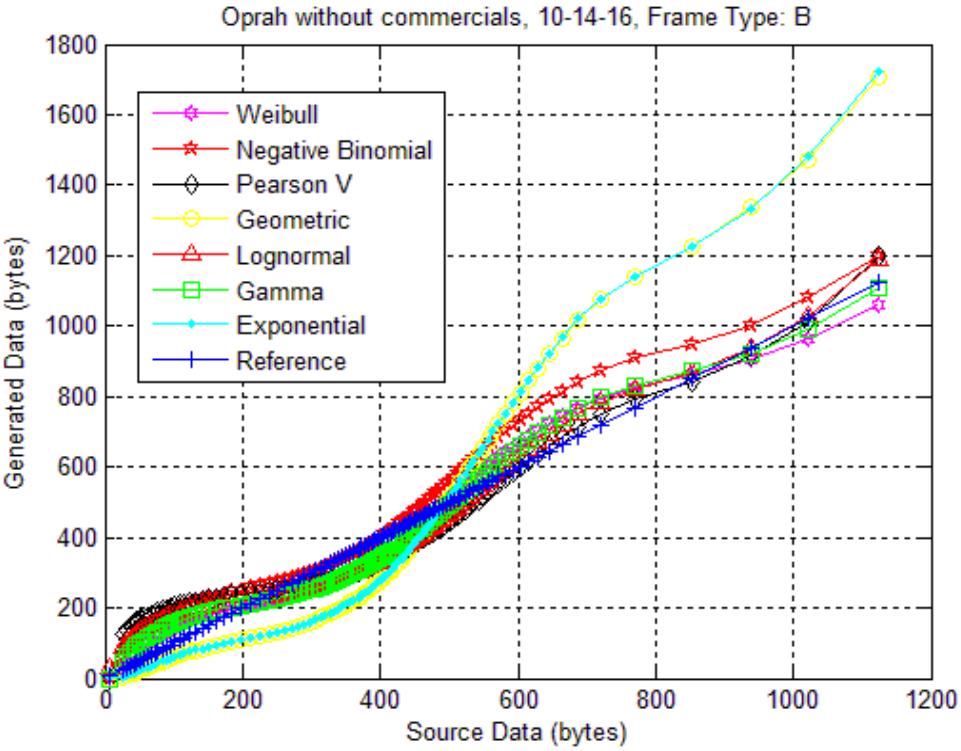

Figure 2.9 *Mediocre fitting, B frames*

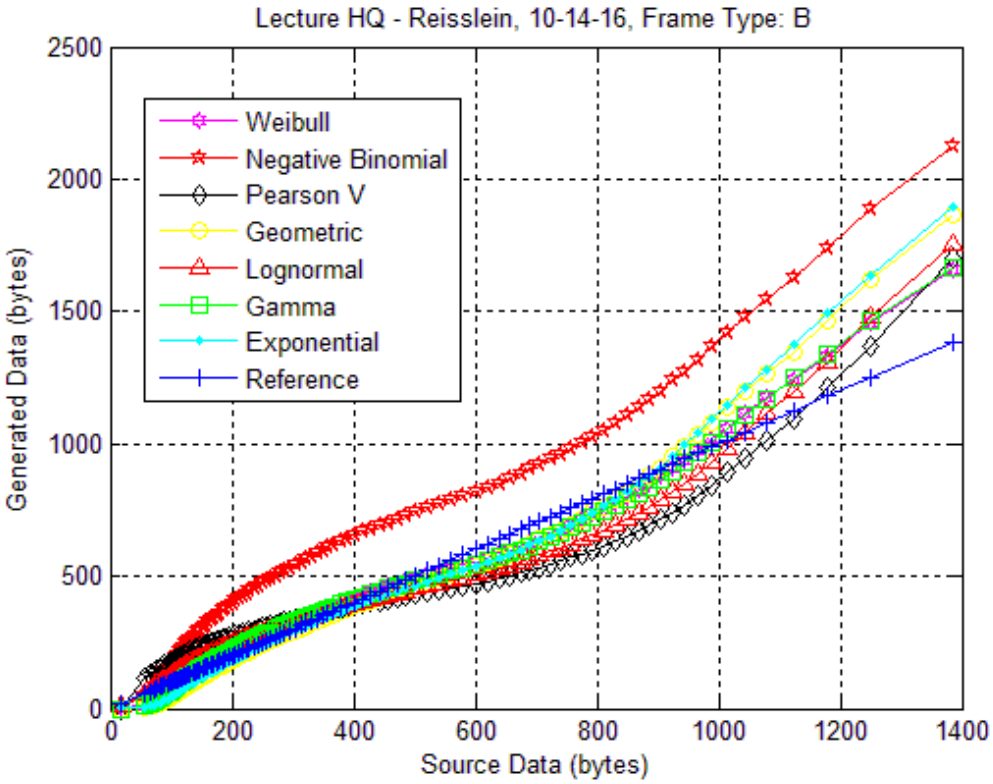

Figure 2.10 *Bad fitting, B frames*

One major difference observed when comparing the plots coming from I, P and B frames is that the worst fittings in the cases of P and B frames are much better than the ones in the case of I frames.

Finally, even though the majority of the plots examined provided good to mediocre fitting results, no distribution was proven capable of perfectly "capturing" the behavior of a trace under study. The reason behind this incapability of achieving perfect accuracy lies on the fact that the high autocorrelation, especially of the traces of the same frame type, cannot be "captured" by a distribution generating frame sizes independently, according to a declared mean and standard deviation.

2.3.2 Multiplexed MPEG-4 Traffic Modeling

As previously stated, the DAR(1) model makes use of the autocorrelation coefficient of every trace under study, denoted as ρ. As far as ρ is concerned, one can observe that, from all the traces examined, whole movies have the lowest autocorrelation coefficients while I frames' sequences have the highest. More details are shown in Table 2.15.

Trace Type	Min ρ	Max ρ
Whole movies	0.0940	0.4489
I frames	0.8473	0.9926
P frames	0.4365	0.9794
B frames	0.4692	0.9905

TABLE 2.15 – MIN AND MAX AUTOCORRELATION COEFFICIENT VALUES PER TRACE TYPE

- ***Whole traces***

As mentioned before, only six traces were examined as a whole. All 6 Q-Q plots showed that the DAR(1) model provided mediocre results for the specific traces. In Figures 2.11 and 2.12 we present indicatively two of the Q-Q plots.

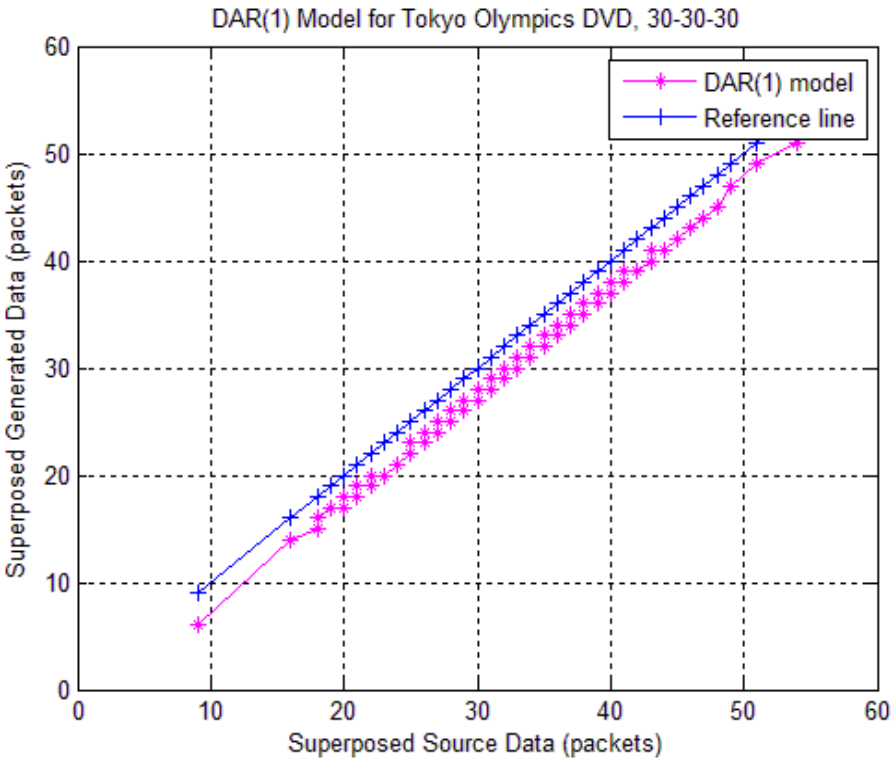

Figure 2.11 *Mediocre Modeling Result (5 sources) for whole traces*

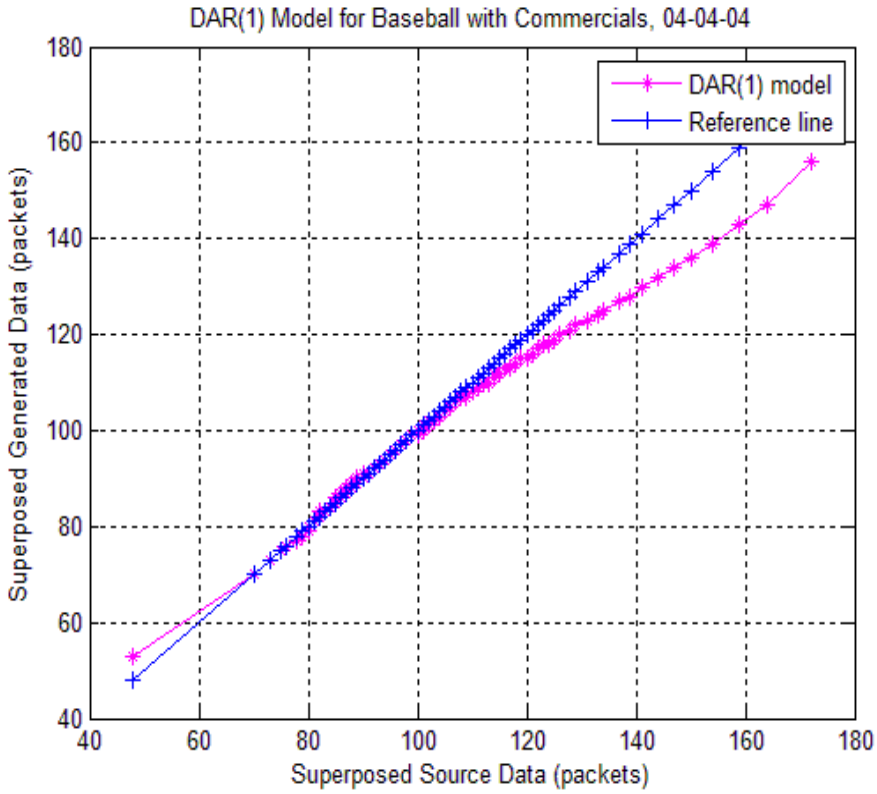

Figure 2.12 *Mediocre Modeling Result (5 sources) for whole traces*

The initial Q-Q plot fittings for all six of these traces (as single sources) ranged from good to slightly mediocre, thus leading us to model them without considering frame type separation. However, despite their relatively low burstiness (<8.5 peak/mean ratio for all six traces) the use of the DAR(1) model did not improve the modeling results in the case of multiplexed sources.

- ***I frames***

We evaluated the DAR(1) model via 54 Q-Q plots. Most of them showed mediocre modeling results, along with 6 good and 9 bad ones. In the case of most I frames' sequences, a rough conclusion would be that a good modeling result comes after a good initial fitting, a mediocre modeling approach comes after a good or mediocre initial fitting, whereas a bad modeling result follows a bad initial fitting. Indicative examples of the three categories follow.

For 3 out of the 63 traces under study, we were incapable of determining the best distribution fit and hence, we didn't run the DAR(1) model (see Table 2.16). Also, let us remind the reader that 6 traces were modeled as a whole.

Excluded Traces
Die Hard One, 30-30-30
Die Hard One, 04-04-04
Oprah without Commercials, 04-04-04
Terminator One, 04-04-04 (modeled as a whole)
Cinderella, 04-04-04 (modeled as a whole)
Tonight Show with Commercials, 04-04-04 (modeled as a whole)
Baseball with Commercials, 04-04-04 (modeled as a whole)
Tokyo Olympics DVD, 30-30-30 (modeled as a whole)
The Transporter DVD, 30-30-30 (modeled as a whole)

TABLE 2.16 – I TRACES EXCLUDED FROM DAR(1) MODELING

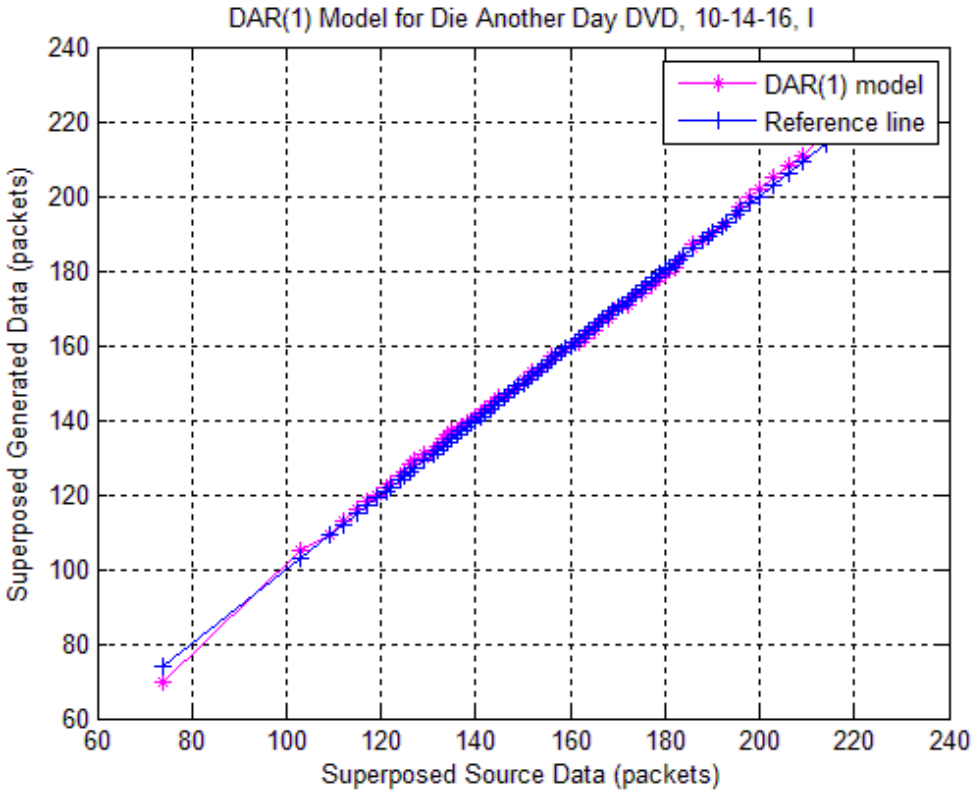

Figure 2.13 *Good Modeling Result (5 sources) for I frames*

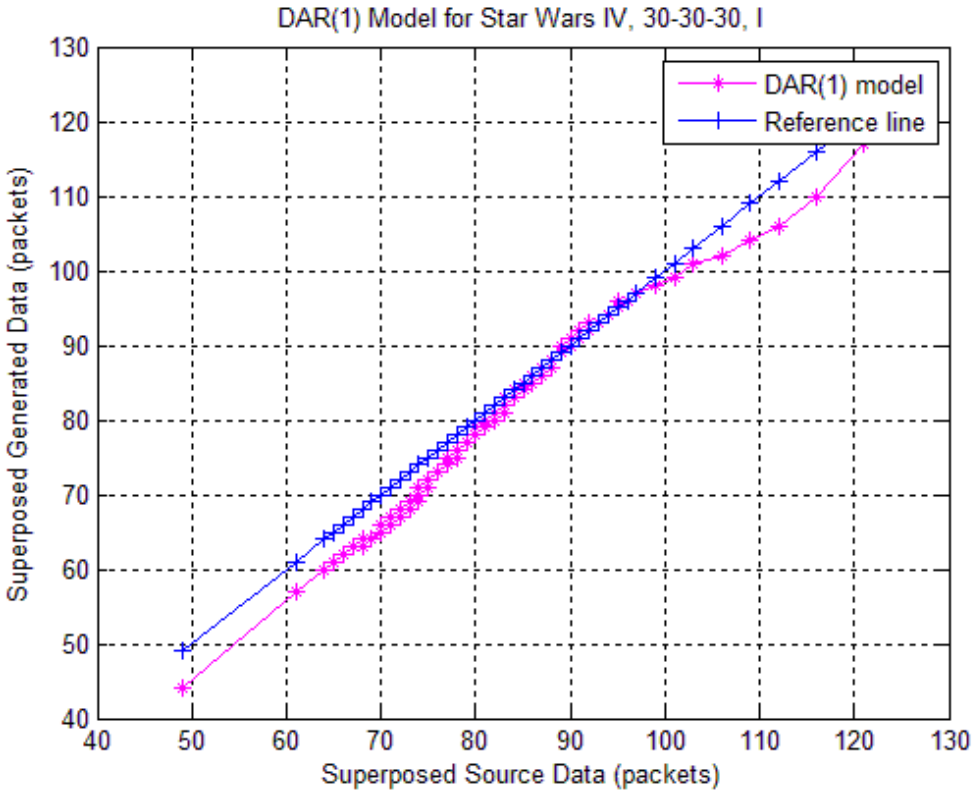

Figure 2.14 *Mediocre Modeling Result (5 sources) for I frames*

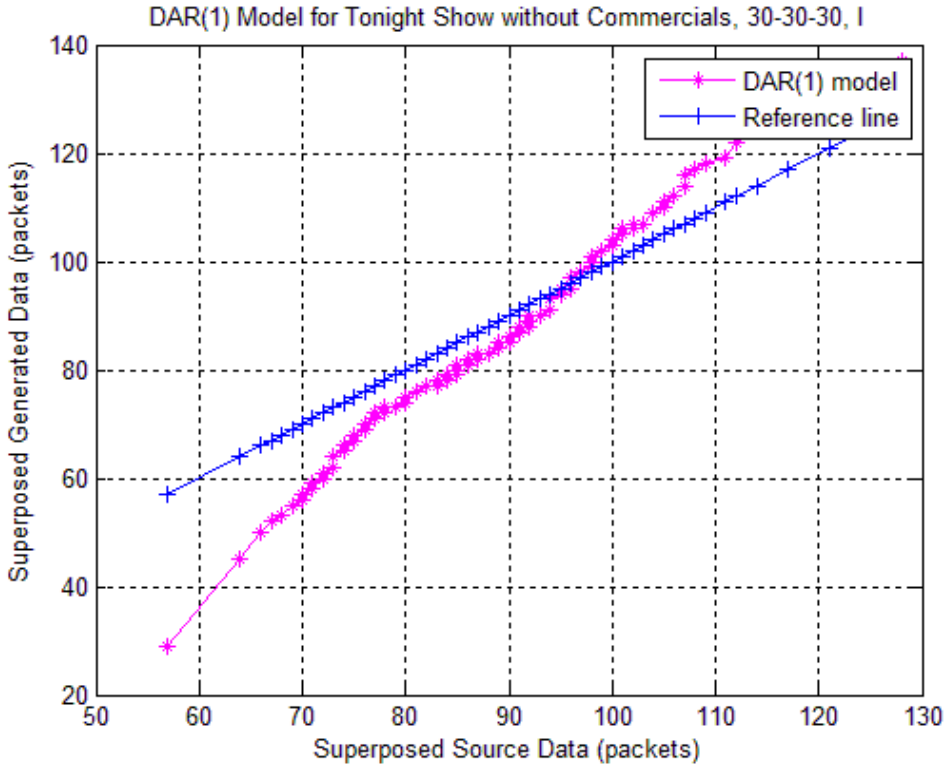

Figure 2.15 *Bad Modeling Result (5 sources) for I frames*

- ***P frames***

In the case of P frames, we evaluated the DAR(1) model via 51 Q-Q plots. Most of them showed mediocre modeling results, along with 3 good and 11 bad ones. Similarly to I frames, in the case of most P frame traces, a rough conclusion would be that a good modeling result comes after a good initial fitting, a mediocre modeling result comes after a good or mediocre initial fitting, whereas a bad modeling result follows a mediocre or bad initial fitting. However, there are cases where good initial fittings result in bad modeling approaches (i.e., Die Another Day DVD 10-14-16). Indicative examples of the three categories follow.

For 6 out of the 63 traces under study, we were incapable of determining the best distribution fit and hence, we didn't run the DAR(1) model (see Table 2.17). Also, let us remind the reader that 6 traces were modeled as a whole.

Excluded Traces
Silence of the Lambs, 30-30-30
Lecture - Reisslein, 04-04-04
Friends vol.4 DVD, 30-30-30
O Brother DVD, 10-14-16
Die Another Day DVD, 04-04-04
Charlie's Angels DVD, 10-14-16
Terminator One, 04-04-04 (modeled as a whole)
Cinderella, 04-04-04 (modeled as a whole)
Tonight Show with Commercials, 04-04-04 (modeled as a whole)
Baseball with Commercials, 04-04-04 (modeled as a whole)
Tokyo Olympics DVD, 30-30-30 (modeled as a whole)
The Transporter DVD, 30-30-30 (modeled as a whole)

TABLE 2.17 – P TRACES EXCLUDED FROM DAR(1) MODELING

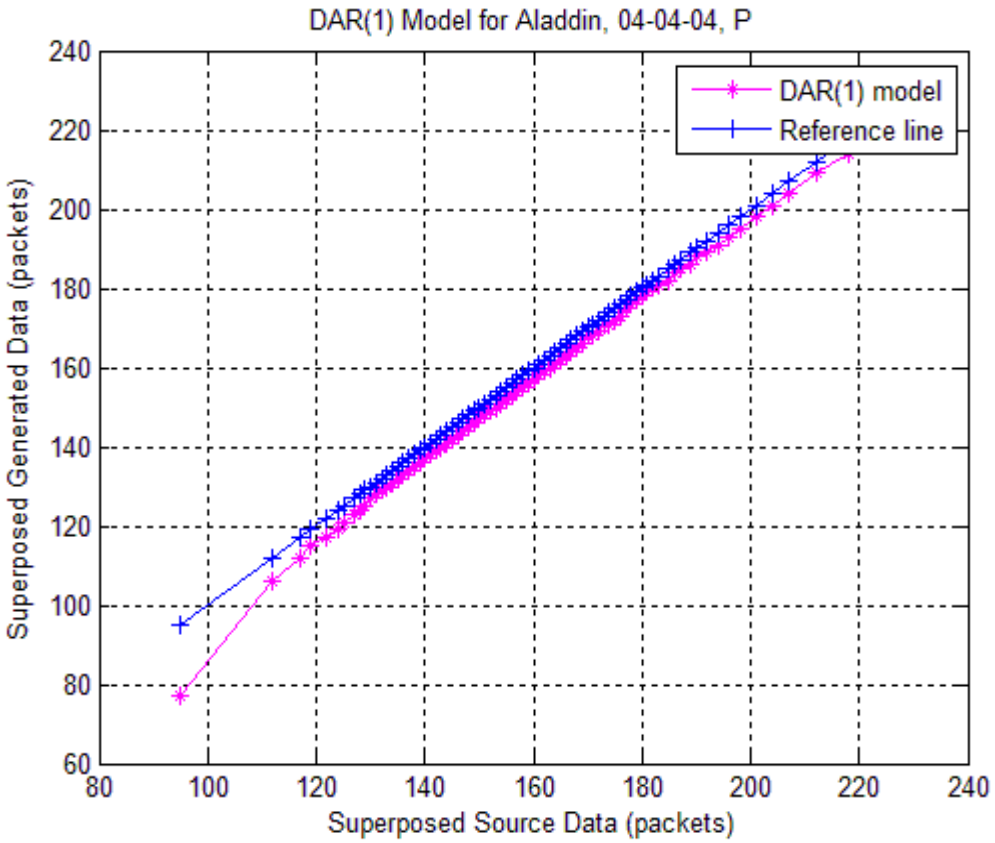

Figure 2.16 *Good Modeling Result (5 sources) for P frames*

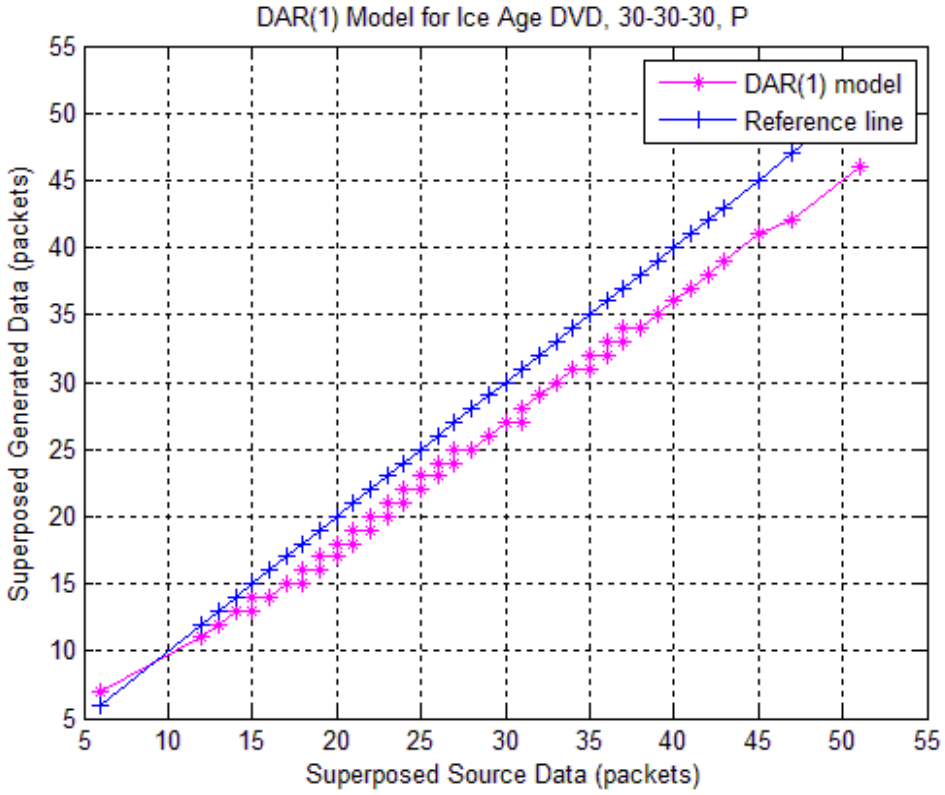

Figure 2.17 *Mediocre Modeling Result (5 sources) for P frames*

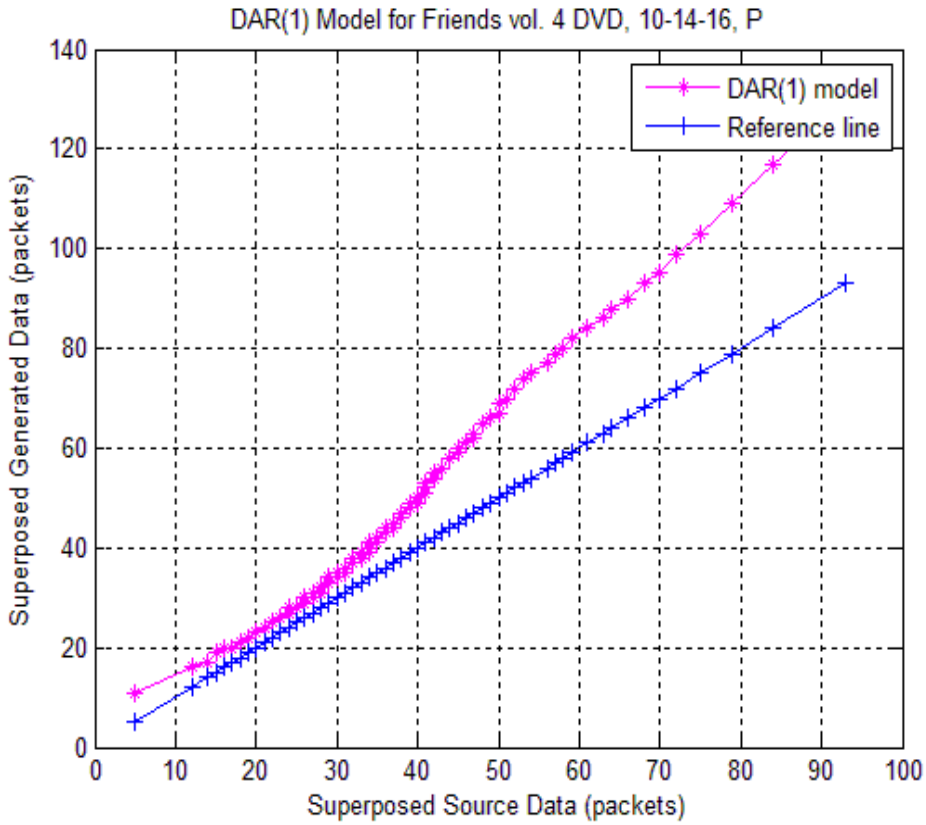

Figure 2.18 *Bad Modeling Result (5 sources) for P frames*

- ***B frames***

In the case of B frames, we evaluated the DAR(1) model via 51 Q-Q plots. Most of them showed mediocre modeling results, along with1 good and 20 bad ones. In the case of most B frame traces, a mediocre modeling result comes after a good or mediocre initial fitting. As to the case of bad modeling results, we cannot reach clear conclusions regarding the preceding fittings. The reason is that there are many cases where good fittings result in bad modeling results (i.e., Charlie's Angels DVD 04-04-04, Die Hard One 10-14-6, Friends vol.4 DVD 30-30-30 and 10-14-16 and 04-04-04, O Brother DVD 04-04-04, The Transporter DVD 10-14-16 and 04-04-04) and many cases where bad modeling results follow mediocre or bad fittings. Representative examples are shown in Figures 2.19, 2.20 and 2.21.

For 6 out of the 63 traces under study, we were incapable of determining the best distribution fit and hence, we didn't run the DAR(1) model (see Table 2.18). Also, let us remind the reader that 6 traces were modeled as a whole.

Excluded Traces
Tonight Show without Commercials, 30-30-30
Lecture - Reisslein, 30-30-30
Tokyo Olympics DVD, 04-04-04
O Brother DVD, 10-14-16
Die Another Day DVD, 04-04-04
Ice Age DVD, 04-04-04
Terminator One, 04-04-04 (modeled as a whole)
Cinderella, 04-04-04 (modeled as a whole)
Tonight Show with Commercials, 04-04-04 (modeled as a whole)
Baseball with Commercials, 04-04-04 (modeled as a whole)
Tokyo Olympics DVD, 30-30-30 (modeled as a whole)
The Transporter DVD, 30-30-30 (modeled as a whole)

TABLE 2.18 – B TRACES EXCLUDED FROM DAR(1) MODELING

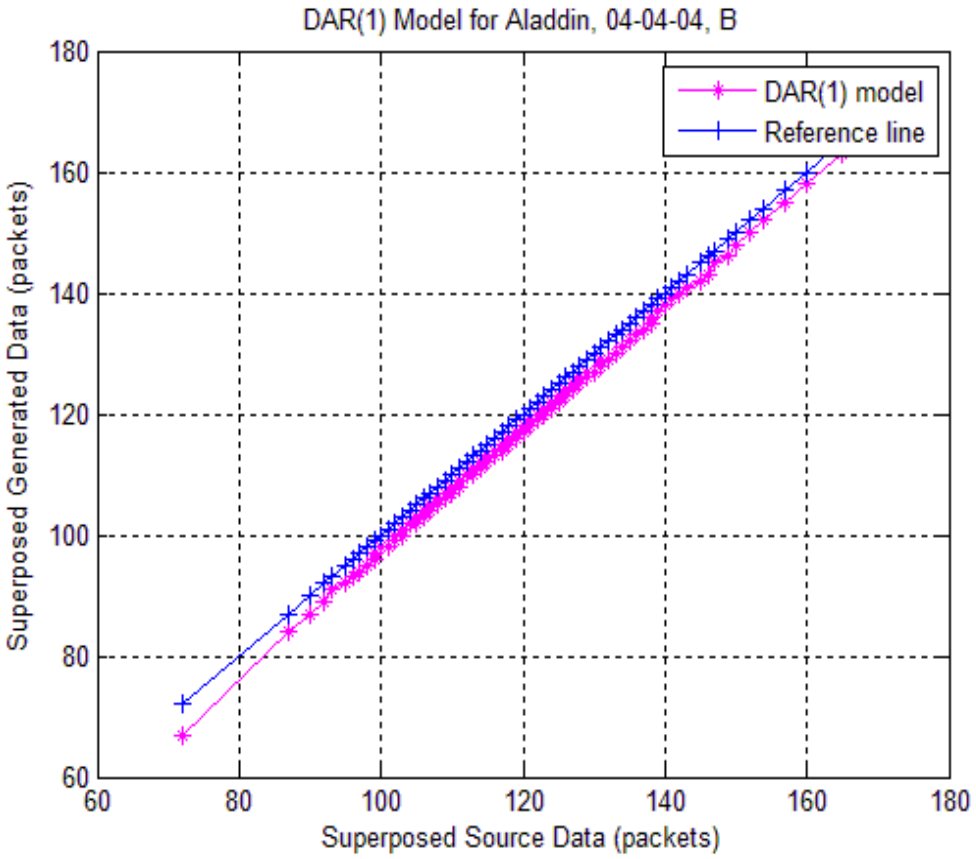

Figure 2.19 *Good Modeling Result (5 sources) for B frames*

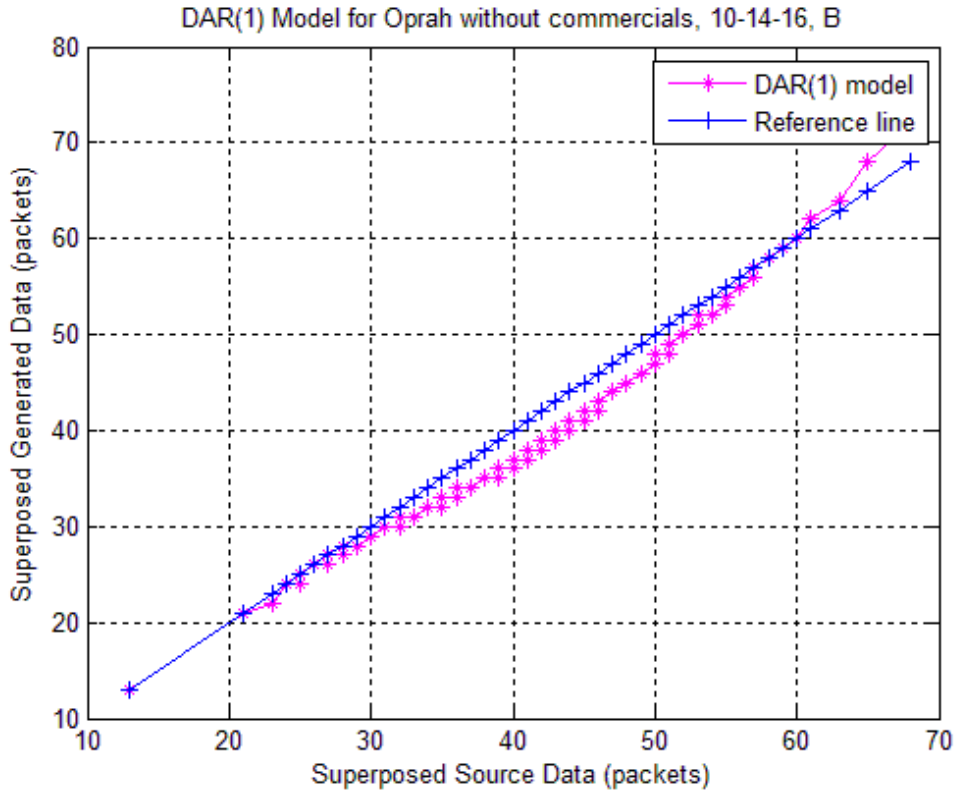

Figure 2.20 *Mediocre Modeling Result (5 sources) for B frames*

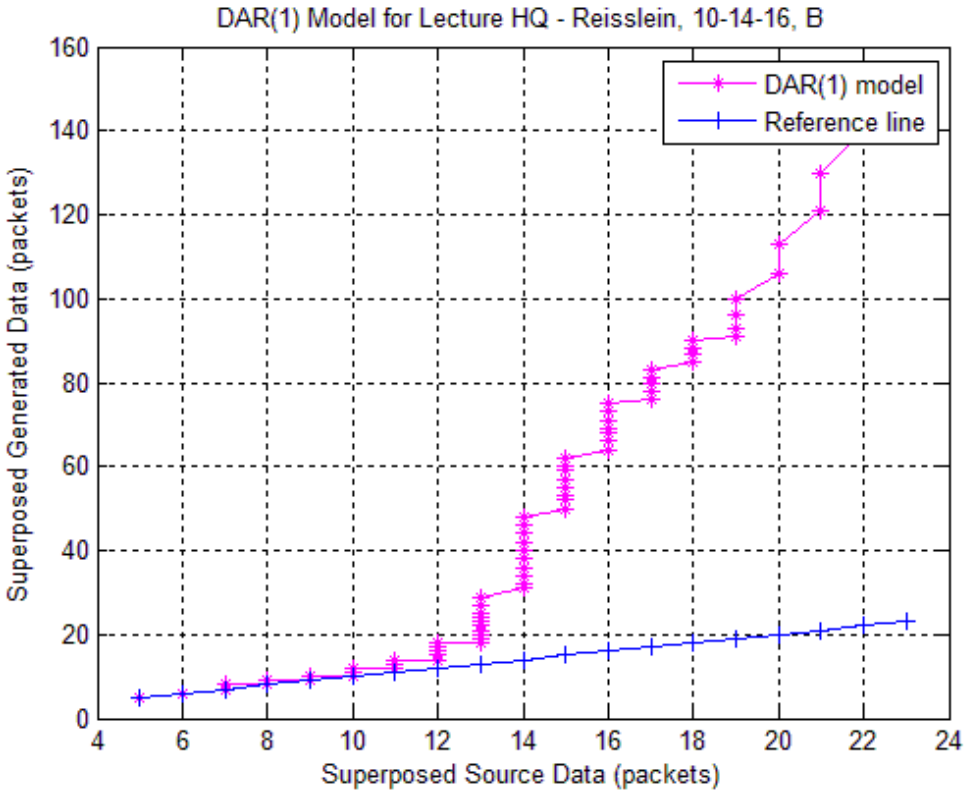

Figure 2.21 *Bad Modeling Result (5 sources) for B frames*

To sum up, in this part of our work we have observed that, out of the four categories examined (whole traces and I, P and B frames), the number of good modeling results in I frames was the highest, with P and B frames following, leaving whole traces last. The fact that almost half of the results in B frames turned out to be bad is an interesting outcome. Not only did B frames have the highest number of bad DAR(1) results, but among those results, one could also find numerous examples of the lowest accuracy achieved by the model throughout this whole part of our work. Additionally, although there were a few cases of high accuracy modeling results, perfect accuracy was never achieved. Another conclusion is that the majority of the I, P and B traces' sequences which the DAR(1) models badly were relatively to pretty bursty, with a burstiness between 10 and 25.

As the number of the superposed sources increases from 5 to 10 and then to 15, the majority of the results, regardless of frame type, remain unaffected or deteriorate. Improvements can be observed in a limited number of cases. Also, most of the bursty movies (burstiness ratio > 10) that were tagged as bad modeling results in the case of 5 traces tend to worsen with the increase in the number of superposed sources. An exception and a confirmation of that can be found below.

- Improvement Example – Lecture HQ Reisslein 30-30-30, I frames

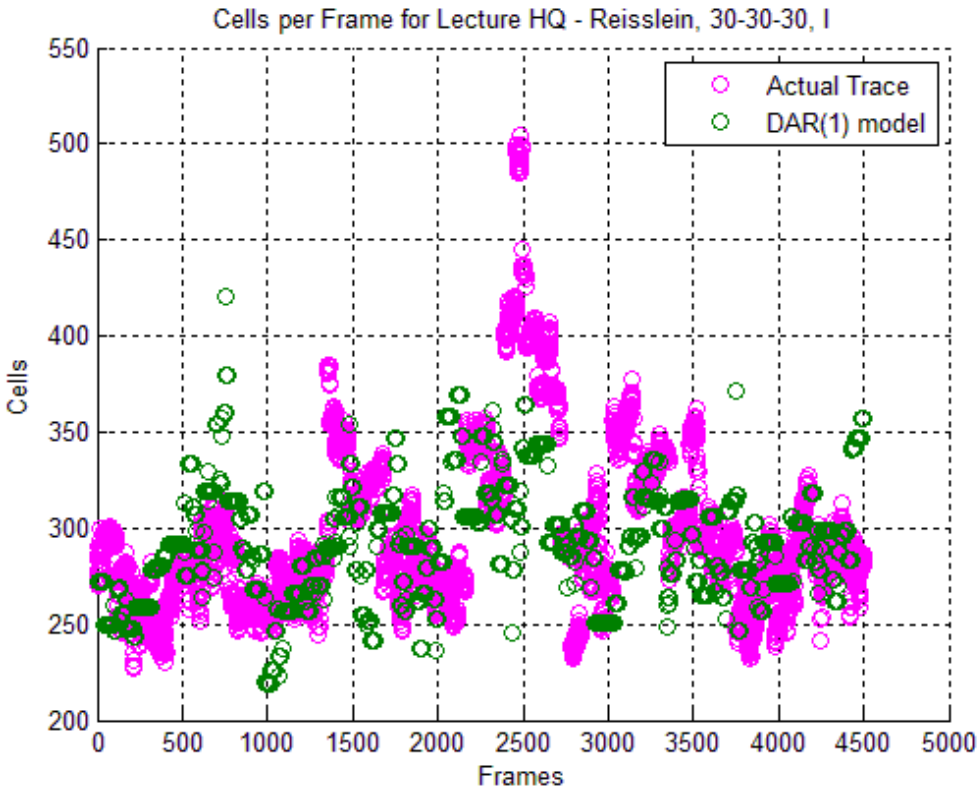

Figure 2.22 *Cells per Frame for trace improving with the increase in the number of sources (5 sources)*

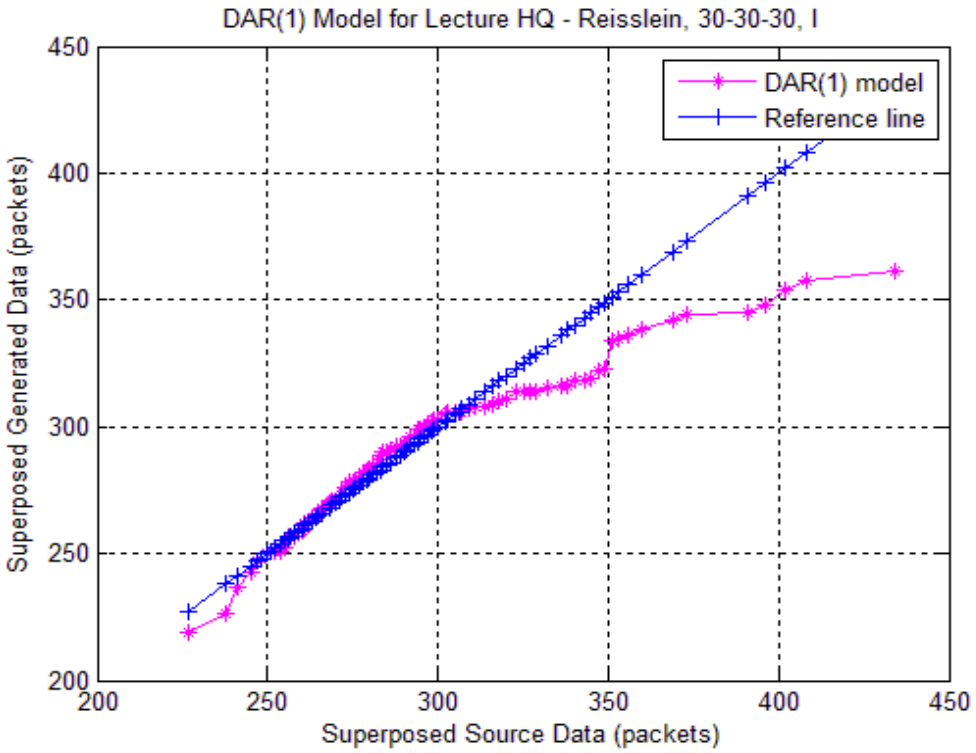

Figure 2.23 *DAR(1) modeling result for trace improving with the increase in the number of sources (5 sources)*

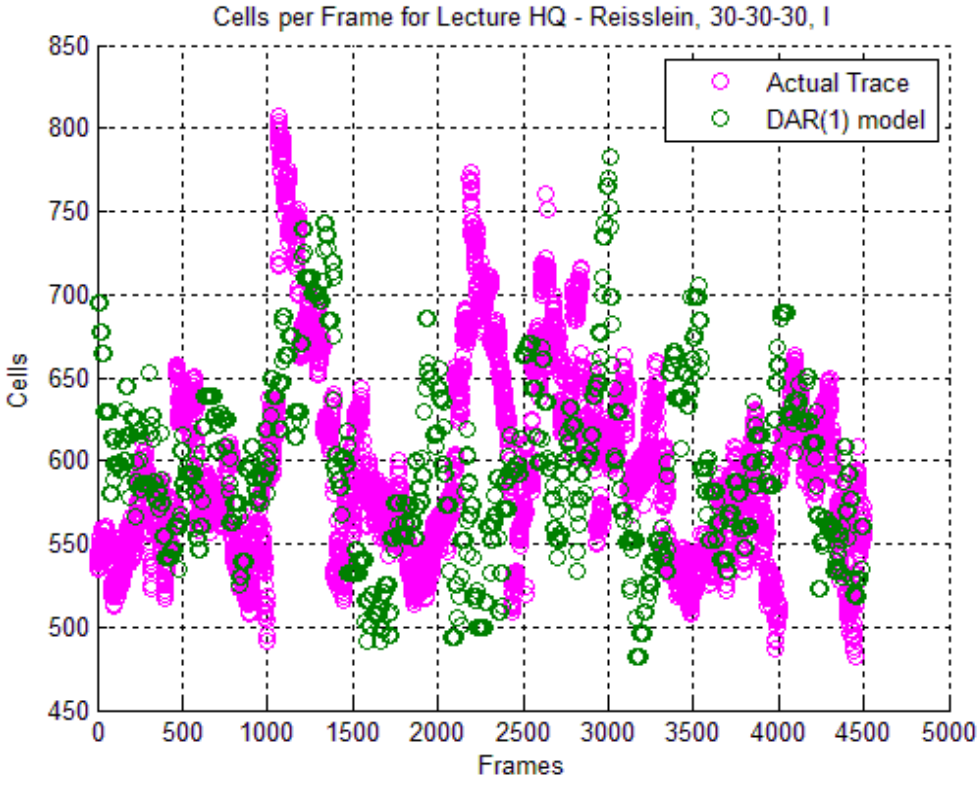

Figure 2.24 *Cells per Frame for trace improving with the increase in the number of sources (10 sources)*

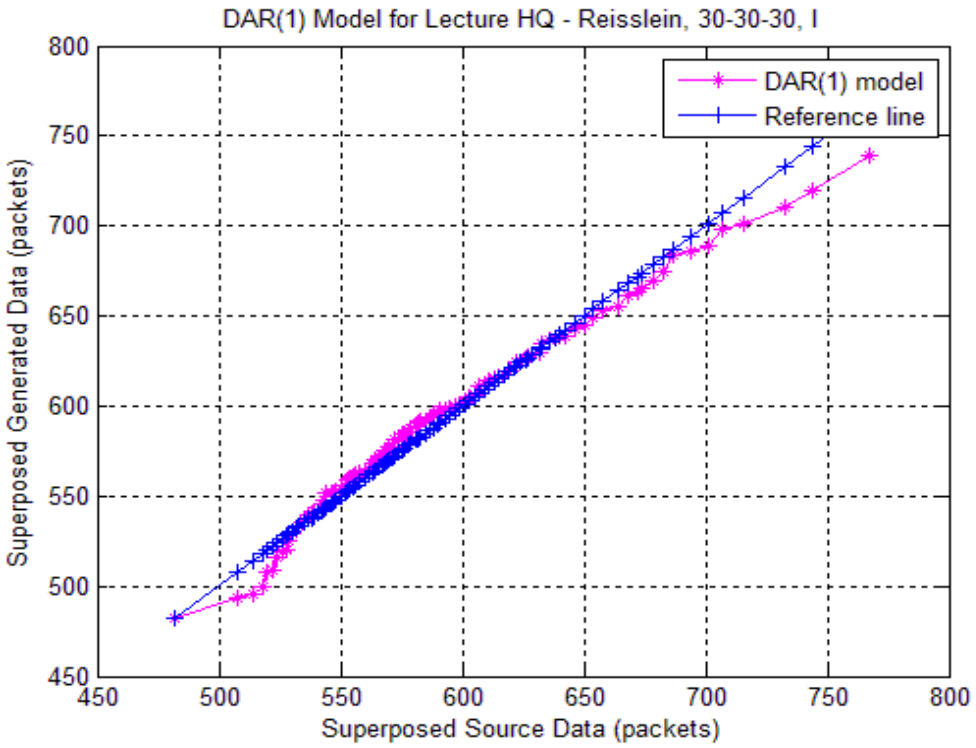

Figure 2.25 *DAR(1) modeling result for trace improving with the increase in the number of sources (10 sources)*

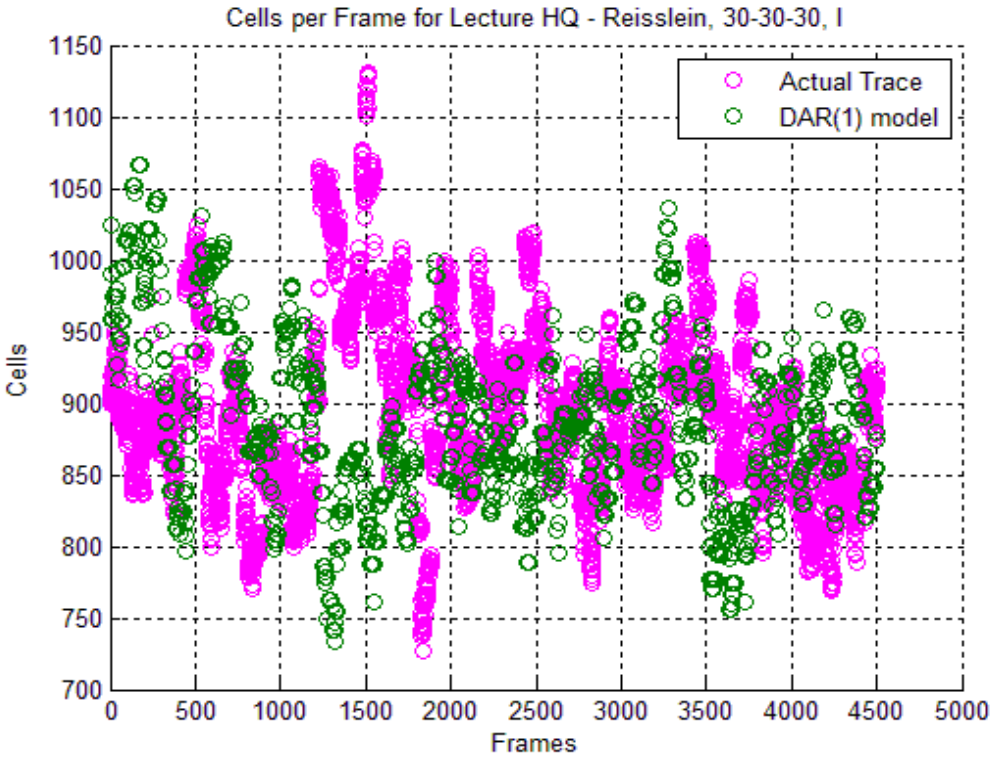

Figure 2.26 *Cells per Frame for trace improving with the increase in the number of sources (15 sources)*

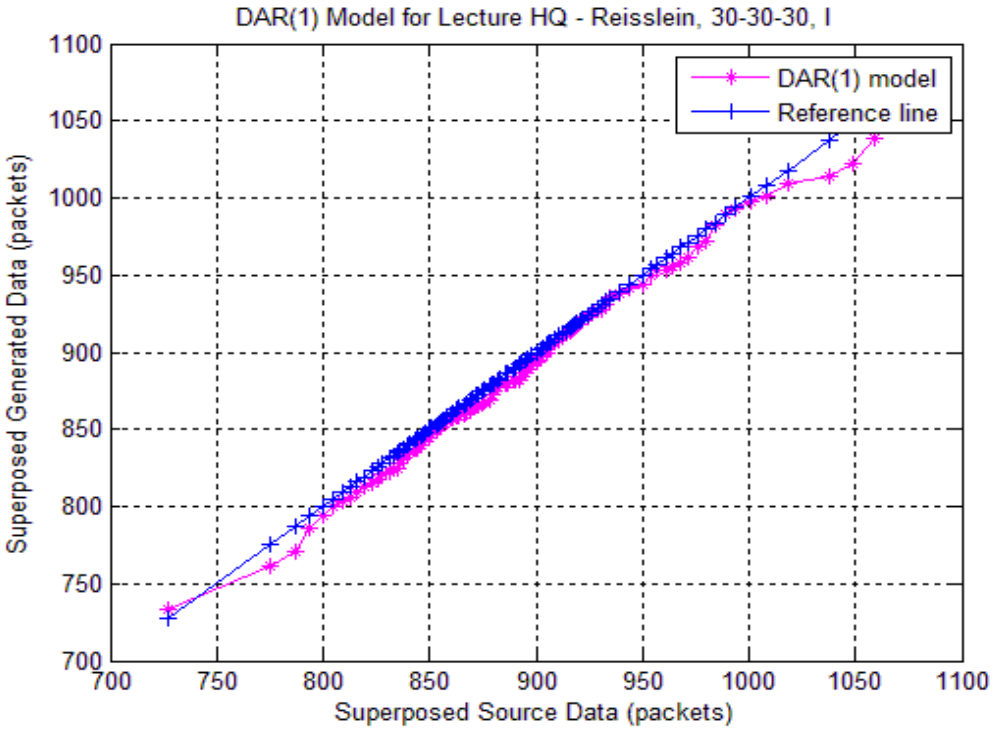

Figure 2.27 *DAR(1) modeling result for trace improving with the increase in the number of sources (15 sources)*

- Deterioration Example – Tonight Show without Commercials 10-14-16, B frames

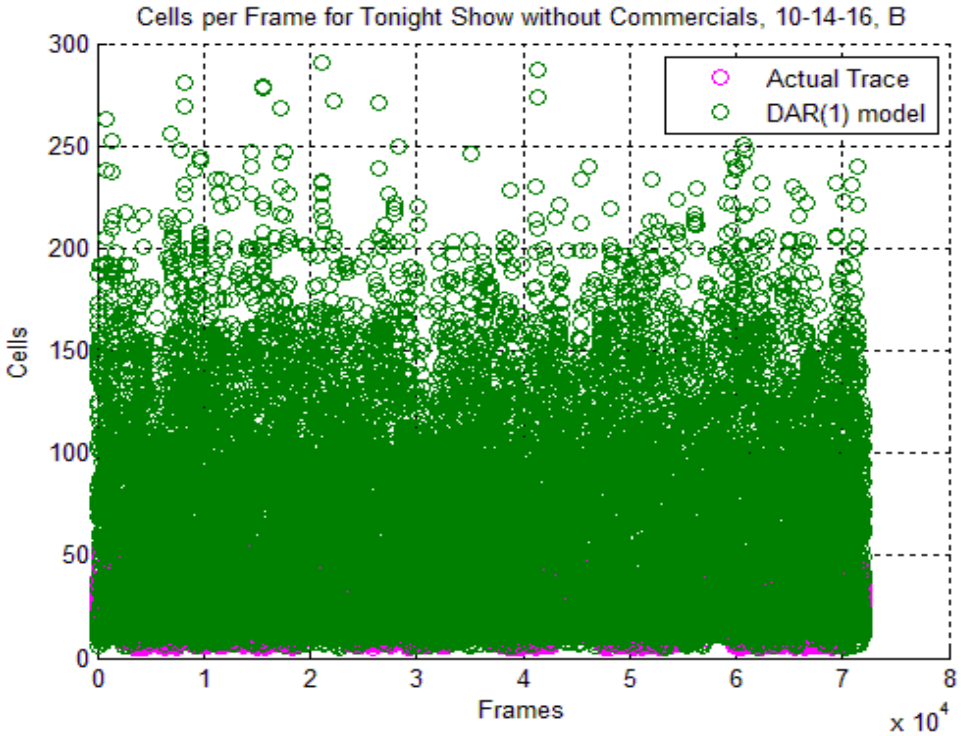

Figure 2.28 *Cells per Frame for trace deteriorating with the increase in the number of sources (5 sources)*

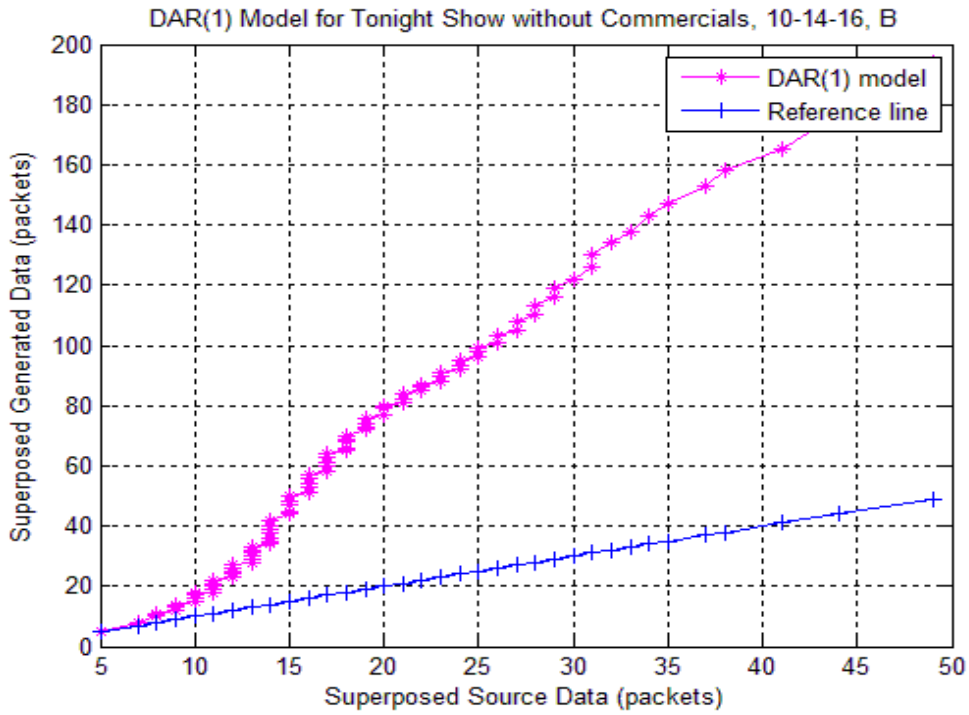

Figure 2.29 *DAR(1) modeling result for trace deteriorating with the increase in the number of sources (5 sources)*

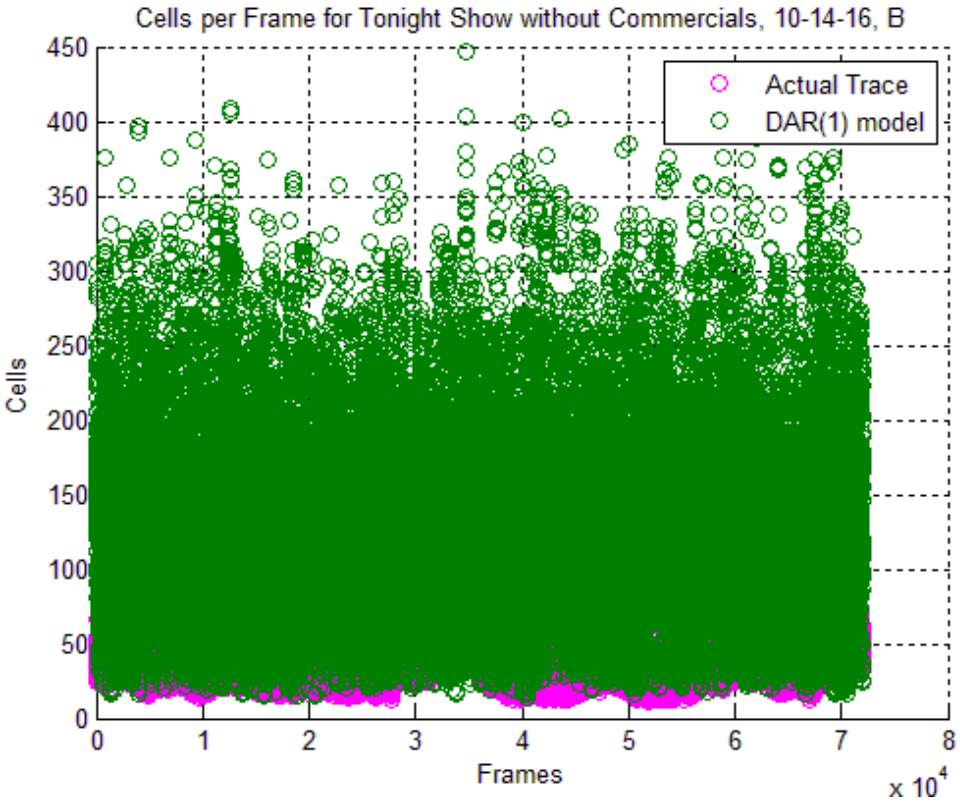

Figure 2.30 *Cells per Frame for trace deteriorating with the increase in the number of sources (10 sources)*

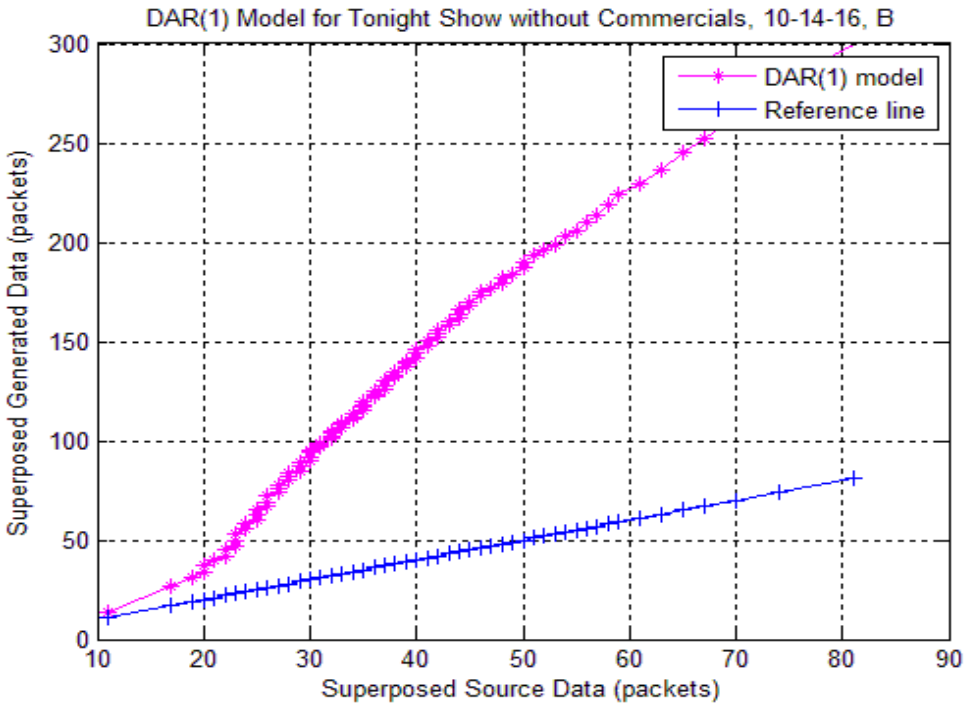

Figure 2.31 *DAR(1) modeling result for trace deteriorating with the increase in the number of sources (10 sources)*

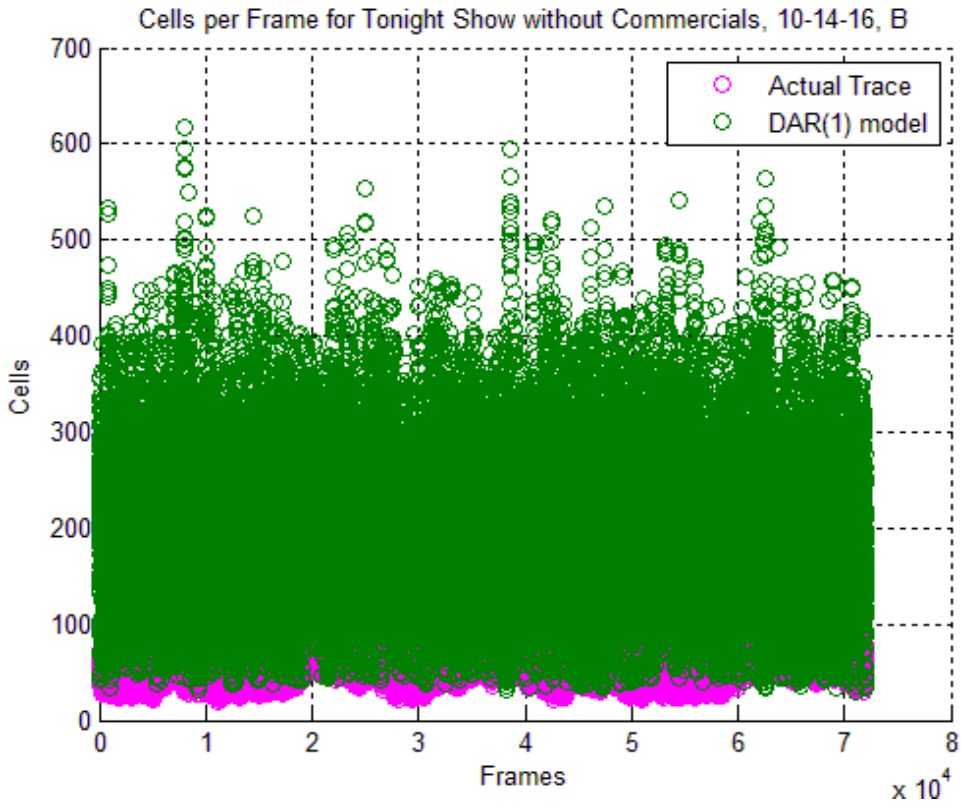

Figure 2.32 *Cells per Frame for trace deteriorating with the increase in the number of sources (15 sources)*

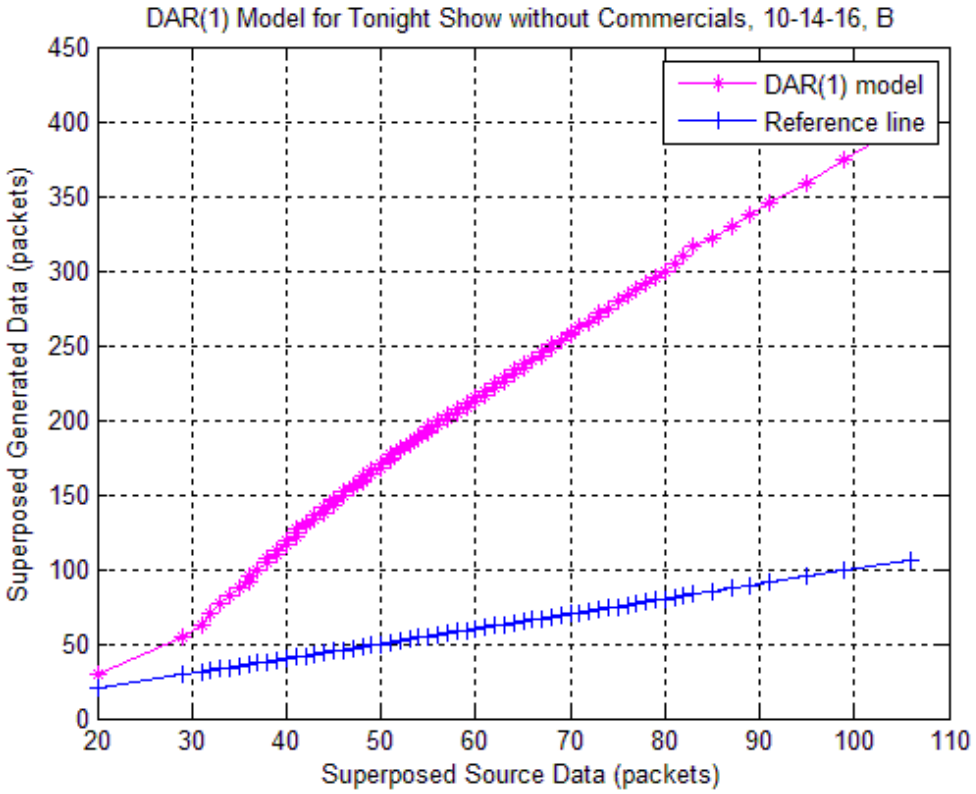

Figure 2.33 *DAR(1) modeling result for trace deteriorating with the increase in the number of sources (15 sources)*

2.4 Final DAR(1) Modeling Results

Our results in section 2.3, on modeling I, P and B frames from multiplexed sources, were a strong indication of whether the DAR(1) model can succeed in capturing the behavior of specific traces. However, a clear result on the feasibility of this type of modeling can only be derived by: a) generating I, P and B frame sizes according to the GoP pattern of each original trace, hence creating a model for a single trace, and b) superposing a number of the generated traces (5, 10 and 15 in our work) and assessing the modeling results via statistical tests (we used Q-Q plots).

In the cases that one or more of the three frame type sequences of a trace was excluded from the DAR(1) modeling of the previous section, the specific movie was not examined in this part of our work (see Table 2.19). Also, the 6 traces modeled as a whole in section 2.3.2 were left out.

Excluded Traces
Die Hard One, 30-30-30
Die Hard One, 04-04-04
Silence of the Lambs, 30-30-30
Terminator One, 04-04-04 (modeled as a whole)
Cinderella, 04-04-04 (modeled as a whole)
Tonight Show with Commercials, 04-04-04 (modeled as a whole)
Tonight Show without Commercials, 30-30-30
Lecture – Reisslein, 30-30-30
Lecture – Reisslein, 04-04-04
Baseball with Commercials, 04-04-04 (modeled as a whole)
Friends vol.4 DVD, 30-30-30
Tokyo Olympics DVD, 30-30-30 (modeled as a whole)
Tokyo Olympics DVD, 04-04-04
O Brother DVD, 10-14-16
Die Another Day DVD, 04-04-04
The Transporter DVD, 30-30-30 (modeled as a whole)
Charlie's Angels DVD, 10-14-16
Ice Age DVD, 04-04-04
Oprah without Commercials, 04-04-04

TABLE 2.19 – TRACES EXCLUDED FROM FINAL DAR(1) MODELING

Hence, we evaluated the DAR(1) model via 44 Q-Q plots. As expected by the results in section 2.3, most of the modeling results were once again mediocre (25 in total) or bad (12 in total); accurate results were limited (7 in total). Indicative examples are presented in Figures 2.34 - 2.36.

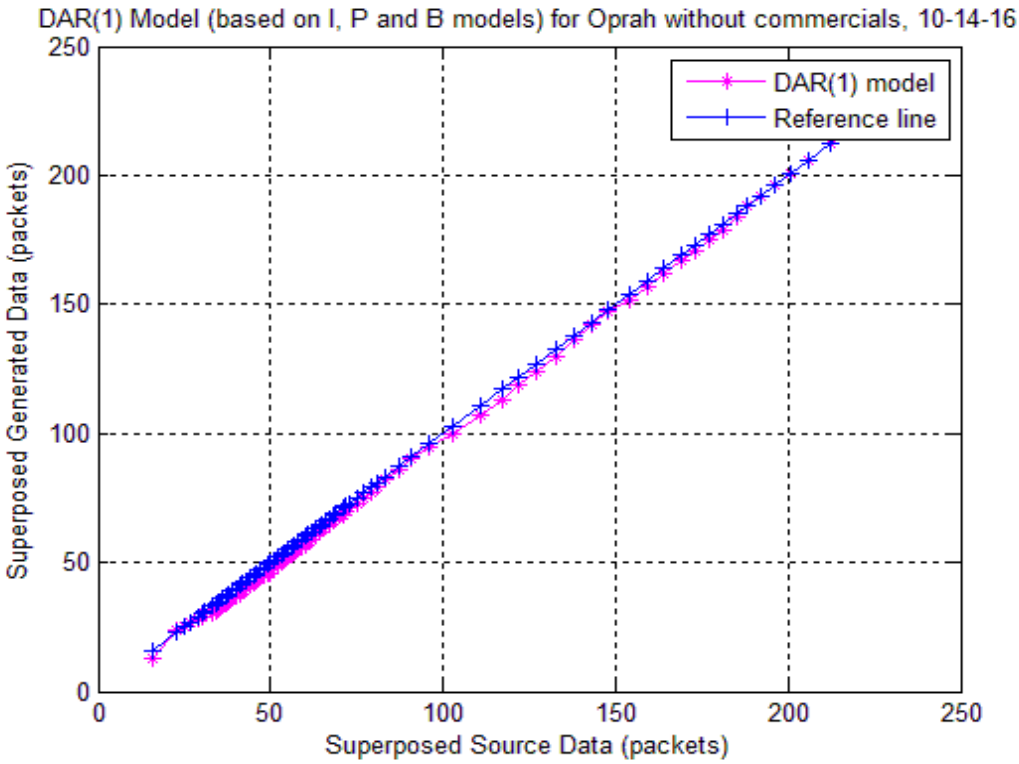

Figure 2.34 *Good synthetic modeling result (5 sources) – Movie Burstiness = 10.001, ρ = -0.0715*

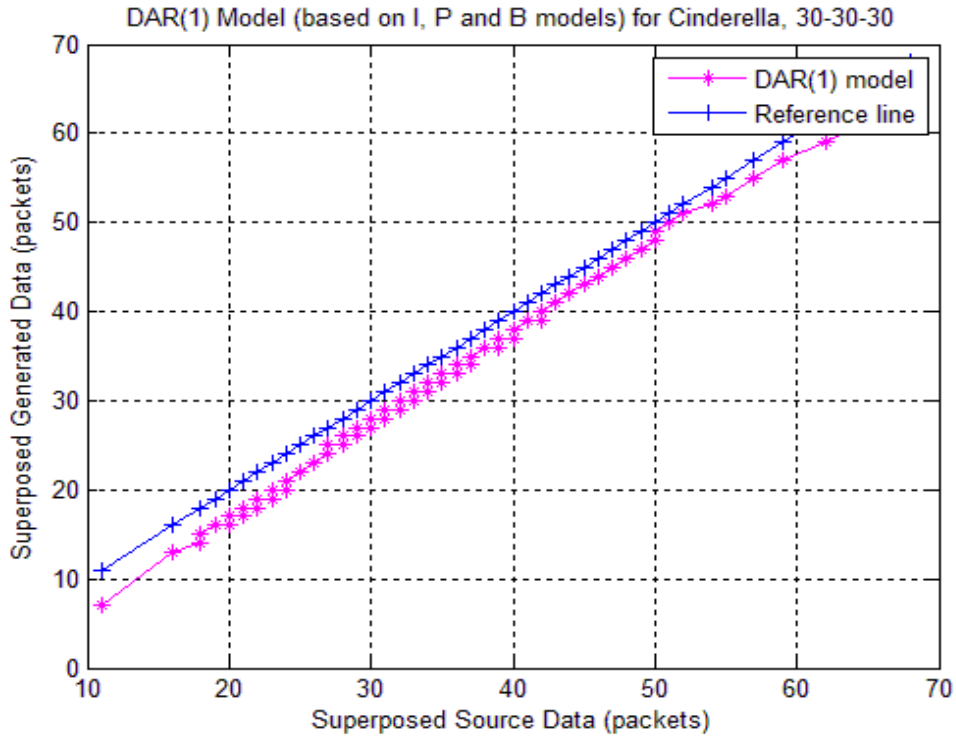

Figure 2.35 *Mediocre synthetic modeling result (5 sources) – Movie Burstiness = 14.8314, ρ = 0.1574*

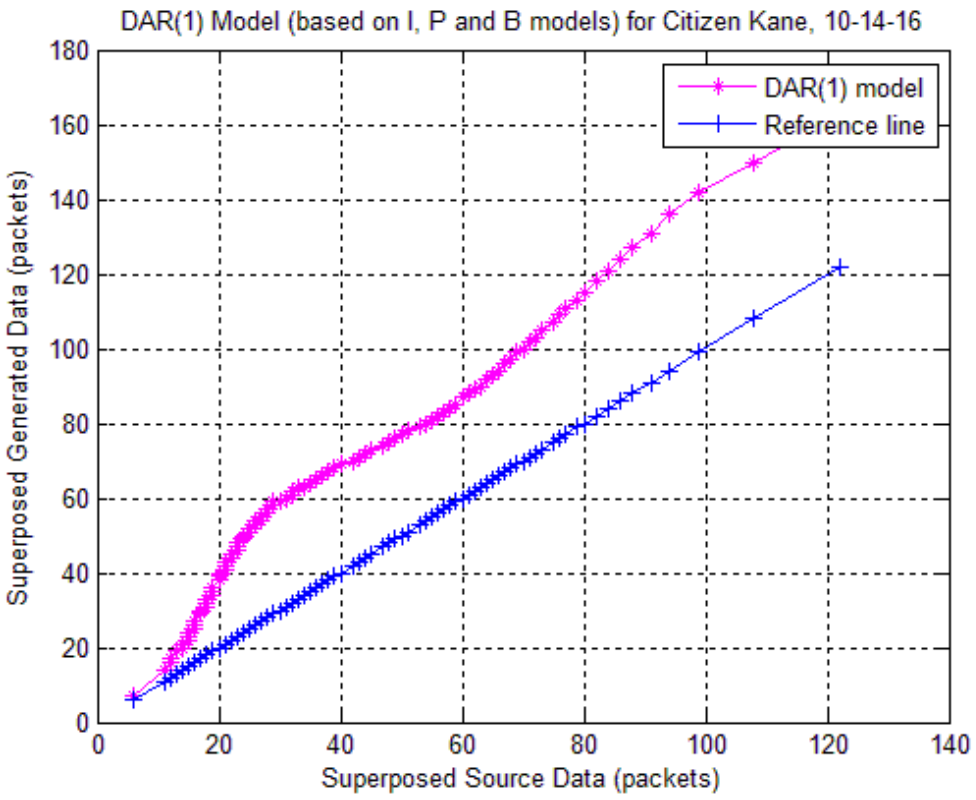

Figure 2.36 *Bad synthetic modeling result (5 sources) – Movie Burstiness = 21.3502, ρ = -0.0381*

An interesting observation is that all the 30-30-30 quantization scale traces modeled (14 totally) are associated with mediocre modeling results. Almost one half of the 10-14-16 quantization scale traces modeled are classified as mediocre (8 out of 19) modeling results and almost one half as bad (8 out of 19) modeling results. The traces of the 04-04-04 scale seem to be sharing an almost equal number of good (4 out of 11), mediocre (3 out of 11) and bad (4 out of 11) results.

In other words, in most cases of the 30-30-30 and the 10-14-16 movies, the accuracy of this model seems to follow a pattern that is highly influenced by the quantization parameters of the movies and thus, their autocorrelation coefficient and their burstiness. In the majority of the cases under study, the 04-04-04 movies have the highest autocorrelation coefficient while the 10-14-16 movies have the lowest autocorrelation coefficient. The 30-30-30 movies are usually in between. The 04-04-04 movies present the lowest burstiness whereas the 10-14-16 movies present the highest burstiness (for most of the cases). The 30-30-30 movies are usually in the middle, in terms of burstiness.

To sum up, this model provides relative accuracy for traces with mediocre burstiness and an autocorrelation coefficient of moderate value. For traces of high burstiness and low autocorrelation, the model usually provides relative or low accuracy. The modeling results for the traces used in our study are worse than those for the videoconference-type traces in [2]. Also, for traces of low burstiness and high autocorrelation, we cannot reach clear conclusions regarding the behavior of the

model. The reason is that these traces share an almost equal number of good, mediocre and bad modeling results.

Also, when the number of superposed sources increases (from 5 to 10 and from 10 to 15), the majority of the initial results for 5 sources remain unaffected or deteriorate. Half of the initially good modeling results remain good with the increase of sources in the superposition. For the results initially classified as mediocre or bad, the addition of sources undermines the model's accuracy in most cases. Improvements in the modeling results are rare to observe. Even for the initially good modeling cases, one cannot generally claim that the model constantly improves for a superposition of more sources and this is a result that does not coincide with [2]; there are cases of videoconference type traces (for instance, Lecture Gupta 30-30-30, 10-14-16, 04-04-04 and Lecture HQ Reisslein 10-14-16 and 04-04-04) where the opposite occurs. Indicative examples are presented in Figures 2.37 - 2.42.

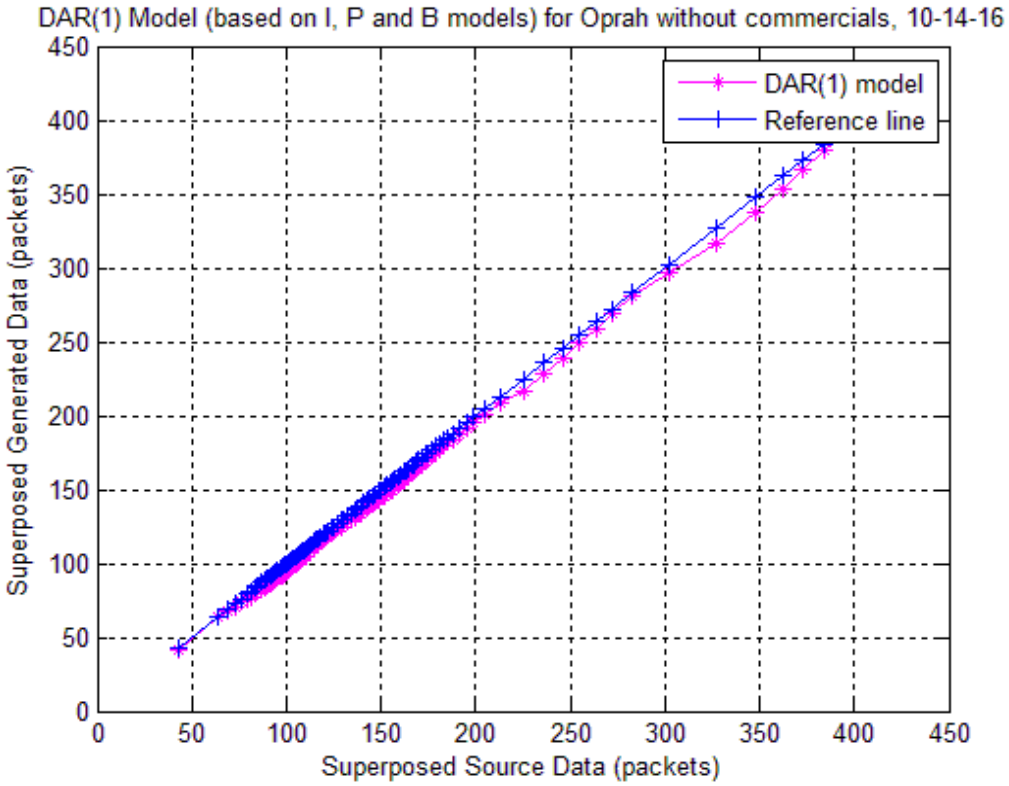

Figure 2.37 *Initially good synthetic modeling result remains unaffected (10 sources) – Movie Burstiness = 10.001,* ρ *= -0.0715*

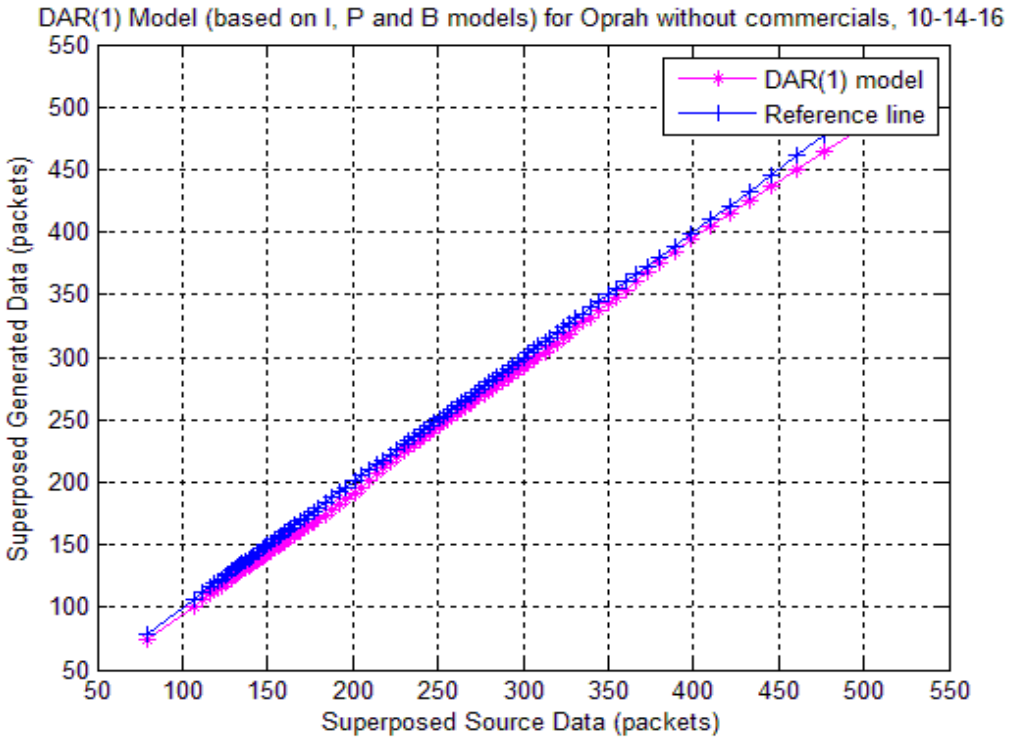

Figure 2.38 *Initially good synthetic modeling result remains unaffected (15 sources) – Movie Burstiness = 10.001, ρ = -0.0715*

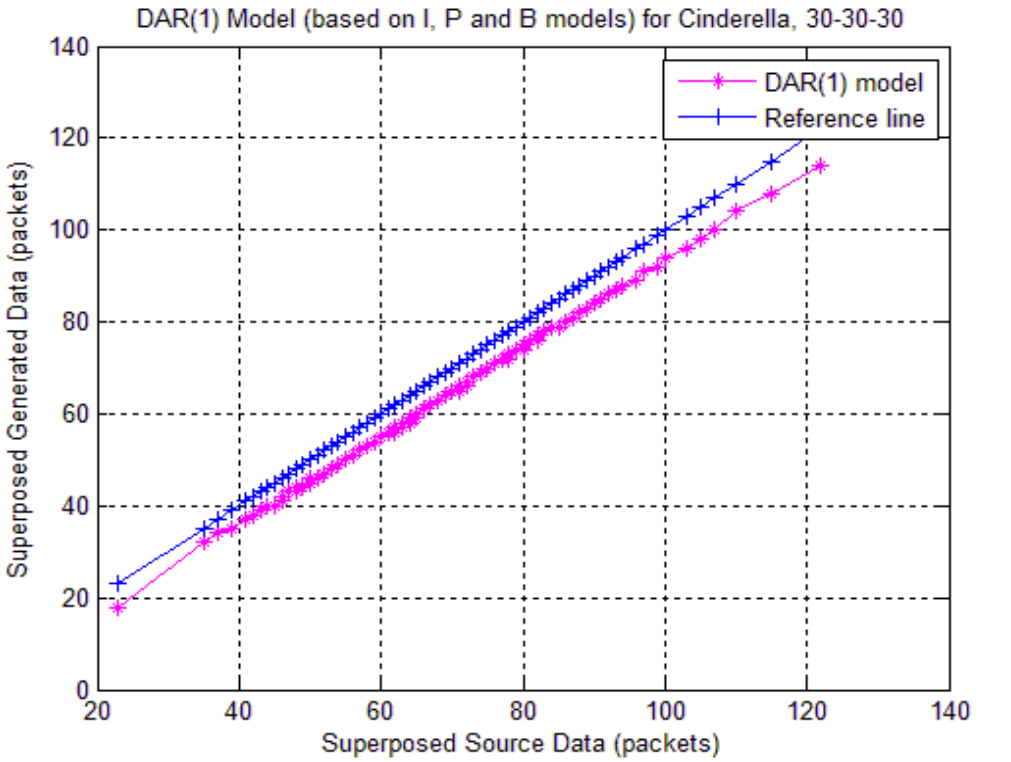

Figure 2.39 *Initially mediocre synthetic modeling result deteriorates (10 sources) – Movie Burstiness = 14.8314, ρ = 0.1574*

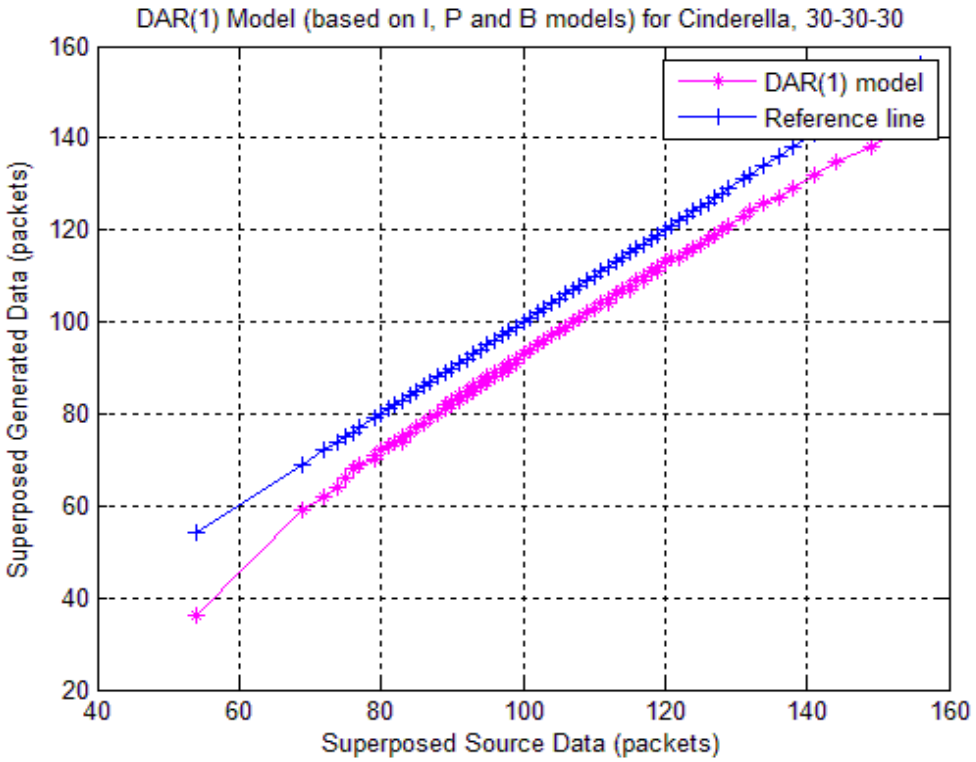

Figure 2.40 *Initially mediocre synthetic modeling result deteriorates (15 sources) – Movie Burstiness = 14.8314, ρ = 0.1574*

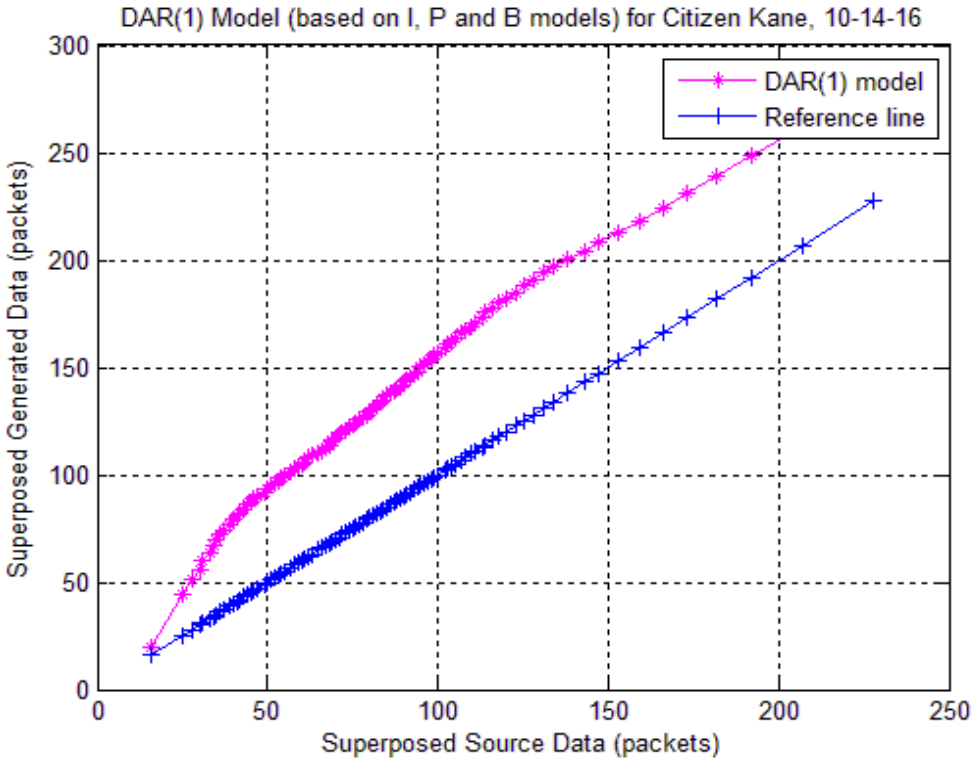

Figure 2.41 *Initially bad synthetic modeling result deteriorates (10 sources) – Movie Burstiness = 21.3502, ρ = -0.0381*

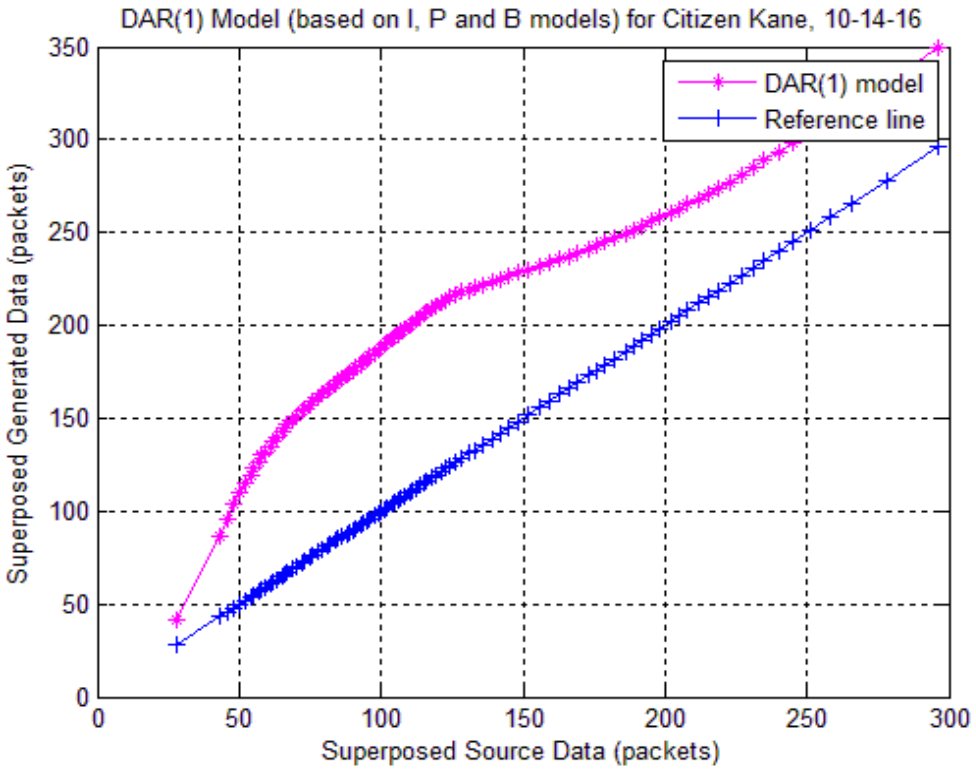

Figure 2.42 *Initially bad synthetic modeling result deteriorates (15 sources) – Movie Burstiness = 21.3502, ρ = -0.0381*

3. DETECTING SCENE CHANGES FOR A NEW HYBRID MODEL

Because of the largely unsatisfactory results of the DAR(1) model, we were led to the creation of a hybrid model combining DAR(1) model with a scene-based Markov chain model, similar to the one proposed in [3]. The main concept behind this lies on the idea of dividing each video trace into scenes, and then classifying the detected scenes into low or high-activity ones. Therefore, each video trace produces two new traces, one consisting of all the low-activity scenes and one consisting of all the high-activity ones. For each movie out of the initial 63 ones, we use a 2-state (High, Low) Markov chain model in order to determine the number of low and high scenes of our modeled source. For every scene in both categories, we then determine the number of I, P and B frames in it and finally, run the DAR(1) model, for every case. Details on the steps followed are presented below.

3.1 Scene Identification

In everyday life, we often use the phrase ‘change of scenery’ when talking about moving to a different place, where the surroundings are different. But what is a scene in terms of MPEG-4 video traffic? A scene typically consists of a few tens or hundreds of frames that depict a real-world scene and can also be interpreted as a collection of related GoPs (groups of pictures).The MPEG sequences that are considered in this thesis have a GoP pattern of the form IBBPBBPBBPBB. Every new scene starts with an I frame, so the I frames of the video streams under study are used to detect scene changes. More specifically:

Let X(i) denote the bits generated during the ith I frame. The ith frame of the sequence of I frames is said to be the start of a new scene if the following equations are satisfied [3]:

$$\frac{|X(i+1)-X(i)|}{(\Sigma_{j=start\ of\ scene}^{i} X(j))/(i-j+1)} > first\_threshold \quad (1)$$

$$\frac{|X(i+2)-X(i)|}{(\Sigma_{j=start\ of\ scene}^{i} X(j))/(i-j+1)} > second\_threshold \quad (2)$$

It can be seen that the ith I frame size is compared against both the (i+1)th and the (i+2)th I frames, therefore scenes are identified only when the change is persistent. The numerators of the fractions above represent the difference in bits between the size of the ith and (i+1)th or the (i+2)th I frame, respectively. The denominators, on the other hand, represent the sum in bits of all the I frames from the last I frame identified as a scene start, up to the current ith I frame, divided by the number of those I frames. A typical range of thresholds, as suggested in [3], is [0.15, 0.25] for the first and second threshold. In our approach, we have used the value 0.15 for both of them.

3.2 Scene Classification

The next step, after scene identification, is scene classification. A scene can fall into one of two categories: low-activity scenes or high-activity scenes, depending on the average bit rate of the video trace: if a scene has an average bit rate that is greater than the average bit rate of the whole movie, then it is classified as a high-activity scene, else it is classified as a low-activity scene. The average bit rate of each movie was provided in [1] along with other trace statistics, whereas the average bit rate of every scene was calculated as the number of bits transmitted during the scene divided by the scene duration. We divided each low and high activity trace into their respective I, P

and B frames, hence, every movie was “split” into 6 traces: the low-activity and high-activity I frames, the low-activity and high-activity P frames and the low-activity and high-activity B frames.

3.3 Determining Best Fit

We calculated the mean and variance of the frame sizes of each of the 378 traces under study and determined all the distribution parameters. We then ran KL and KS tests and generated Q-Q plots, in order to determine the best fit for all cases, similarly to our work in section 2.

3.4 The Scene-Based Markov Chain Model

We initially calculate the transition probabilities of the 2-state Markov chain (Figure 3.1) (Low-High Activity scenes) using equations (3), (4) for each of the 63 video traces.

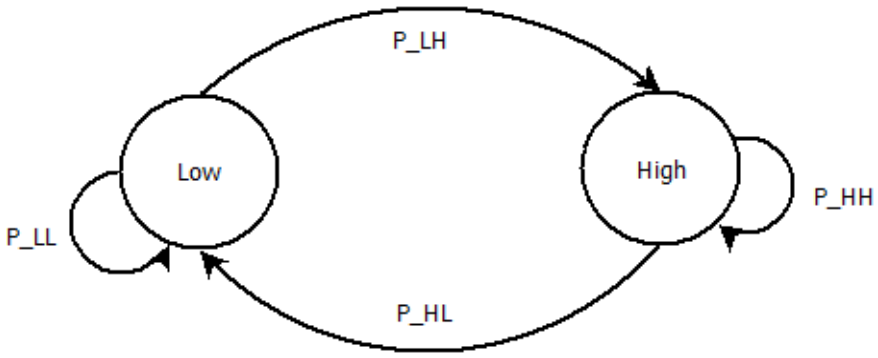

Figure 3.1 *2-state Markov Chain Model*

$$p_{s1,s2} = \frac{\text{number of transitions from } s1 \text{ to } s2}{\text{Total number } (>0) \text{ of transitions from } s1}, \quad s1 = H, \text{ and } s2 \epsilon \{H, L\} \tag{3}$$

$$p_{s1,s2} = \frac{\text{number of transitions from } s1 \text{ to } s2}{\text{Total number } (>0) \text{ of transitions from } s1}, \quad s1 = L, \text{ and } s2 \epsilon \{H, L\} \tag{4}$$

Then, we generate the model traces by generating one scene per each state reached. A low-activity scene was generated after reaching state ‘Low’ whereas a high-activity

scene was generated after reaching state ‘High’. Once the number of the generated scenes equaled the number of the real trace scenes, the procedure ends.

A different approach to ours would be to work deterministically and thus, to ignore the Markov chain model and run the DAR(1) model for as many low and high-activity scenes as detected in the real video trace. However, this last approach defies the concept of modeling: we attempt to model video traffic in order to be able to estimate its required bandwidth even for traces where we have only very basic knowledge of their traffic characteristics. The alternative approach mentioned above would need a perfect knowledge of every trace that would, e.g., attempt to be transmitted over a network; the exact sequence of high and low activity scenes of the trace would be required.

3.5 Determining number of I, P and B frames per Scene

We now need to determine the number of frames per scene. To do this, we choose with equal probability a number out of the ones observed in the real movie. In other words, the vector containing the number of I, P and B frames per scene for the low and high-activity traces of a movie (constructed in step II) is used as the set containing all possible values. Once a number has been chosen, it cannot be selected again. If the number of low or high-activity scenes of the model exceeds the respective one of the real movie, the vector mentioned above is used until there are no more cells to choose from; then, the vector is renewed, meaning that it is given its original values again and the process continues until all scenes have a specific number of I, P and B frames.

3.6 Packets per Frame Generation

In order to determine the number of packets per frame for each trace under study, we calculate the DAR(1) transition probabilities based on the best distribution fit that we have found for each trace, and we run the DAR(1) model. Our results are represented in the form of Q-Q plots and correspond to a superposition of 5, 10 and 15 sources. Most traces are modeled in the form of packets of 200 Bytes, whereas all the 30-30-30 and some 10-14-16 traces are modeled as packets of 48 Bytes.

3.7 Best Fit Results

In this section, we present the statistical data corresponding to the part of our work focusing on finding the best distribution fit. A discussion on the results of this part follows.

Distribution	Corresponding Percentage
Exponential	0.53%
Gamma	26.46%
Lognormal	25.66%
Weibull	23.28%
Pearson V	20.63%
Geometric	0.53%
Negative Binomial	2.91%

TABLE 3.1 - Q-Q PLOTS' CUMULATIVE RESULTS FOR BEST FIT

Distribution	Percentage for *I frames, Low*	Percentage for *P frames, Low*	Percentage for *B frames, Low*	Percentage for *I frames, High*	Percentage for *P frames, High*	Percentage for *B frames, High*
Exponential	0.00%	0.00%	3.17%	0.00%	0.00%	0.00%
Gamma	30.16%	22.22%	34.92%	31.75%	11.11%	28.57%
Lognormal	11.11%	46.03%	4.76%	20.63%	47.62%	23.81%
Weibull	44.44%	15.87%	44.44%	15.87%	0.00%	19.05%
Pearson V	4.76%	14.29%	7.94%	28.57%	39.68%	28.57%
Geometric	0.00%	0.00%	3.17%	0.00%	0.00%	0.00%
Negative Binomial	9.52%	1.59%	1.59%	3.17%	1.59%	0.00%

TABLE 3.2 - Q-Q PLOTS' DETAILED RESULTS FOR BEST FIT

Distribution	Corresponding Percentage
Exponential	1.06%
Gamma	0.00%
Lognormal	66.93%
Weibull	0.26%
Pearson V	0.00%
Geometric	0.00%
Negative Binomial	31.75%

TABLE 3.3 – KL TESTS' CUMULATIVE RESULTS FOR BEST FIT

Distribution	Percentage for *I frames, Low*	Percentage for *P frames, Low*	Percentage for *B frames, Low*	Percentage for *I frames, High*	Percentage for *P frames, High*	Percentage for *B frames, High*
Exponential	0.00%	4.76%	1.59%	0.00%	0.00%	0.00%
Gamma	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lognormal	69.84%	66.67%	68.25%	61.90%	68.25%	66.67%
Weibull	0.00%	0.00%	0.00%	1.59%	0.00%	0.00%
Pearson V	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Geometric	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Negative Binomial	30.16%	28.57%	30.16%	36.51%	31.75%	33.33%

TABLE 3.4 – KL TESTS' DETAILED RESULTS FOR BEST FIT

Distribution	Corresponding Percentage
Exponential	0.53%
Gamma	27.78%
Lognormal	24.07%
Weibull	24.34%
Pearson V	19.84%
Geometric	0.79%
Negative Binomial	2.65%

TABLE 3.5 – KS TESTS' CUMULATIVE RESULTS FOR BEST FIT

Distribution	Percentage for *I frames, Low*	Percentage for *P frames, Low*	Percentage for *B frames, Low*	Percentage for *I frames, High*	Percentage for *P frames, High*	Percentage for *B frames, High*
Exponential	1.59%	0.00%	1.59%	0.00%	0.00%	0.00%
Gamma	30.16%	22.22%	36.51%	30.16%	12.70%	34.92%
Lognormal	9.52%	42.86%	4.76%	17.46%	49.20%	20.635%
Weibull	47.62%	15.87%	46.03%	15.87%	0.00%	20.635%
Pearson V	4.76%	14.29%	7.94%	30.16%	38.10%	23.81%
Geometric	1.59%	1.59%	1.59%	0.00%	0.00%	0.00%
Negative Binomial	4.76%	3.17%	1.59%	6.35%	0.00%	0.00%

TABLE 3.6 – KS TESTS' DETAILED RESULTS FOR BEST FIT

Distribution	Percentage for *I frames, Low*	Percentage for *P frames, Low*	Percentage for *B frames, Low*	Percentage for *I frames, High*	Percentage for *P frames, High*	Percentage for *B frames, High*	Cumulative Percentage
Exponential	0.00%	0.00%	1.59%	0.00%	0.00%	0.00%	0.265%
Gamma	26.98%	17.46%	31.75%	28.57%	9.52%	26.98%	23.54%
Lognormal	9.52%	49.21%	6.35%	28.57%	50.79%	28.57%	28.84%
Weibull	42.86%	15.87%	42.86%	15.87%	0.00%	19.05%	22.75%
Pearson V	4.76%	12.70%	7.94%	23.81%	36.51%	23.81%	18.25%
Geometric	0.00%	0.00%	1.59%	0.00%	0.00%	0.00%	0.265%
Negative Binomial	7.94%	1.59%	1.59%	3.17%	1.59%	0.00%	2.65%

TABLE 3.7 – BEST DISTRIBUTION FIT PERCENTAGES PER TRACE TYPE

Percentage for *I frames, Low*	Percentage for *P frames, Low*	Percentage for *B frames, Low*	Percentage for *I frames, High*	Percentage for *P frames, High*	Percentage for *B frames, High*	Cumulative Percentage
7.94%	3.17%	6.35%	0.00%	1.59%	1.59%	3.44%

TABLE 3.8 – PERCENTAGE PER TRACE TYPE OF MOVIES EXCLUDED FROM DAR(1) MODELING

3.7.1 Low Activity Scenes

In this section, we focus on the Q-Q plot fittings corresponding to the I, P and B frames of the low-activity scenes of the traces examined. The exponential and the geometric distribution are the worst fit among all distributions used. The reason is that the data of those distributions was generated based on just one parameter, whose calculation made sole use of the mean of the traces and not also their variance. The same applies to the case of the high-activity scene traces, as well. We present indicatively some of our results in Figures 3.2 – 3.10.

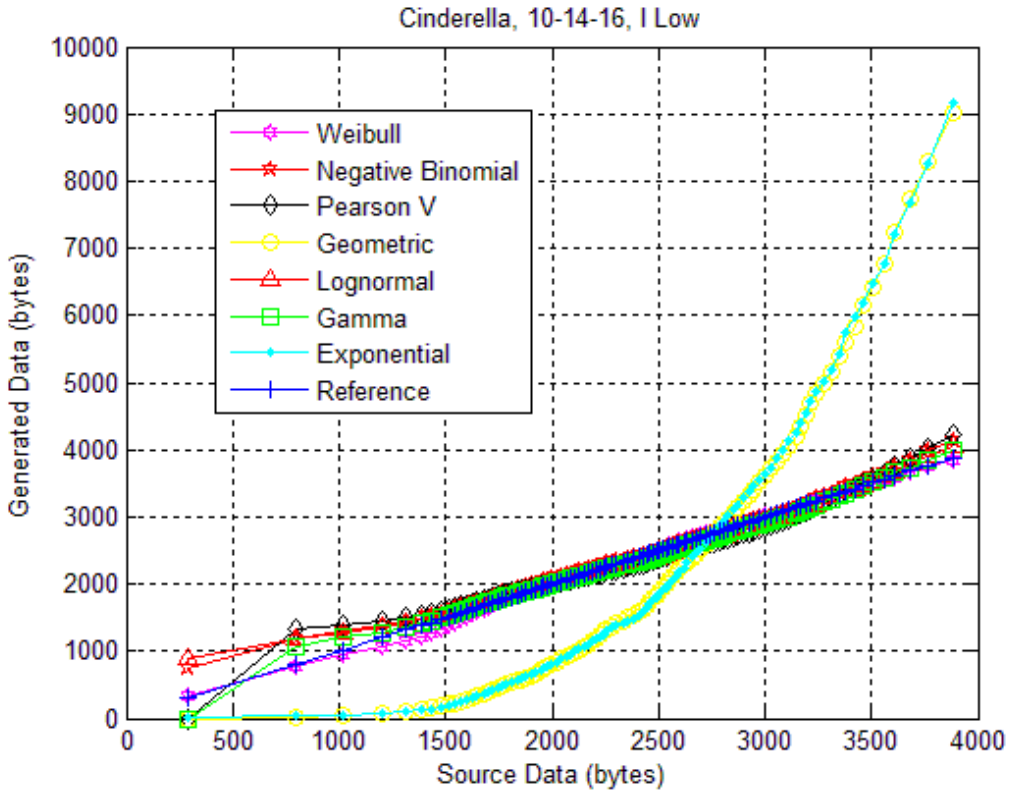

Figure 3.2 *Good fitting, I frames, Low activity*

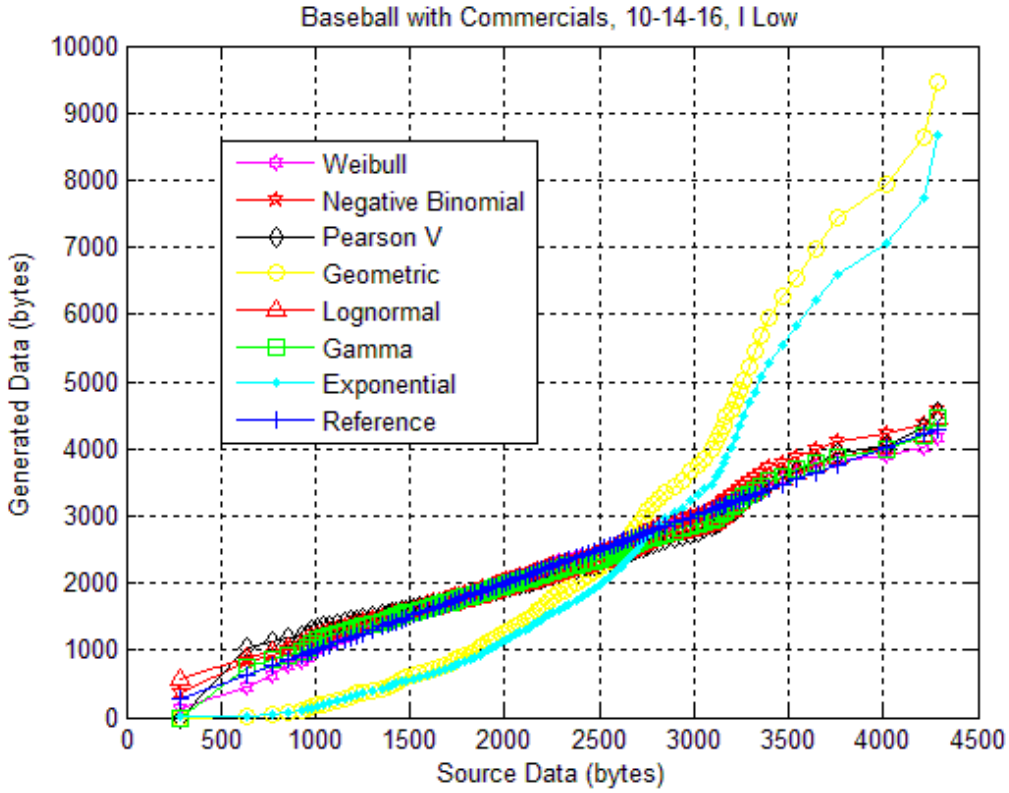

Figure 3.3 *Mediocre fitting, I frames, Low activity*

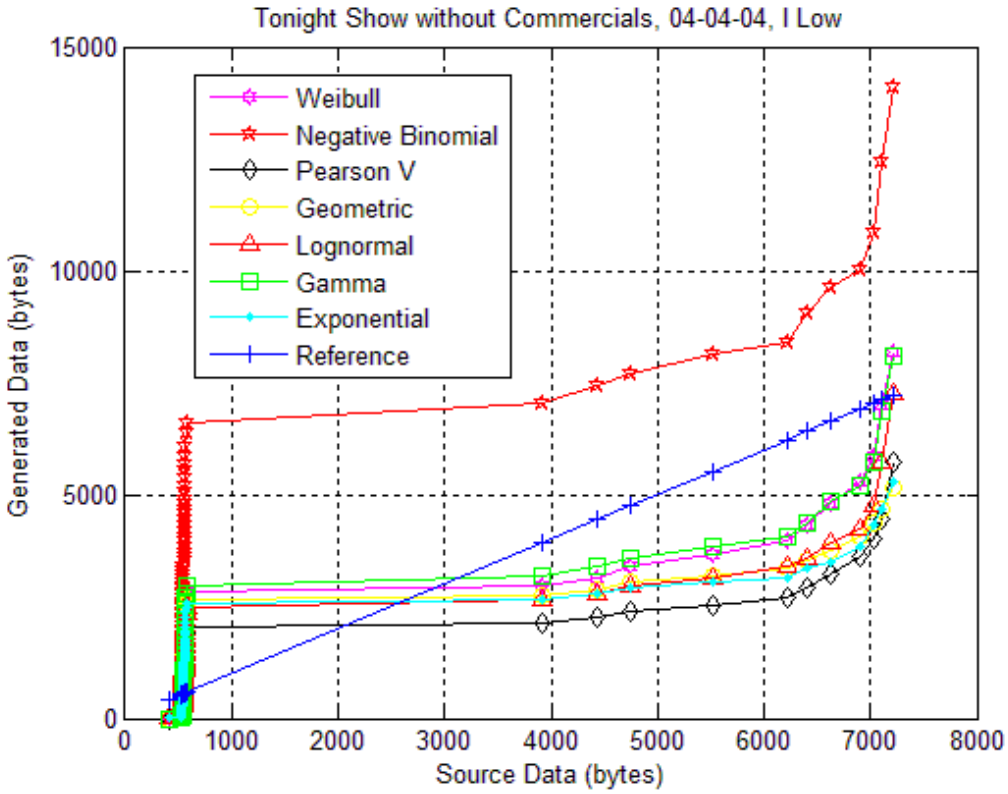

Figure 3.4 *Bad fitting, I frames, Low activity*

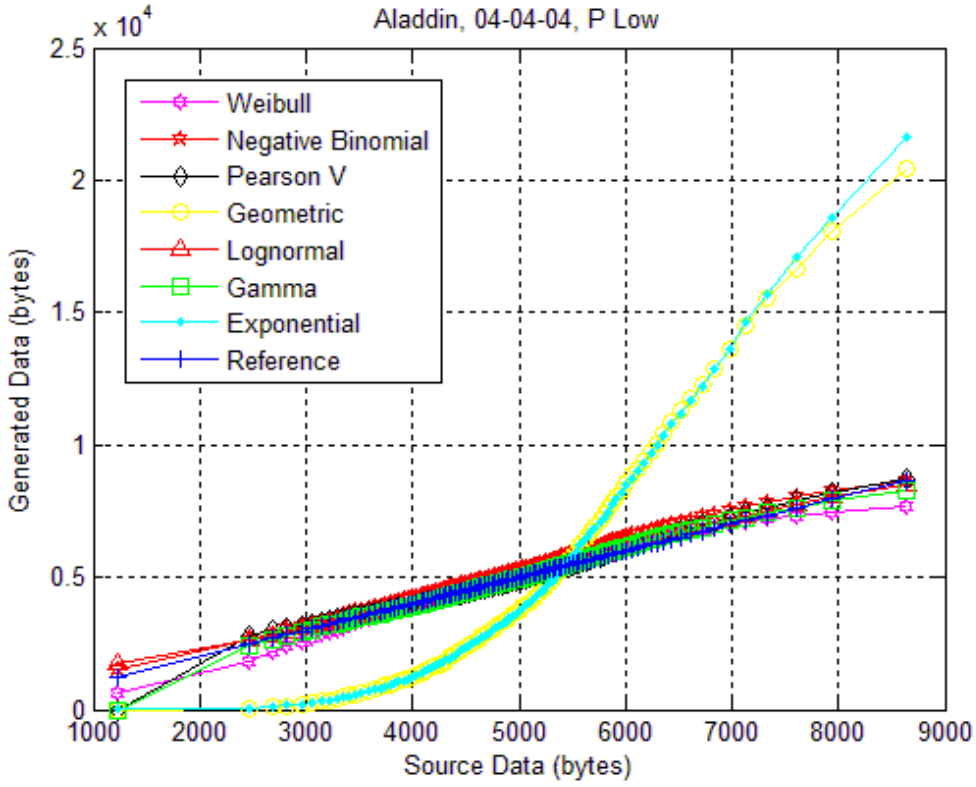

Figure 3.5 *Good fitting, P frames, Low activity*

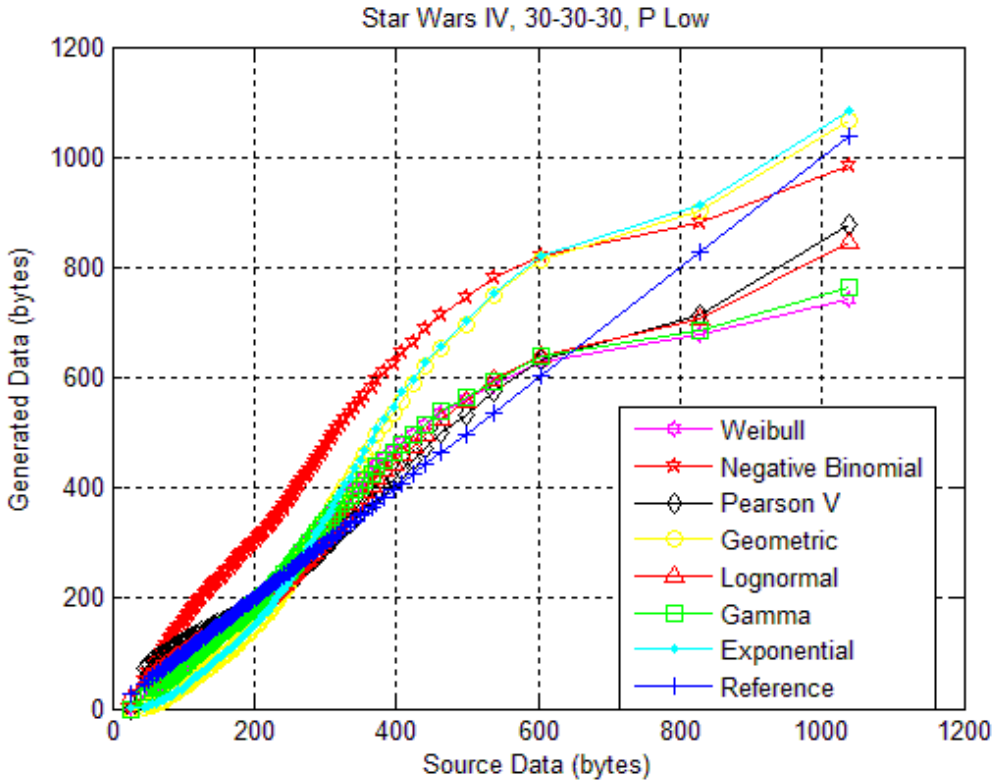

Figure 3.6 *Mediocre fitting, P frames, Low activity*

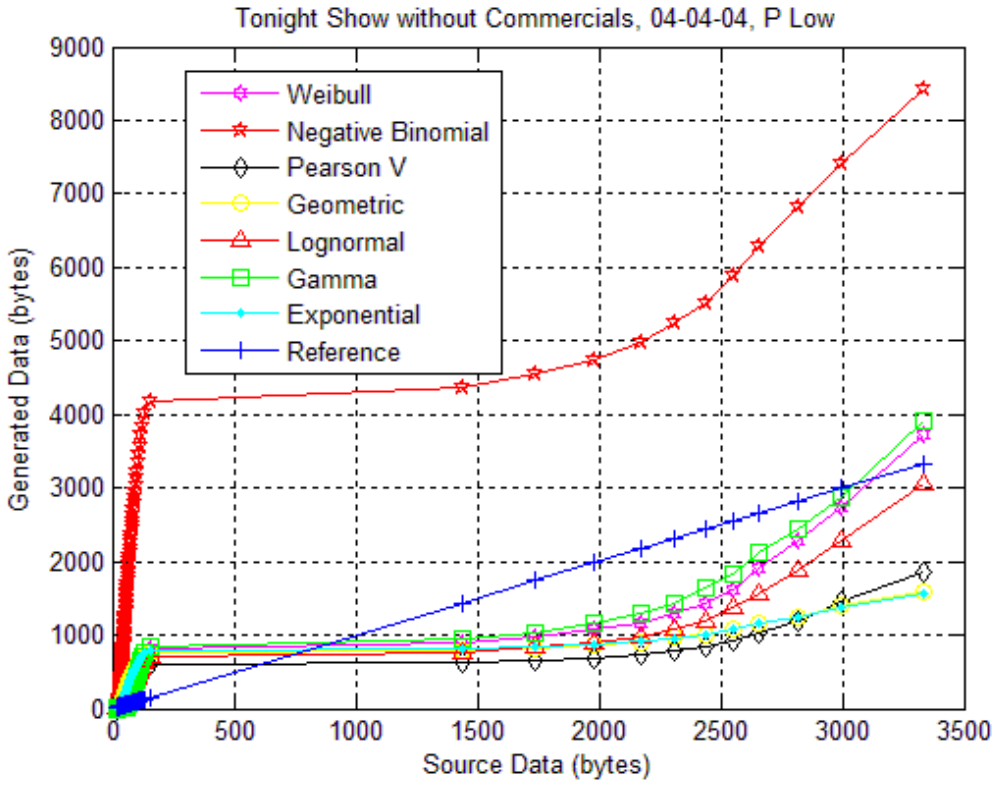

Figure 3.7 *Bad fitting, P frames, Low activity*

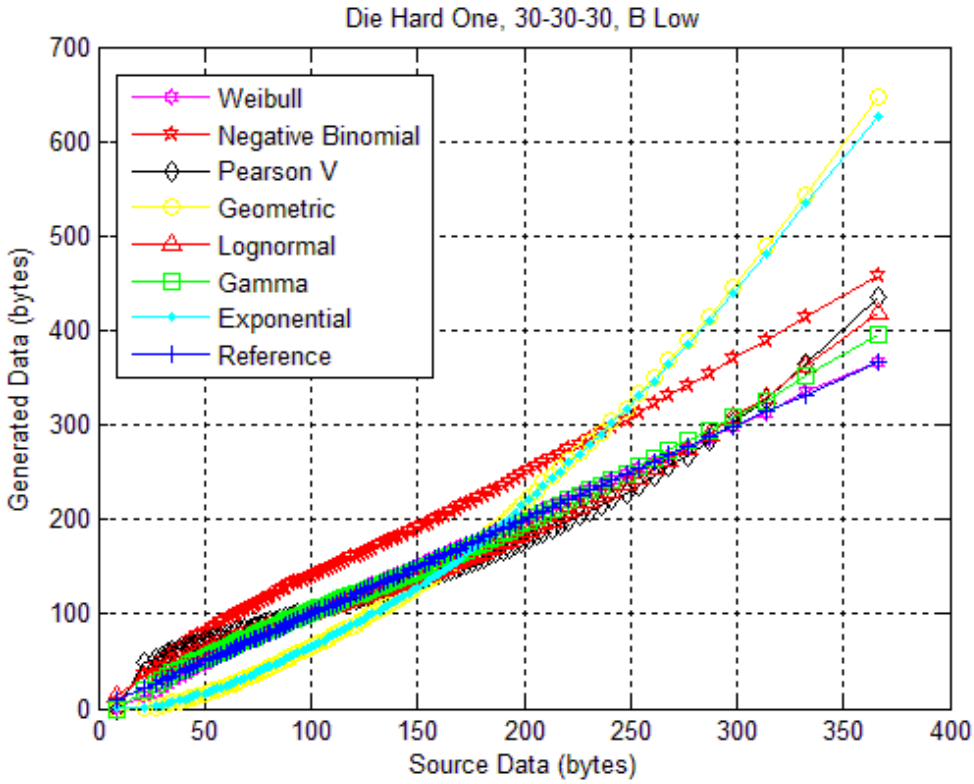

Figure 3.8 *Good fitting, B frames, Low activity*

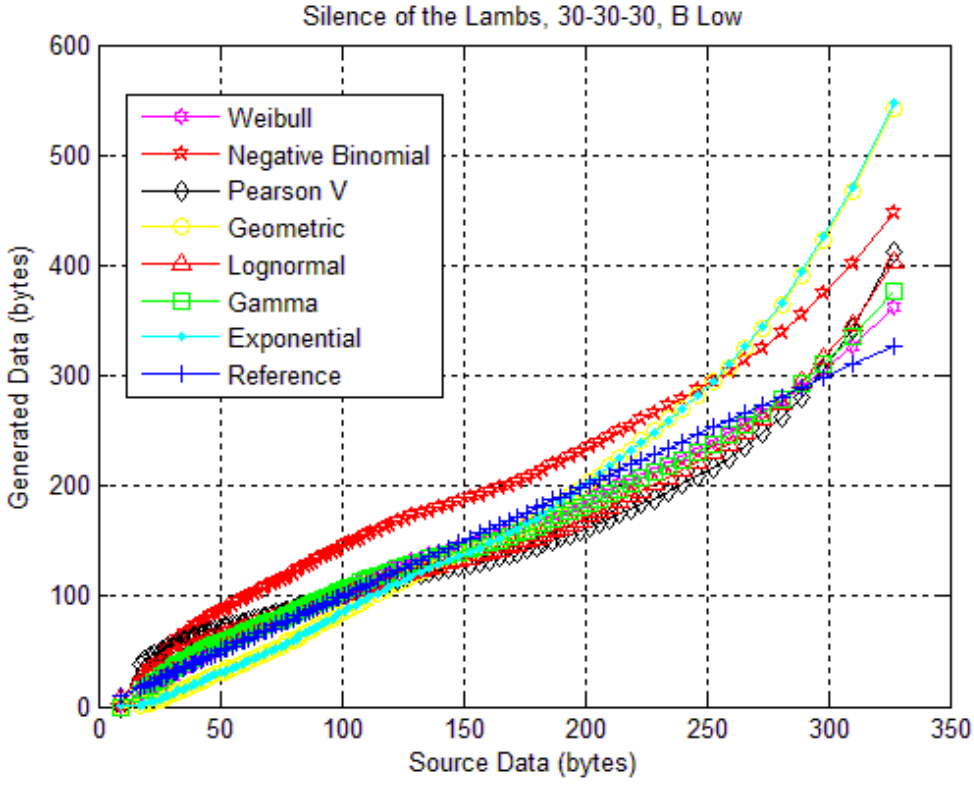

Figure 3.9 *Mediocre fitting, B frames, Low activity*

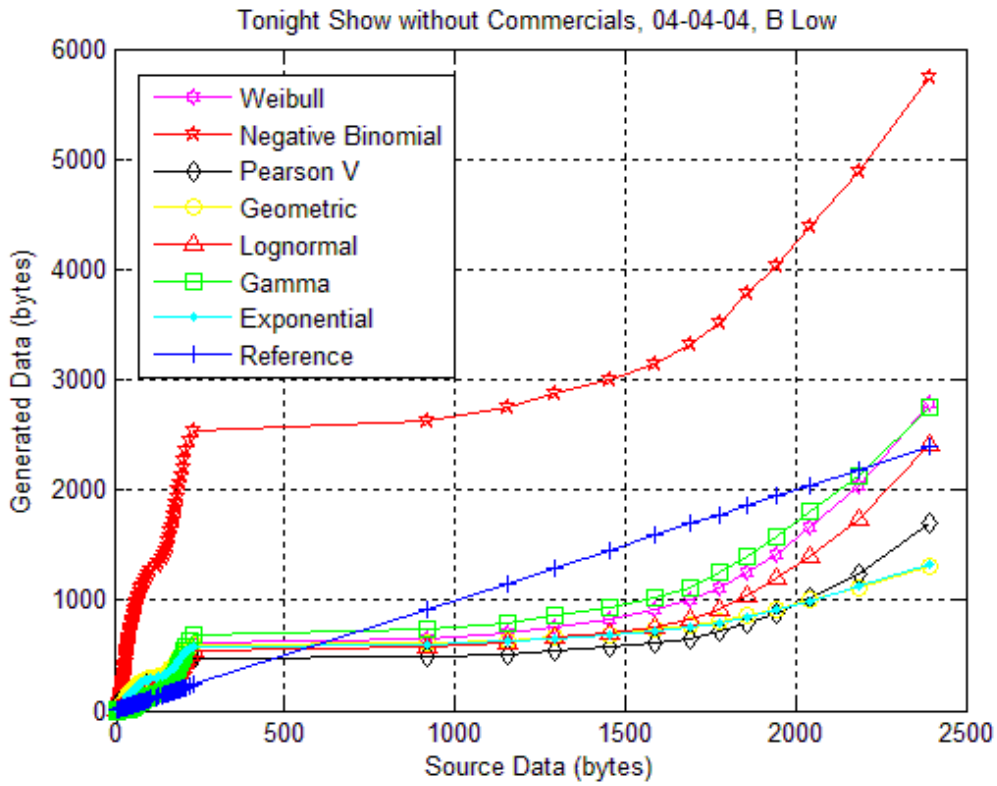

Figure 3.10 *Bad fitting, B frames, Low activity*

In many I frames' cases, as the movie quality increases (via the change in quantization parameters), the accuracy of the fittings increases as well (examples: Silence of the Lambs I frames, Cinderella I frames, Charlie's Angels DVD I frames). In the cases where fittings are bad for all three qualities of a movie, the aforementioned improvement with quality is hard to observe (example: Lecture Gupta I frames). On the other hand, we also sometimes observe the opposite, i.e., the accuracy of the fittings diminishing as quality increases (example: Tonight Show without Commercials I frames). One can draw similar conclusions regarding the P and B frames of the low-activity scene traces.

A common denominator among the three frame type categories, as indicated by the figures displayed above, is that one can find bad fittings in all of them. The worst of them, in terms of deviation from the reference line, are associated with the I and P frames of the low-activity traces.

Lastly, even though the majority of the plots examined provided good to mediocre fitting results, as expected, no distribution was proven capable of perfectly "capturing" the behavior of a trace under study.

3.7.2 High Activity Scenes

In this section, we focus on the Q-Q plot fittings corresponding to the I, P and B frames of the high-activity scenes of the traces examined. We present indicatively some of our results in Figures 3.11 – 3.19.

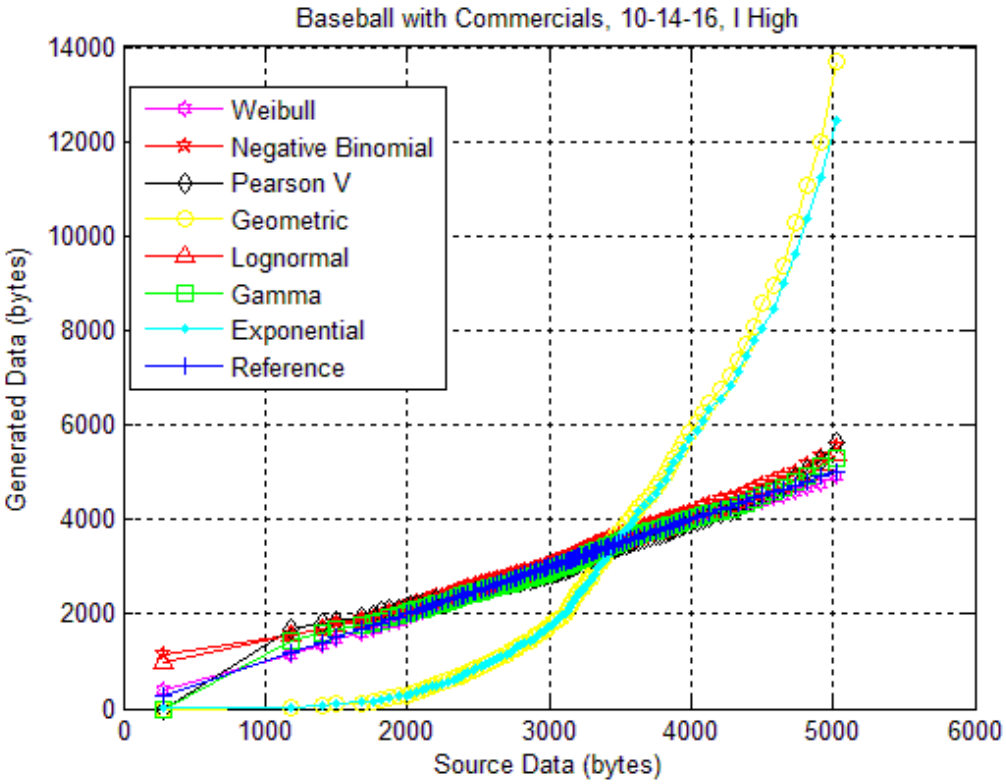

Figure 3.11 *Good fitting, I frames, High activity*

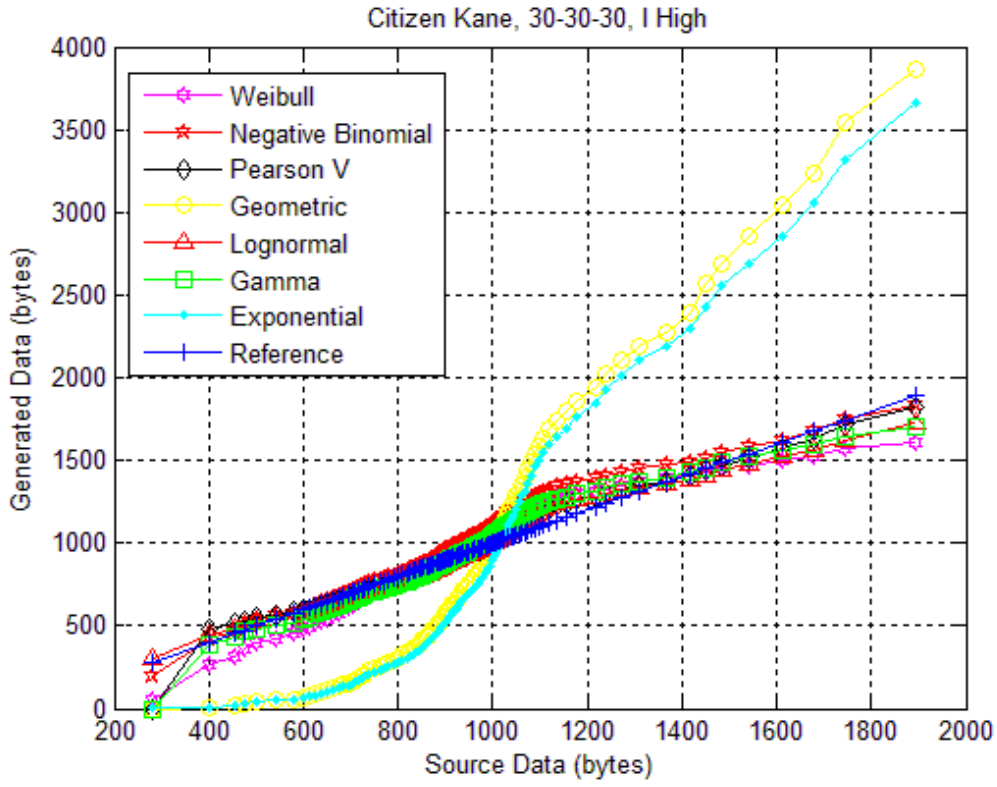

Figure 3.12 *Mediocre fitting, I frames, High activity*

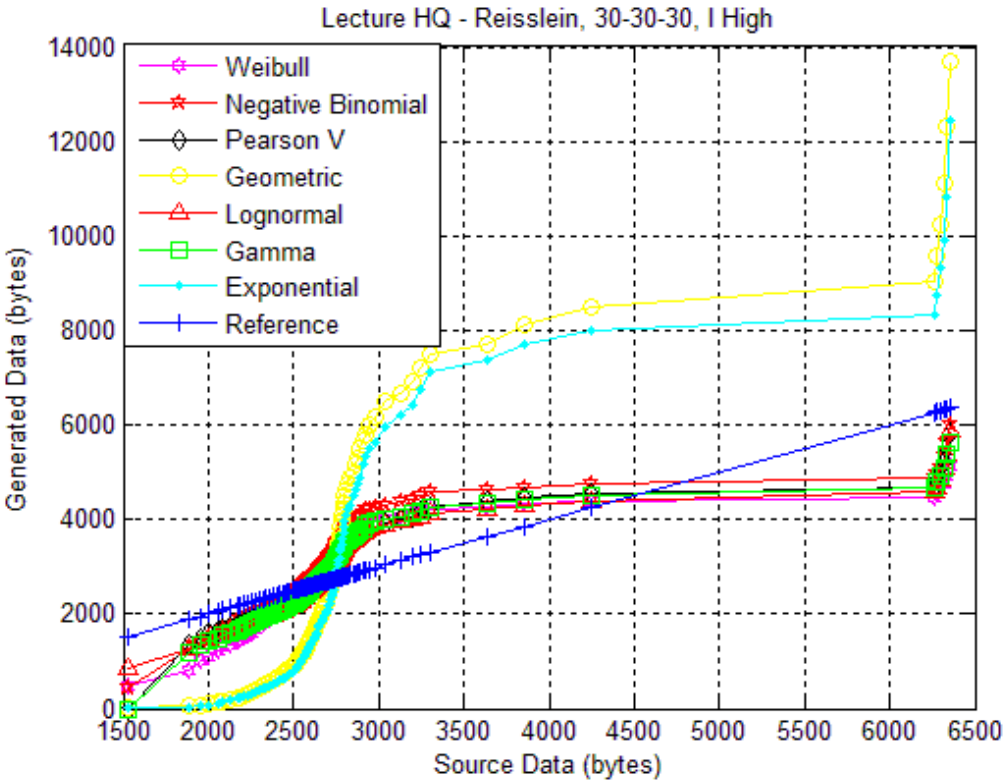

Figure 3.13 *Bad fitting, I frames, High activity*

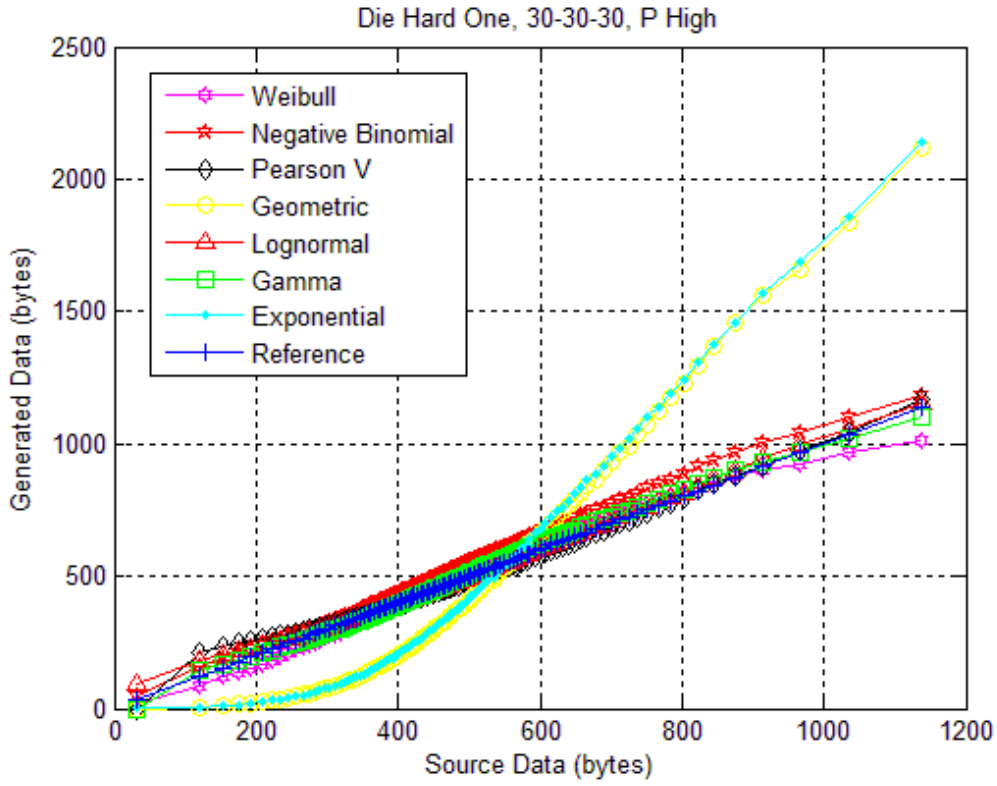

Figure 3.14 *Good fitting, P frames, High activity*

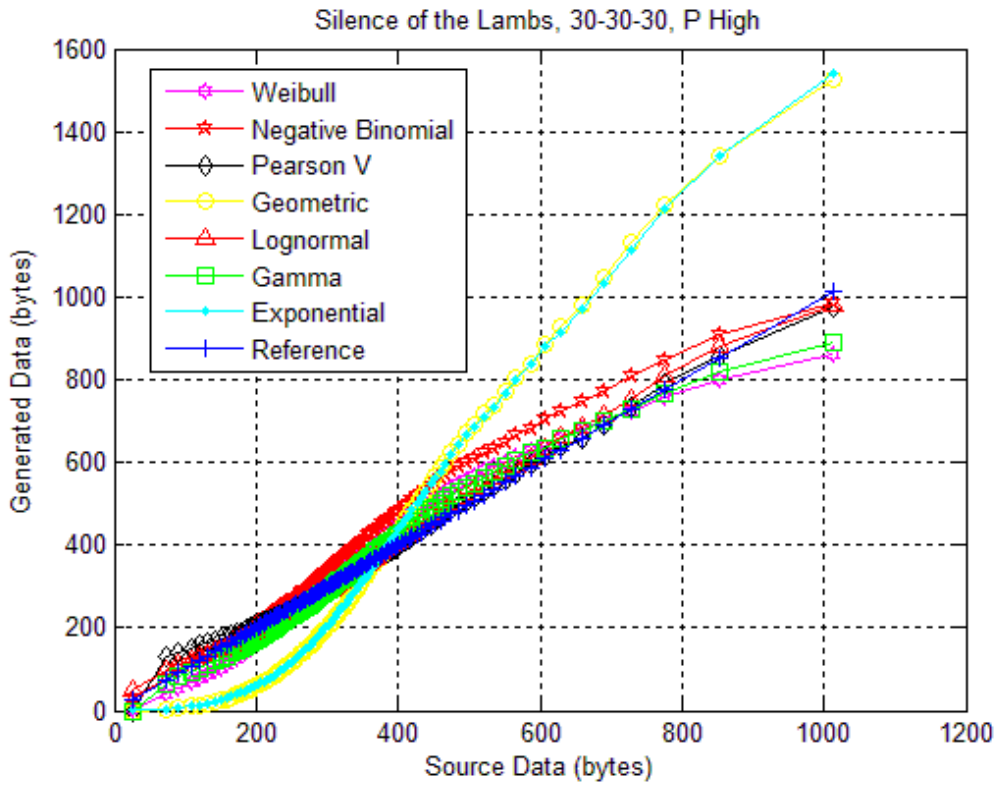

Figure 3.15 *Mediocre fitting, P frames, High activity*

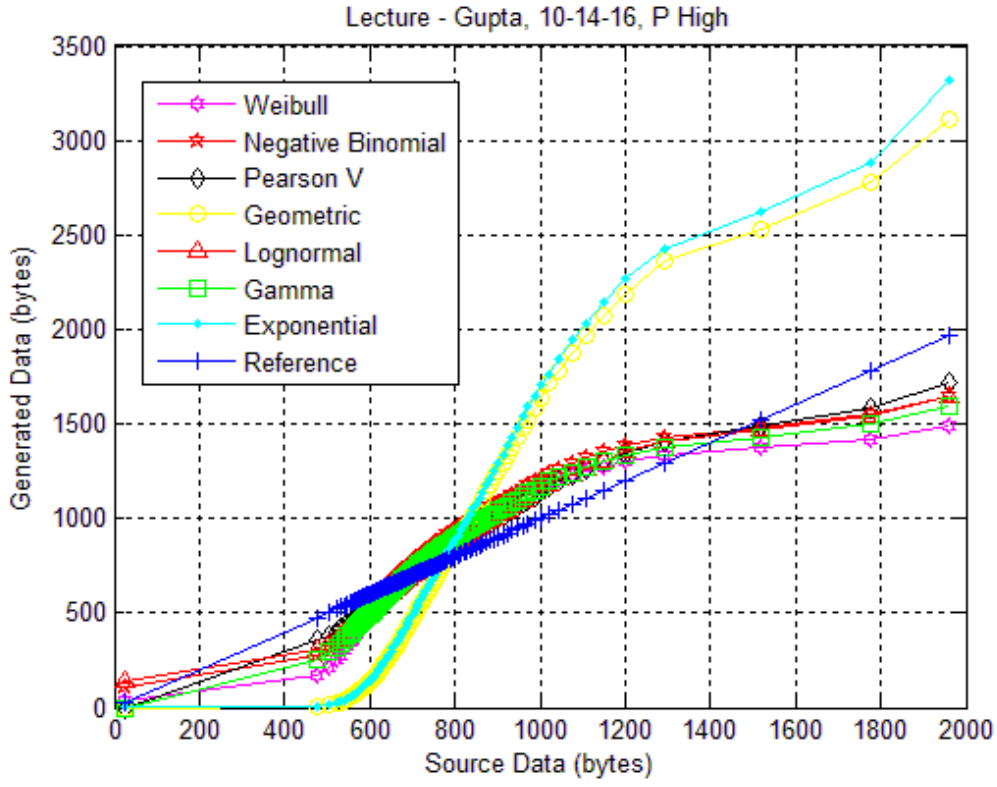

Figure 3.16 *Bad fitting, P frames, High activity*

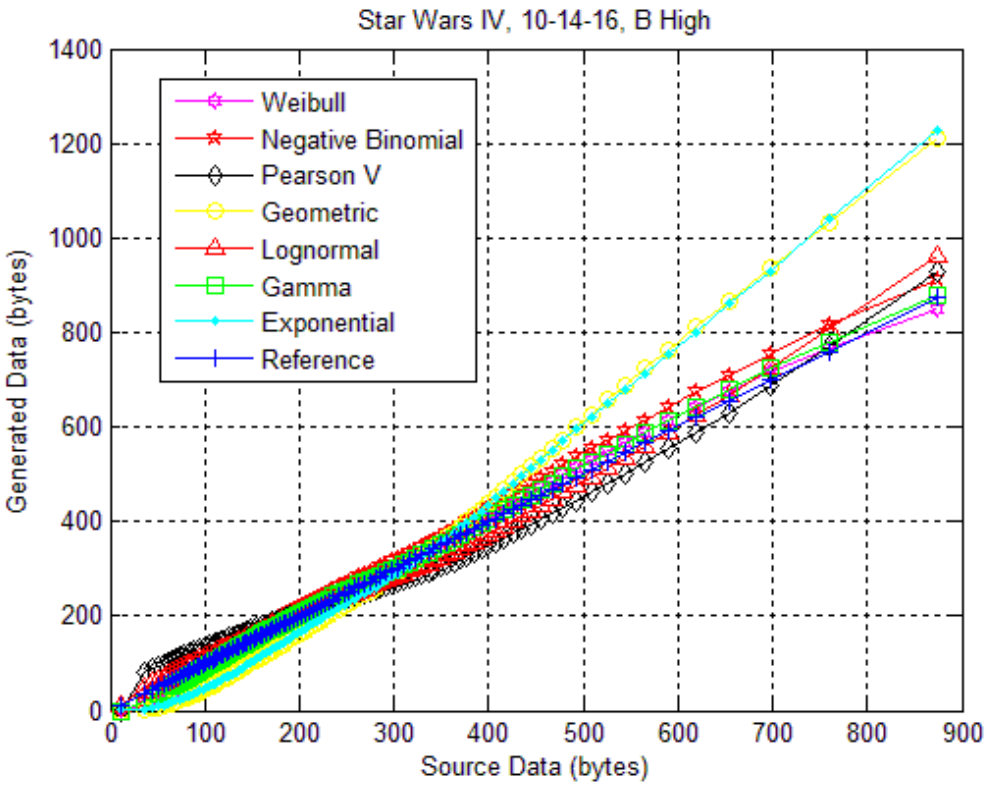

Figure 3.17 *Good fitting, B frames, High activity*

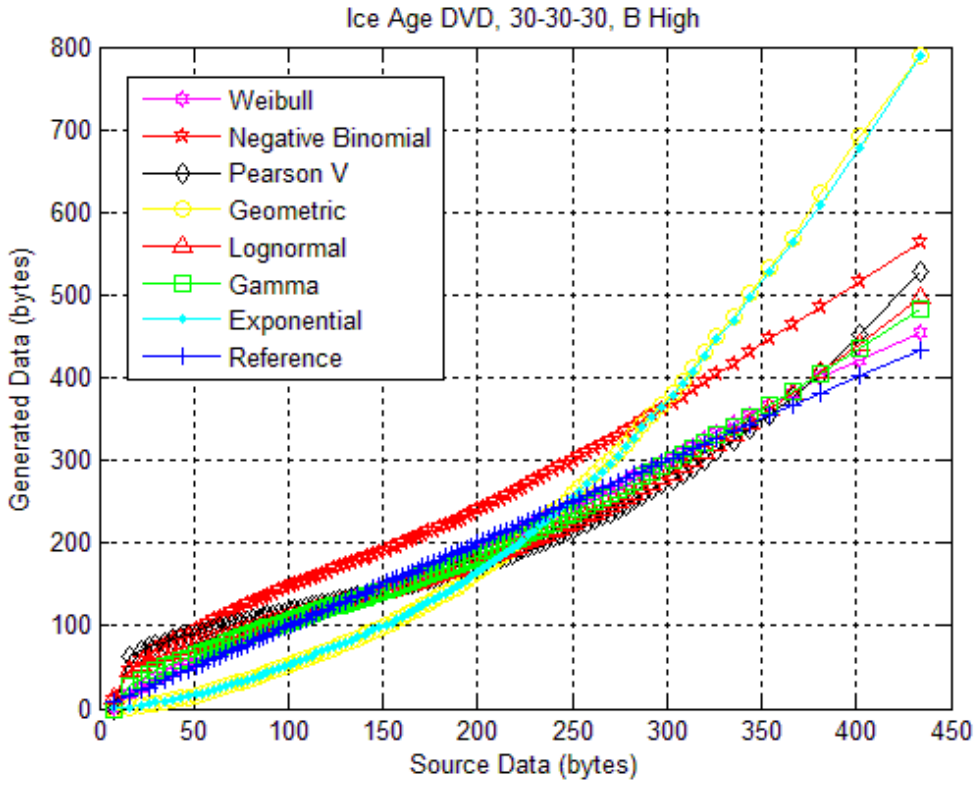

Figure 3.18 *Mediocre fitting, B frames, High activity*

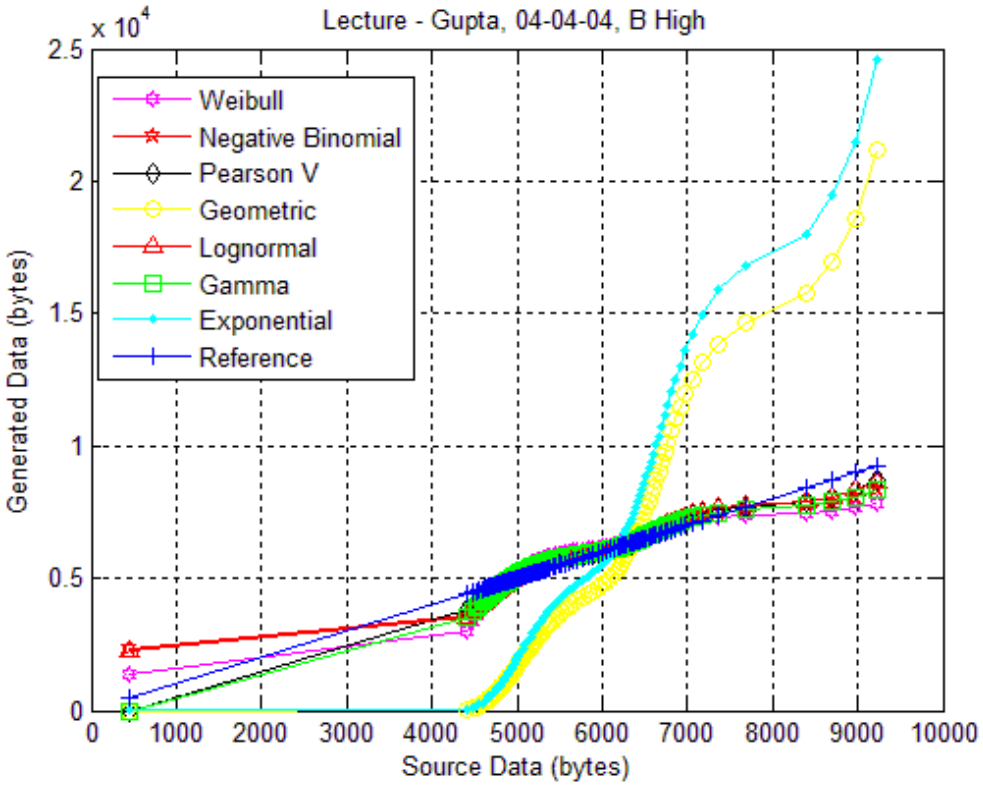

Figure 3.19 *Bad fitting, B frames, High activity*

The general conclusions deducted from all of our results are similar to those for low activity scenes. One noticeable difference is that the worst fittings, in terms of deviation from the reference line, belong to the I frames.

Once again, no distribution was capable of perfectly "capturing" the behavior of a trace under study.

3.8 Multiplexed MPEG-4 Traffic Modeling

As far as the lag-1 autocorrelation coefficient, ρ, is concerned, we observe that the autocorrelation of I frames of Low and High activity scenes is large. The lowest values of ρ can be found for P frames, both of Low and High activity scenes. Generally, the differences in scene activity do not influence the autocorrelation values, for frames of the same type. The range of autocorrelation values is shown in the table below.

Trace Type	Min ρ	Max ρ
I frames, Low	0.7493	0.9870
P frames, Low	0.2223	0.9737
B frames, Low	0.4640	0.9917
I frames, High	0.7166	0.9847
P frames, High	0.3612	0.9269
B frames, High	0.4580	0.9623

TABLE 3.9 – MIN AND MAX AUTOCORRELATION COEFFICIENT VALUES PER TRACE TYPE

- *I frames, Low activity*

We evaluated the hybrid model via 58 Q-Q plots. Most of them showed mediocre modeling results, along with 5 good and 11 bad ones. In most of the I frames' cases, a rough conclusion would be that a good or mediocre modeling result comes after a good or mediocre initial fitting, whereas a bad modeling result follows a mediocre or bad initial fitting. However, in the case of Aladdin 04-04-04, we found an exception: a good initial fitting is followed by a bad modeling result. Some indicative results are presented in Figures 3.20 - 3.22.

For 5 out of the 63 traces under study, we were incapable of determining the best distribution fit and hence, we did not run the hybrid model. The five traces are presented in Table 3.10.

Excluded Traces
Lecture – Reisslein, 10-14-16
Lecture – Reisslein, 04-04-04
Tokyo Olympics DVD, 10-14-16
Ice Age DVD, 10-14-16
Ice Age DVD, 04-04-04

TABLE 3.10 – I LOW TRACES EXCLUDED FROM HYBRID MODELING

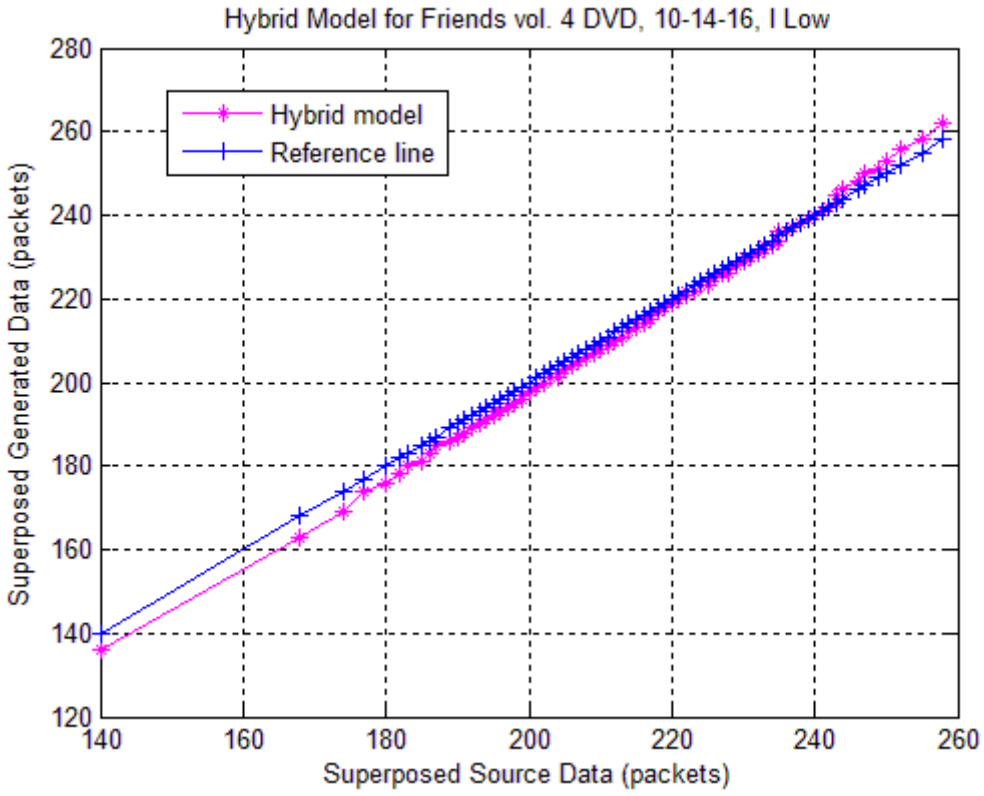

Figure 3.20 *Good Modeling Result (5 sources) for I frames of Low activity*

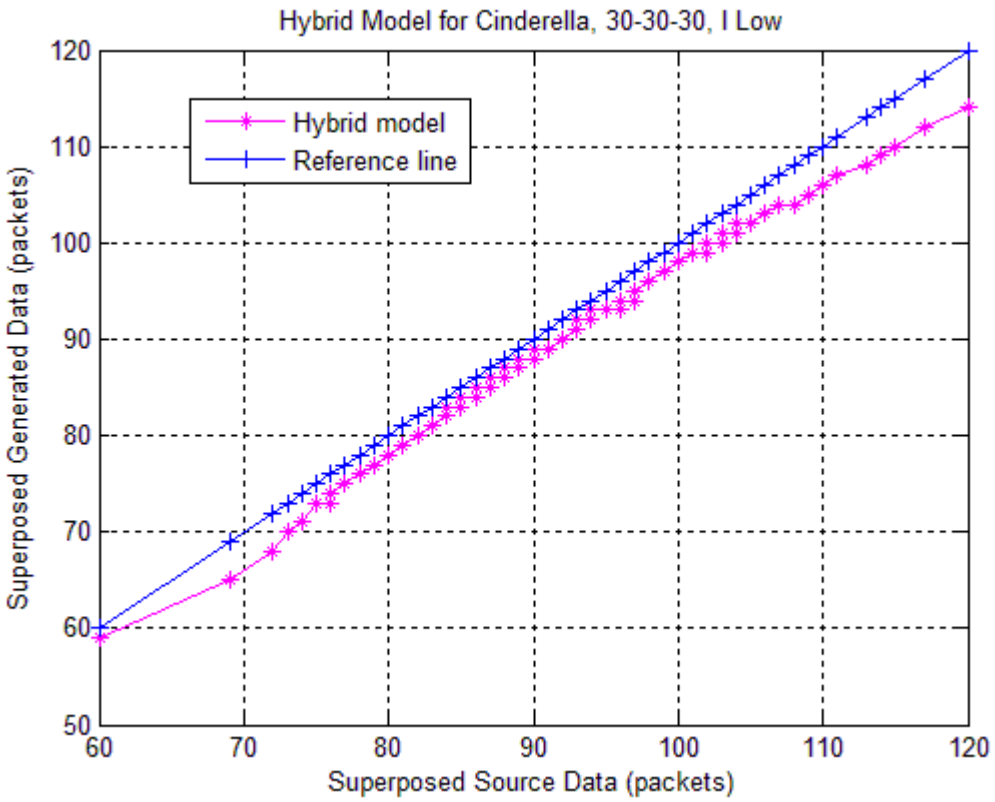

Figure 3.21 *Mediocre Modeling Result (5 sources) for I frames of Low activity*

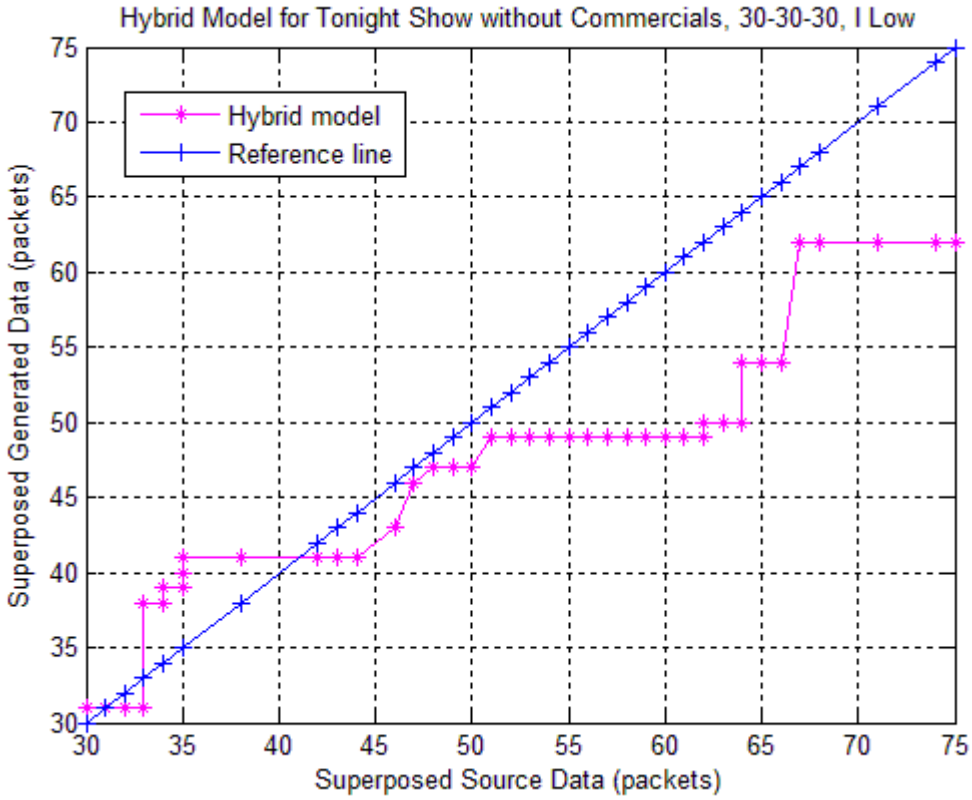

Figure 3.22 *Bad Modeling Result (5 sources) for I frames of Low activity*

- *P frames, Low activity*

In the case of P frames, we evaluated the hybrid model via 61 Q-Q plots. Most of them showed mediocre modeling results, along with 4 good and 11 bad ones. Similarly to I frames, in the case of most P frame traces, a rough conclusion would be that a good or mediocre modeling result comes after a good or mediocre initial fitting, whereas a bad modeling result follows a mediocre or bad initial fitting. Some indicative results are presented in Figures 3.23 - 3.25.

For 2 out of the 63 traces under study, we were incapable of determining the best distribution fit and hence, we did not run the hybrid model. The two traces are presented in Table 3.11.

Excluded Traces
Tonight Show without Commercials, 30-30-30
Tonight Show without Commercials, 10-14-16

TABLE 3.11 – P LOW TRACES EXCLUDED FROM HYBRID MODELING

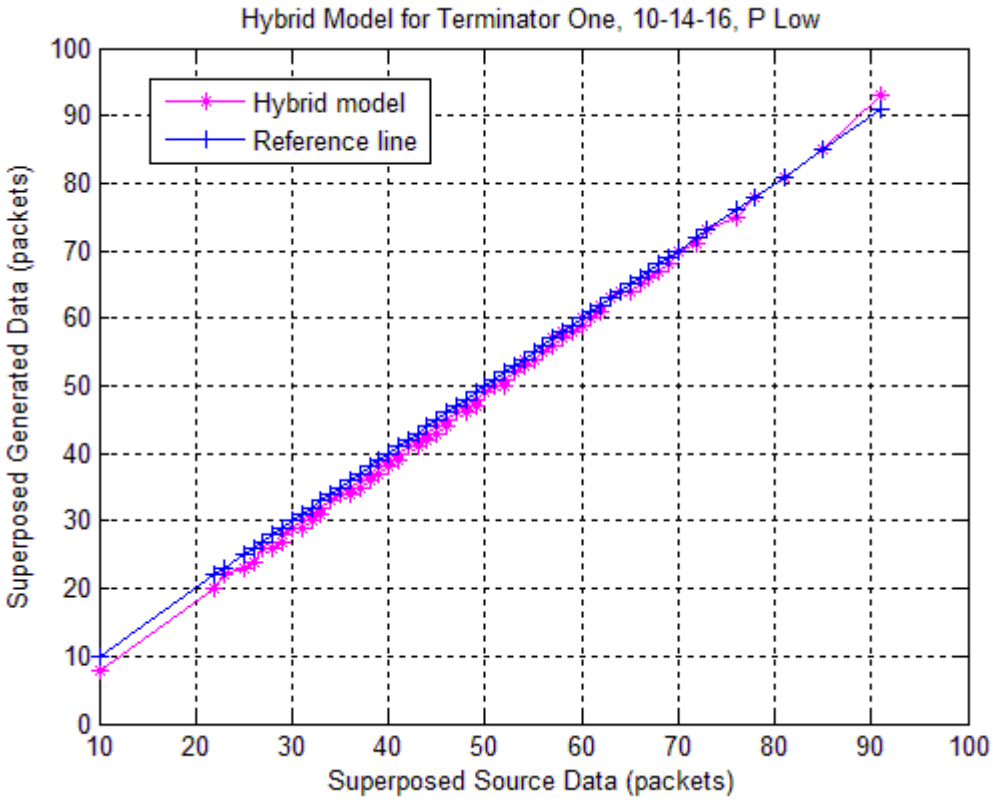

Figure 3.23 *Good Modeling Result (5 sources) for P frames of Low activity*

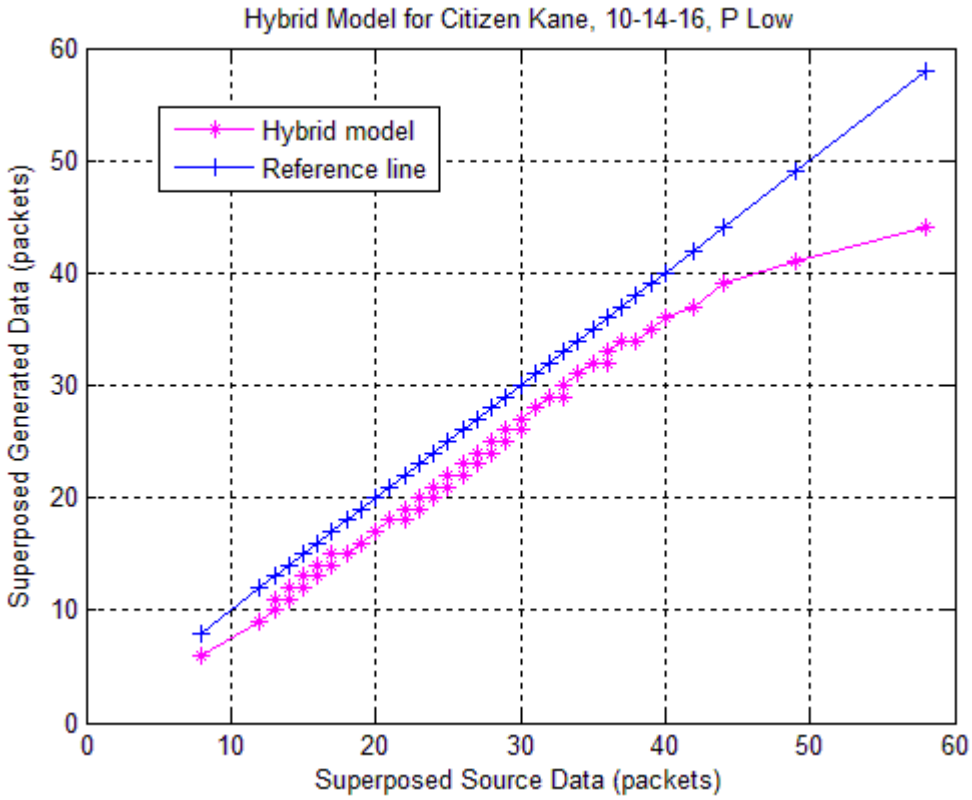

Figure 3.24 *Mediocre Modeling Result (5 sources) for P frames of Low activity*

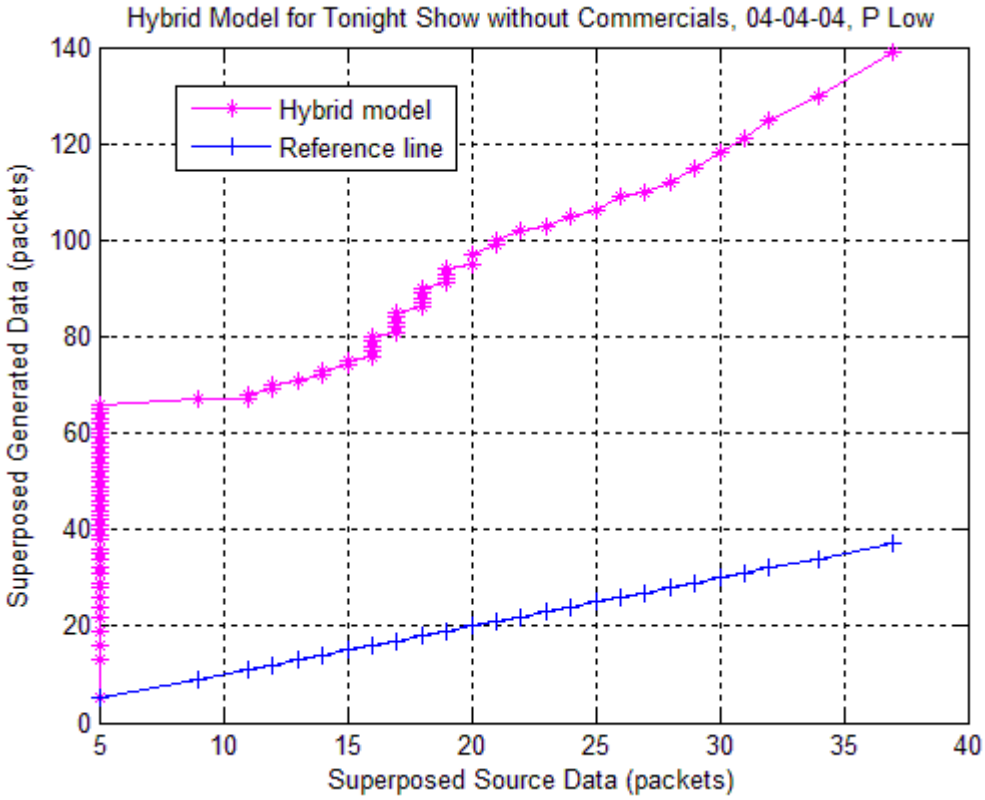

Figure 3.25 *Bad Modeling Result (5 sources) for P frames of Low activity*

- *B frames, Low activity*

We evaluated the hybrid model via 59 Q-Q plots. Most of them showed mediocre modeling results, along with 1 good and 25 bad ones. In the case of most B frame traces, we cannot reach clear conclusions other than that a good or mediocre initial fitting cannot guarantee a good or mediocre modeling result. The reason is that there are many examples of bad modeling results following mediocre or even good initial fittings (i.e., Charlie's Angles DVD 04-04-04, Citizen Kane 10-14-16, Die Hard One 10-14-16, Star Wars IV 10-14-16, Terminator One 30-30-30, The Transporter DVD 10-14-16).Some indicative results are presented in Figures 3.26 - 3.28.

For 4 out of the 63 traces under study, we were incapable of determining the best distribution fit and hence, we did not run the hybrid model. The four traces are presented in Table 3.12.

Excluded Traces
Terminator One, 10-14-16
Tonight Show without Commercials, 30-30-30
Tonight Show without Commercials, 10-14-16
Tonight Show without Commercials, 04-04-04

TABLE 3.12 – B LOW TRACES EXCLUDED FROM HYBRID MODELING

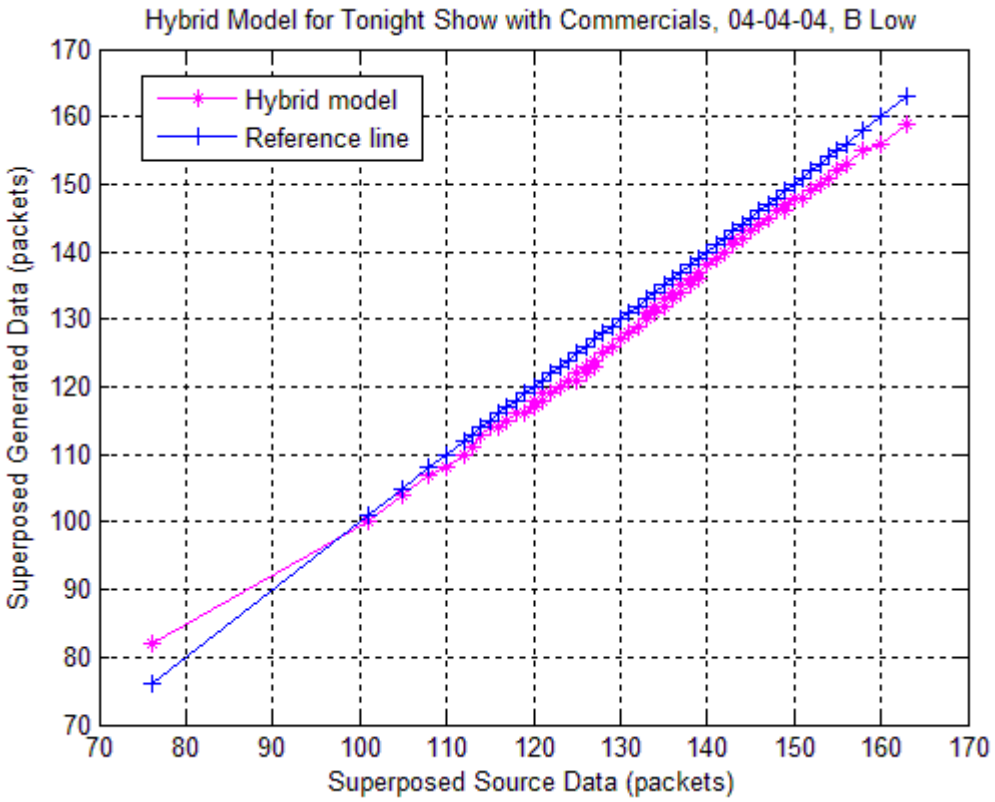

Figure 3.26 *Good Modeling Result (5 sources) for B frames of Low activity*

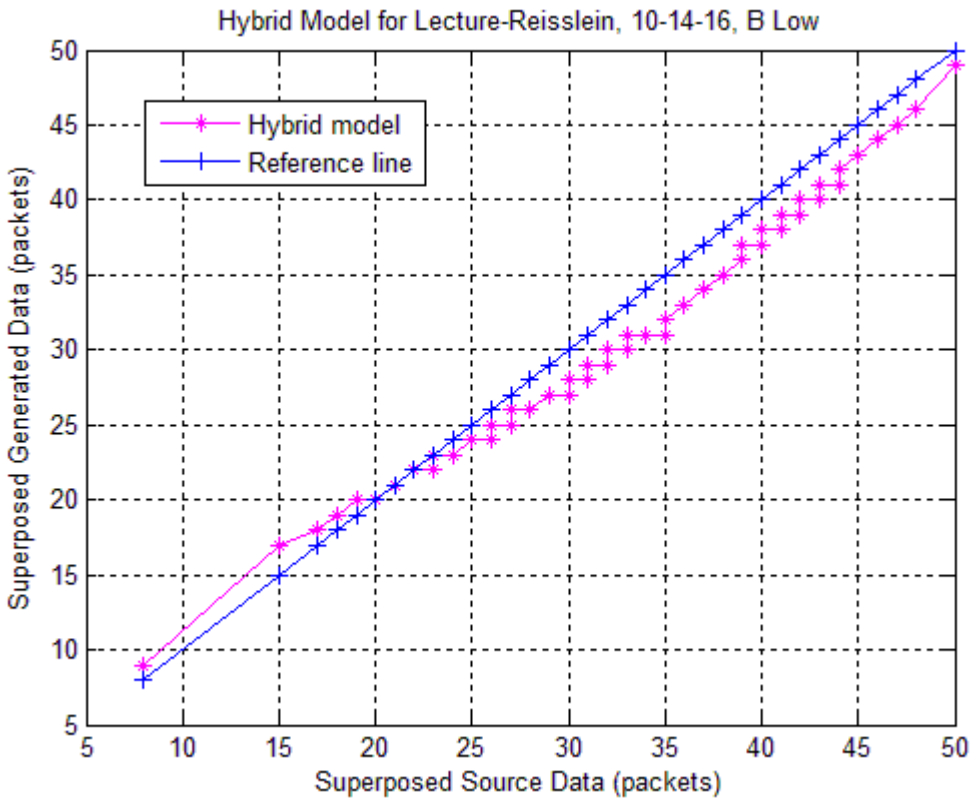

Figure 3.27 *Mediocre Modeling Result (5 sources) for B frames of Low activity*

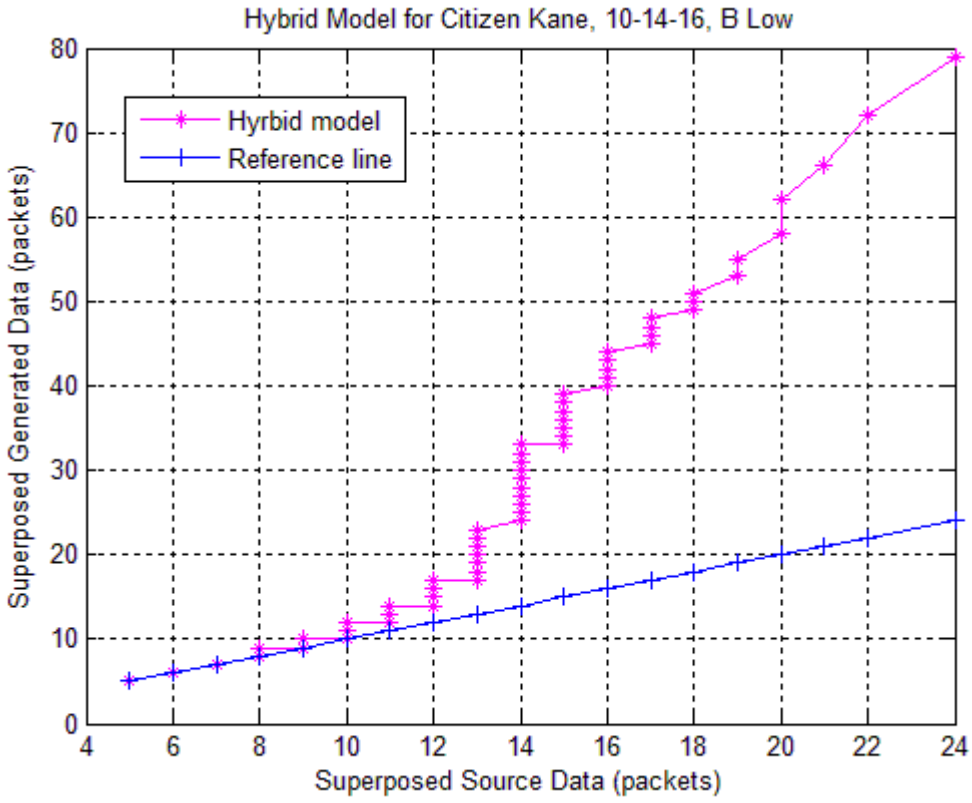

Figure 3.28 *Bad Modeling Result (5 sources) for B frames of Low activity*

In this part of our work, an interesting result is that among the three types of Low activity sequences, B frames had the highest number of bad modeling results, while the respective bad modeling cases for I and P frames were about equal. Additionally, among all the bad modeling results for low activity scenes, those belonging to P and B frames were of the lowest accuracy. Perfect accuracy was never achieved.

- *I frames, High activity*

In the case of I frames of High activity sequences, we evaluated the hybrid model via 63 Q-Q plots. Most of them showed mediocre modeling results, along with 6 good and 13 bad ones. In most of the I frames' cases, a rough conclusion would be that a good modeling result comes after a good or mediocre initial fitting, a mediocre modeling result comes after a mediocre or bad initial fitting, whereas a bad modeling result follows a mediocre or bad initial fitting. However, in the case of Friends vol.4 DVD 04-04-04, we found an exception: a good initial fitting is followed by a bad modeling result. Some indicative results are presented in Figures 3.29 - 3.31.

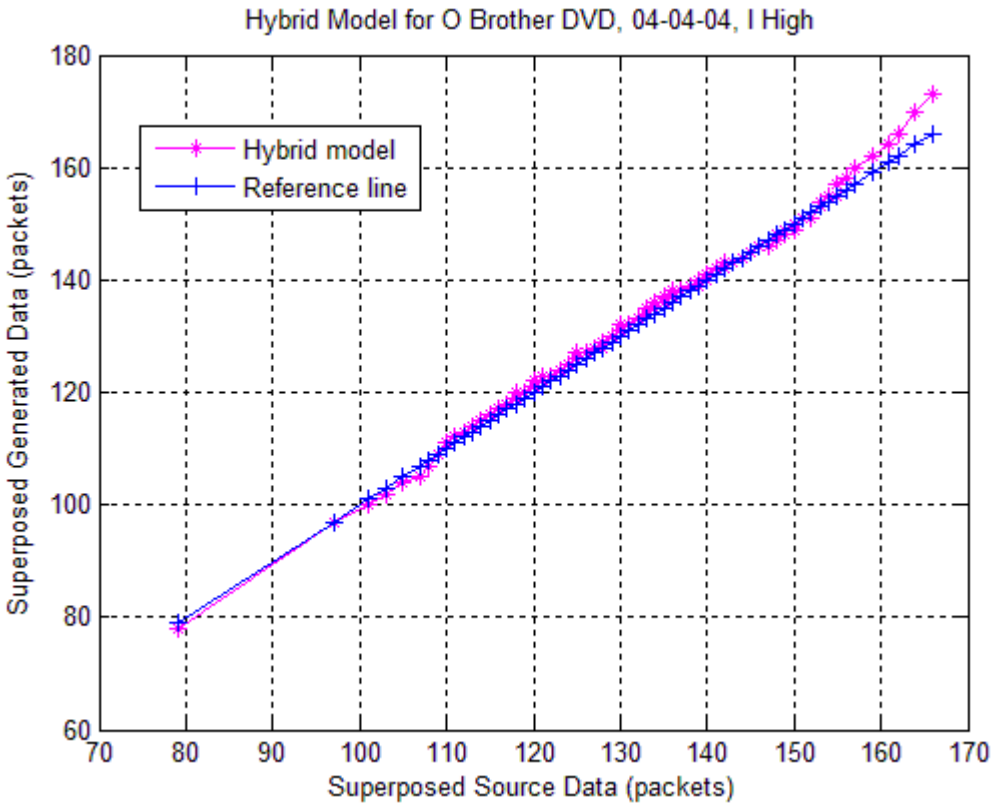

Figure 3.29 *Good Modeling Result (5 sources) for I frames of High activity*

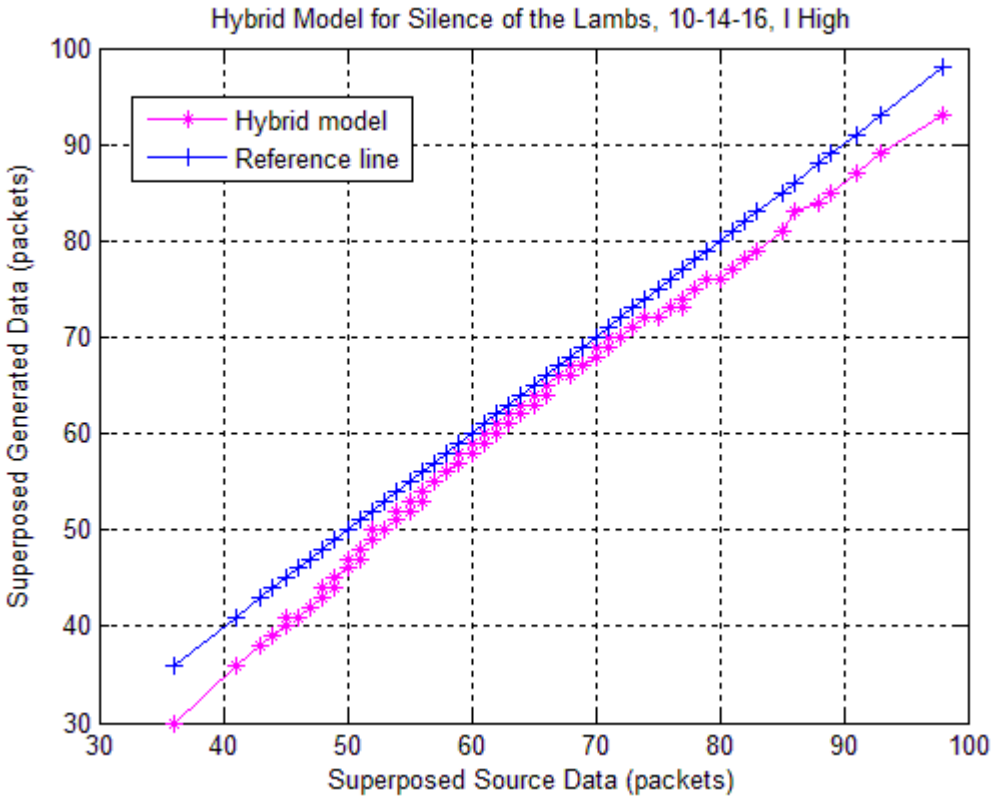

Figure 3.30 *Mediocre Modeling Result (5 sources) for I frames of High activity*

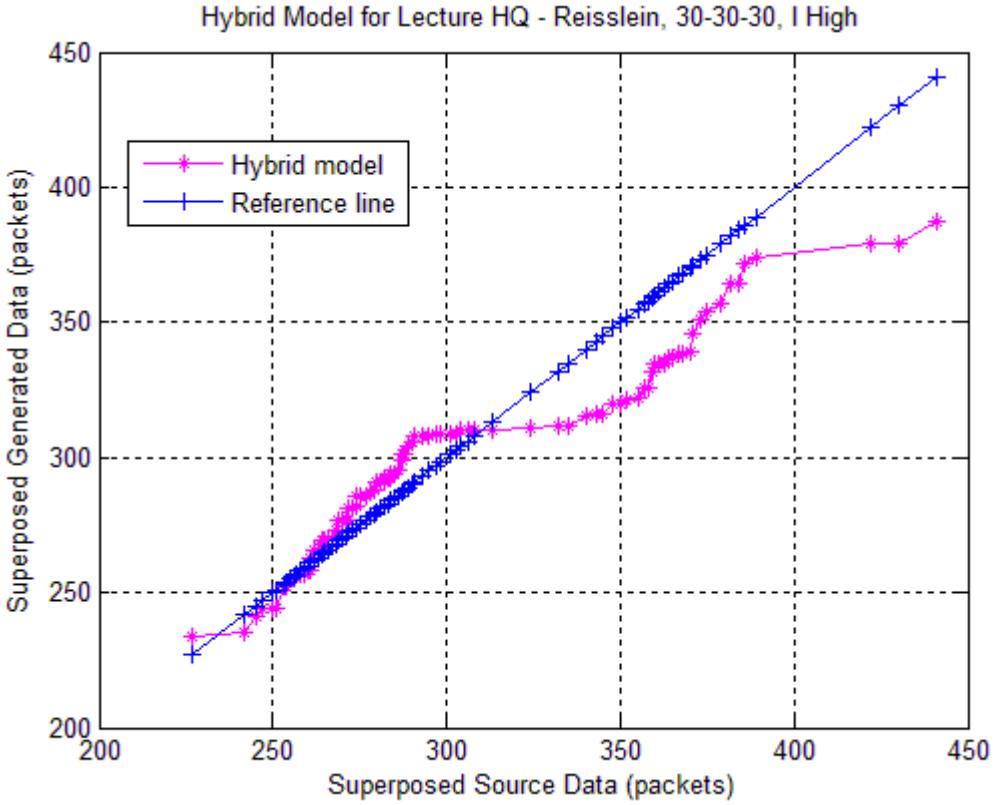

Figure 3.31 *Bad Modeling Result (5 sources) for I frames of High activity*

- *P frames, High activity*

We evaluated the hybrid model via 62 Q-Q plots. Most of them showed mediocre modeling results, along with 2 good and 2 bad ones. In the case of most P frame traces, a rough conclusion would be that a good modeling result comes after a mediocre initial fitting, a mediocre modeling result comes after a mediocre or bad initial fitting, whereas a bad modeling result follows a mediocre or bad initial fitting. Exceptions, once again, were encountered: in the case of Cinderella 04-04-04, a good initial fitting is followed by a bad modeling result. Some indicative results are presented in Figures 3.32 - 3.34.

For 1 out of the 63 traces under study, we were incapable of determining the best distribution fit and hence, we did not run the hybrid model. The trace excluded is presented in Table 3.13.

Excluded Traces
O Brother DVD, 30-30-30

TABLE 3.13 – P HIGH TRACES EXCLUDED FROM HYBRID MODELING

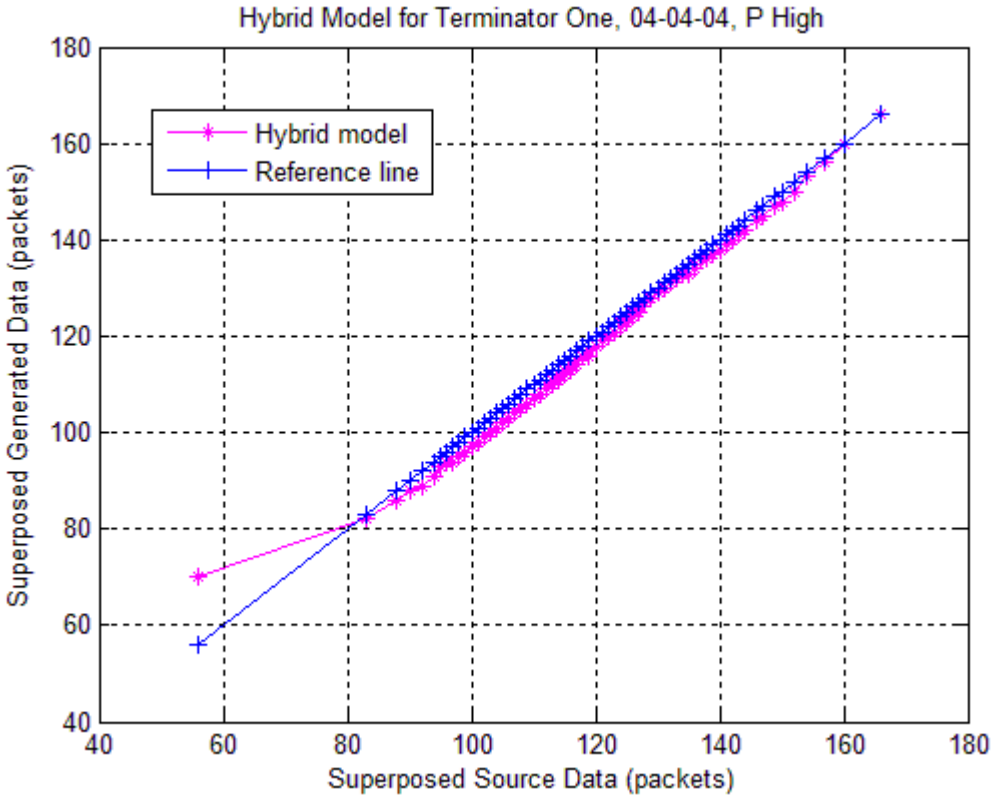

Figure 3.32 *Good Modeling Result (5 sources) for P frames of High activity*

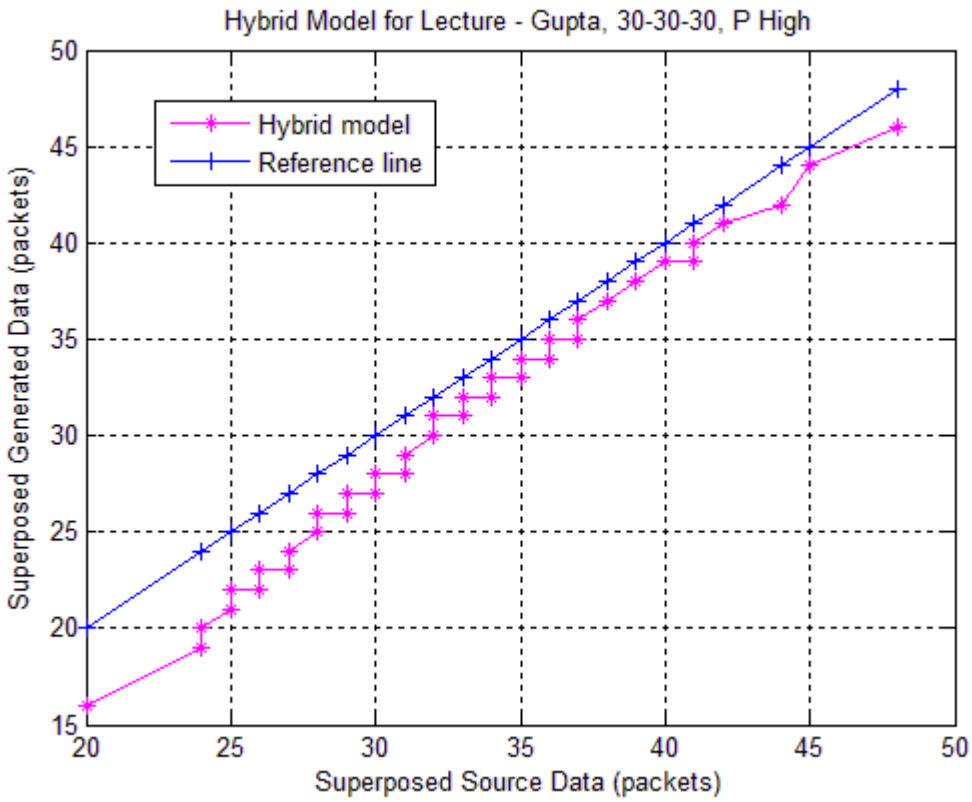

Figure 3.33 *Mediocre Modeling Result (5 sources) for P frames of High activity*

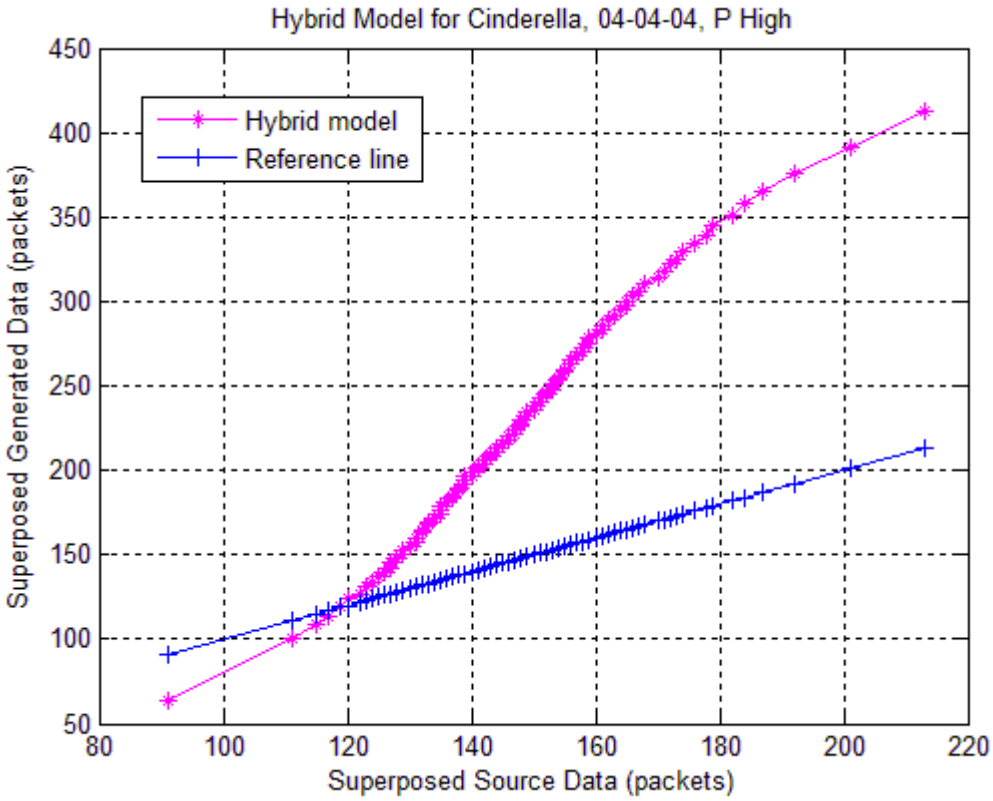

Figure 3.34 *Bad Modeling Result (5 sources) for P frames of High activity*

- *B frames, High activity*

We evaluated the hybrid model via 62 Q-Q plots. Most of them showed mediocre modeling results, along with 6 good and 7 bad ones. In the case of most B frame traces, a rough conclusion would be that a good modeling result comes after a good or mediocre initial fitting. We cannot reach similarly clear conclusions regarding mediocre or bad modeling results. The reason is that there are mediocre and bad results coming after all types of fittings (good, mediocre and bad ones). For instance, in the case of Tonight Show without Commercials 04-04-04, a bad initial fitting is followed by a mediocre modeling result, while in the case of Ice Age DVD 10-14-16, a good initial fitting is followed by a bad modeling attempt. Some indicative results are presented in Figures 3.35 - 3.37.

For 1 out of the 63 traces under study, we were incapable of determining the best distribution fit and hence, we did not run the hybrid model. The trace excluded is presented in Table 3.14.

Excluded Traces
Silence of the Lambs, 10-14-16

TABLE 3.14 – B HIGH TRACES EXCLUDED FROM HYBRID MODELING

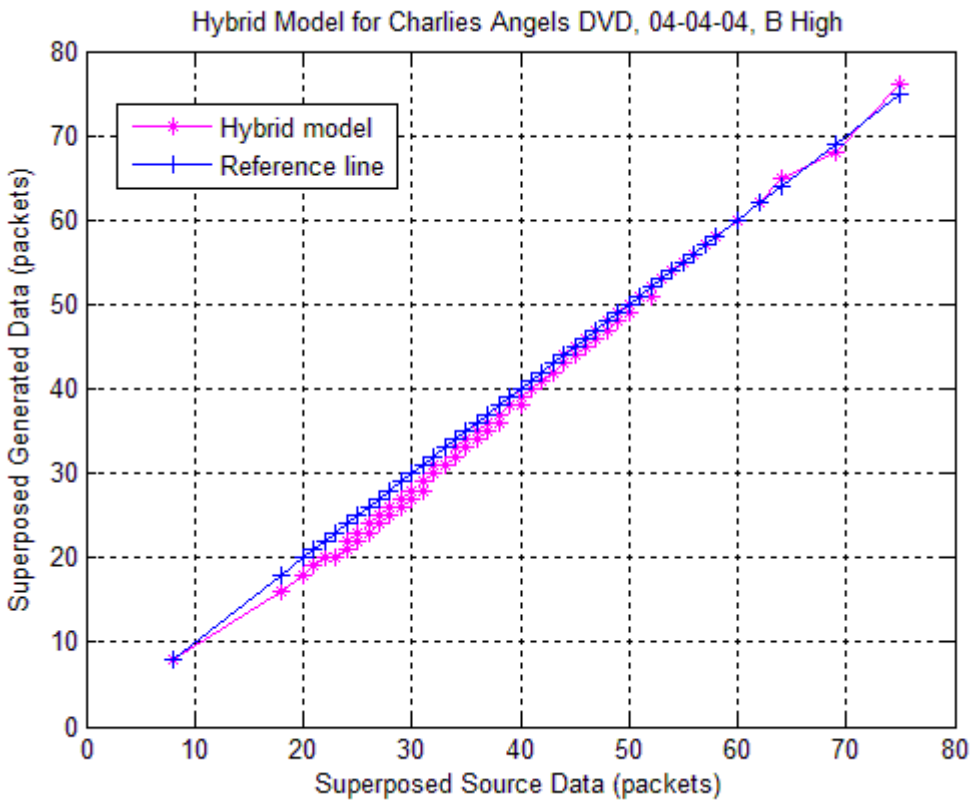

Figure 3.35 *Good Modeling Result (5 sources) for B frames of High activity*

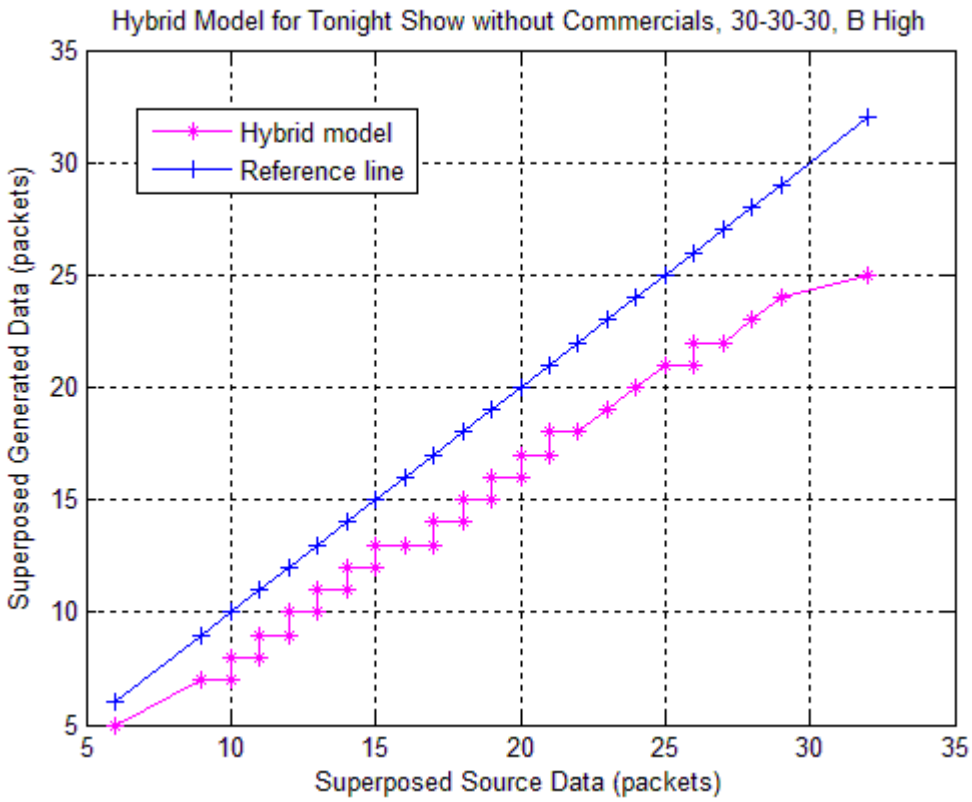

Figure 3.36 *Mediocre Modeling Result (5 sources) for B frames of High activity*

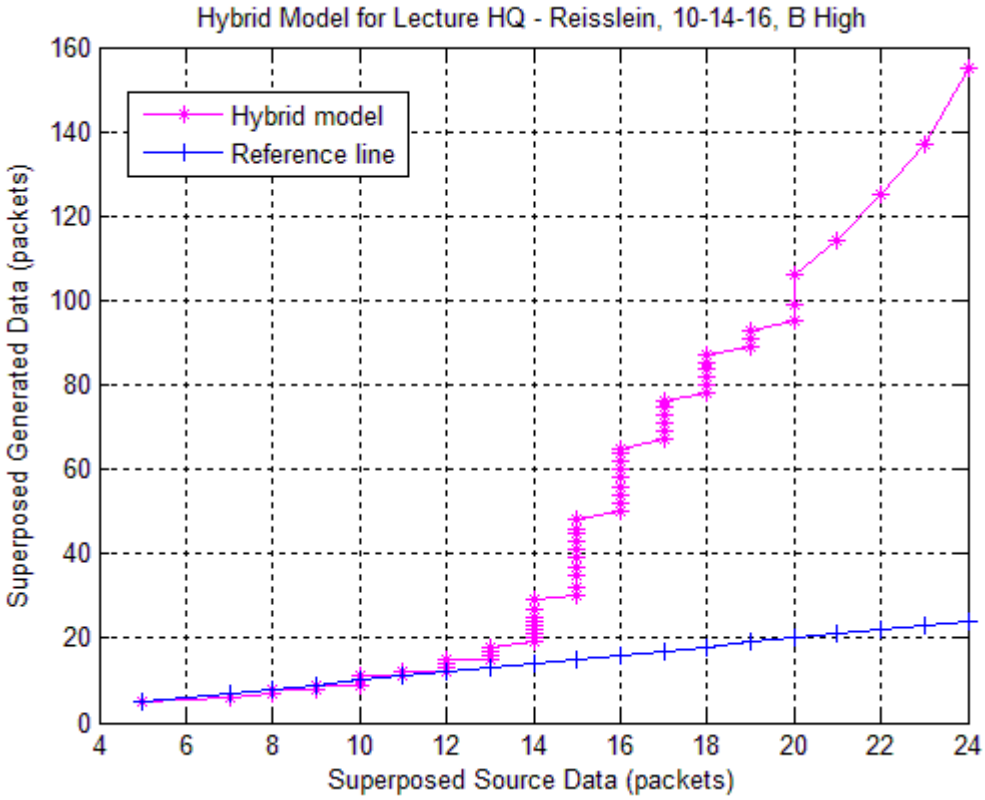

Figure 3.37 *Bad Modeling Result (5 sources) for B frames of High activity*

In this part of our work, an interesting result is that among the three types of High activity sequences, I frames had the highest number of bad modeling results, followed by B frames and then by P frames. Additionally, among all bad modeling results for this type of activity, those belonging to P and B frames were of the lowest accuracy. Perfect accuracy was never achieved.

As the number of the superposed sources increases from 5 to 10 and then to 15, the majority of the results, regardless of frame type and degree of activity, deteriorate. The cases where the modeling results remain unaffected are fewer. Improvements can be observed in a very limited number of cases and they usually last for only one transition, i.e., from 5 to 10 or 10 to 15 sources. The largest percentage of these improvements belongs to the I Low and I High results. Indicative examples are presented below.

- Improvement Example – Charlie's Angels DVD 10-14-16, I frames Low activity

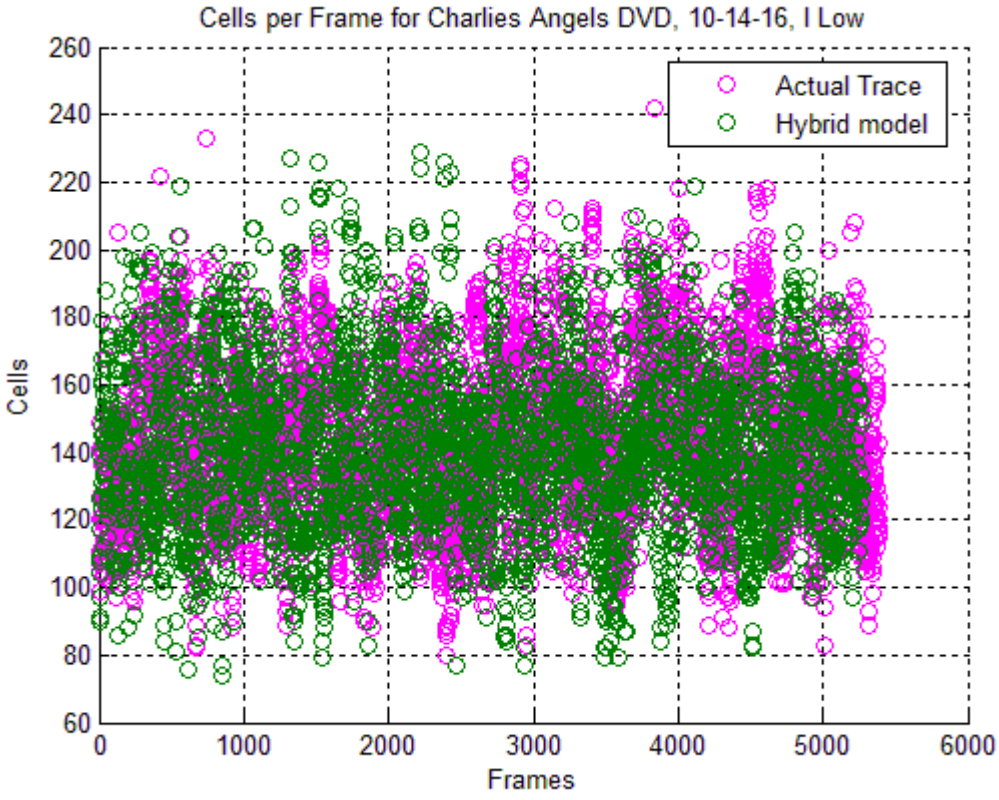

Figure 3.38 *Cells per Frame for trace improving with the increase in the number of sources (5 sources)*

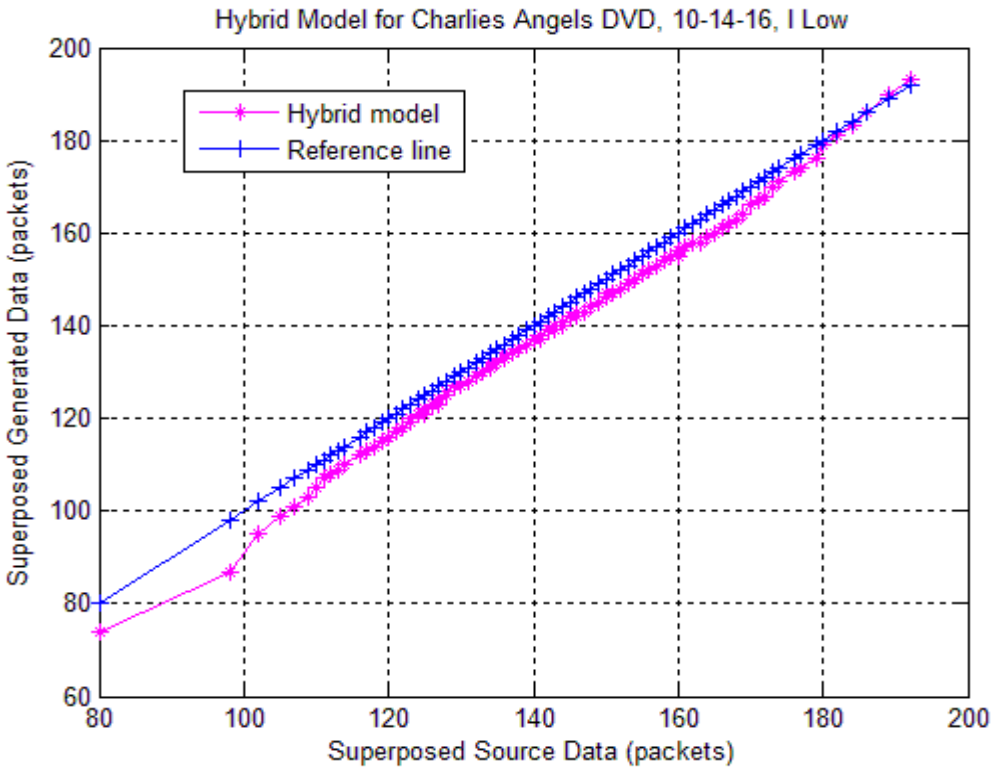

Figure 3.39 *Hybrid modeling result for trace improving with the increase in the number of sources (5 sources)*

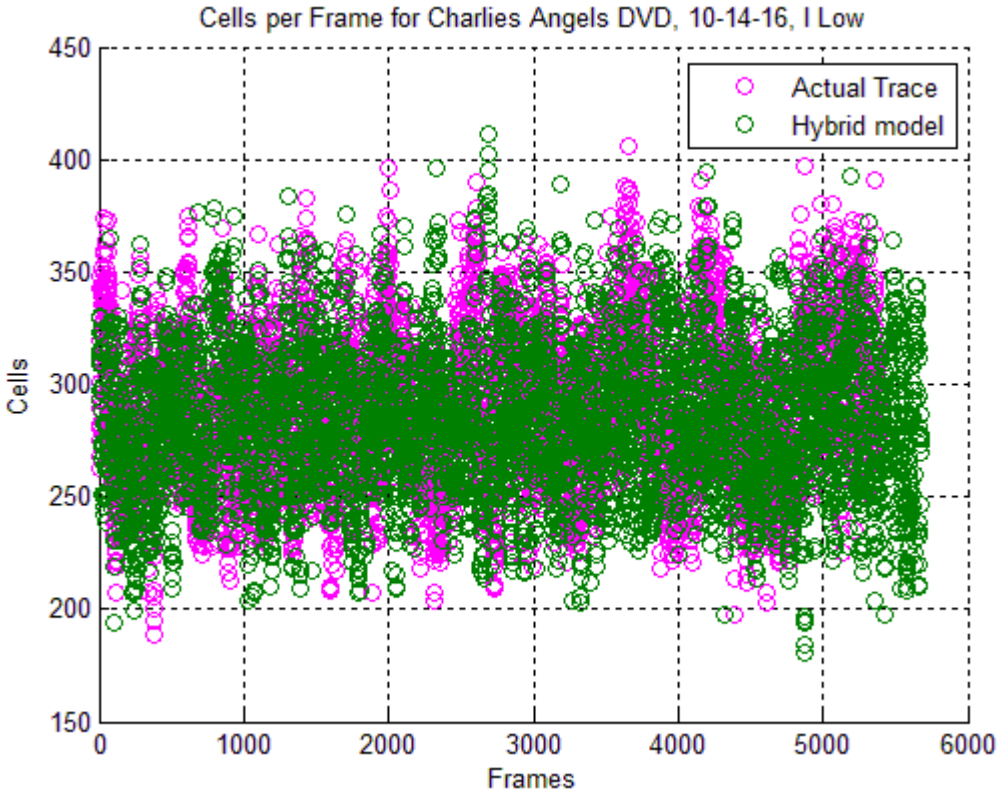

Figure 3.40 *Cells per Frame for trace improving with the increase in the number of sources (10 sources)*

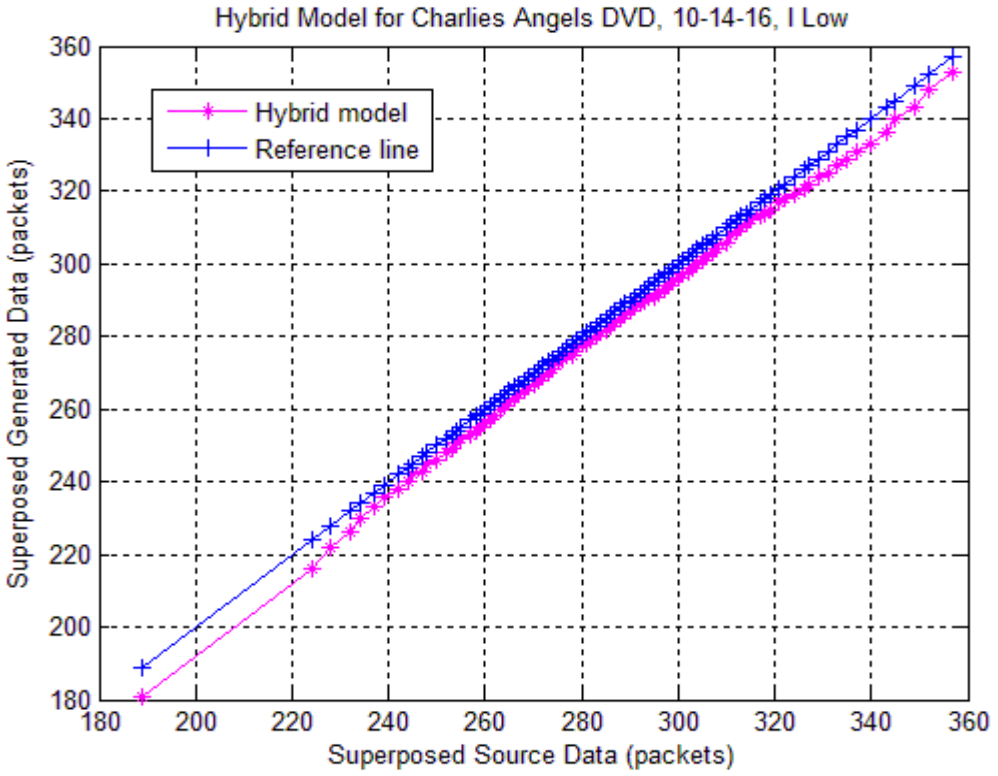

Figure 3.41 *Hybrid modeling result for trace improving with the increase in the number of sources (10 sources)*

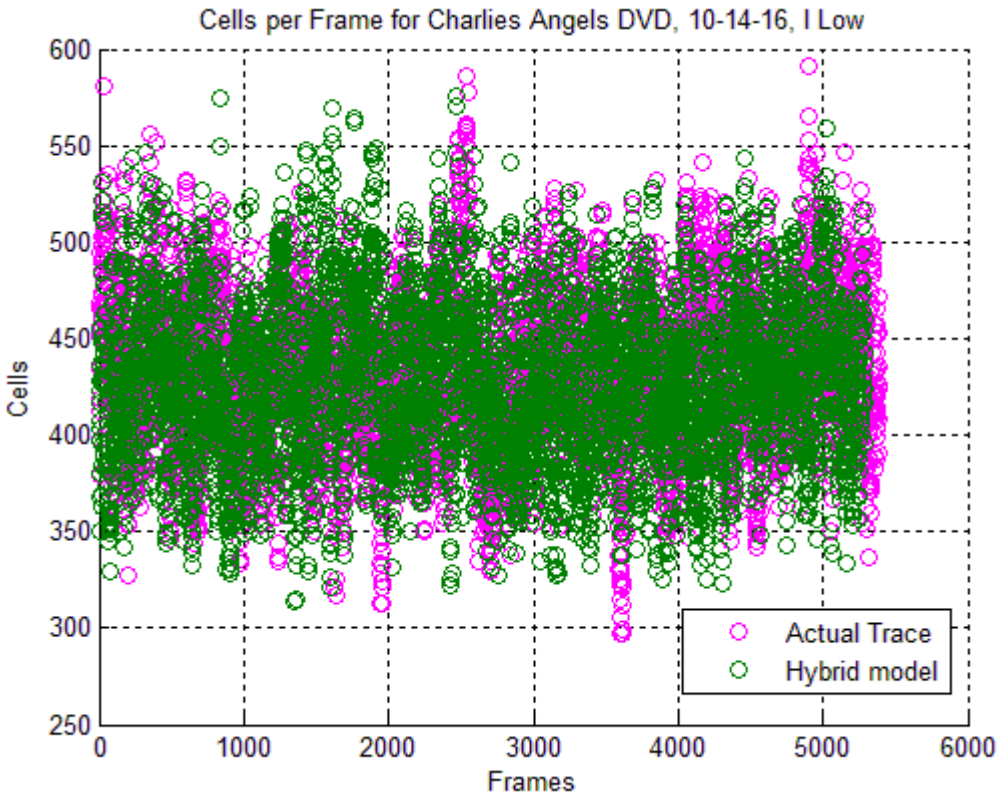

Figure 3.42 *Cells per Frame for trace improving with the increase in the number of sources (15 sources)*

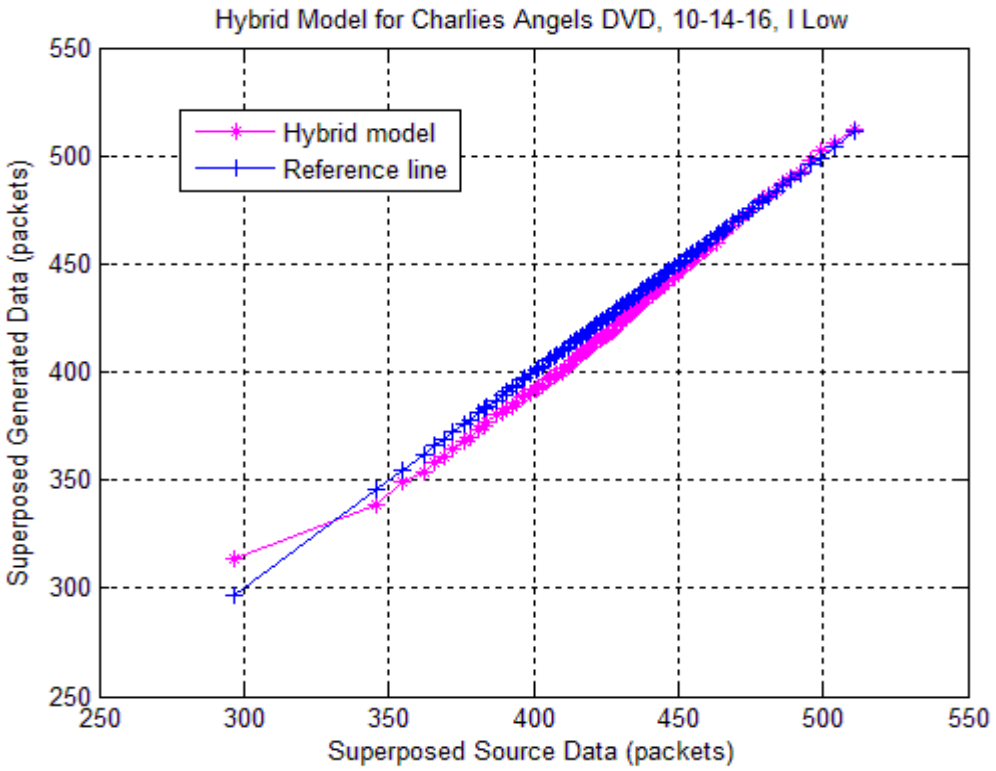

Figure 3.43 *Hybrid modeling result for trace improving with the increase in the number of sources (15 sources)*

- Deterioration Example – Lecture Reisslein 30-30-30, P frames Low activity

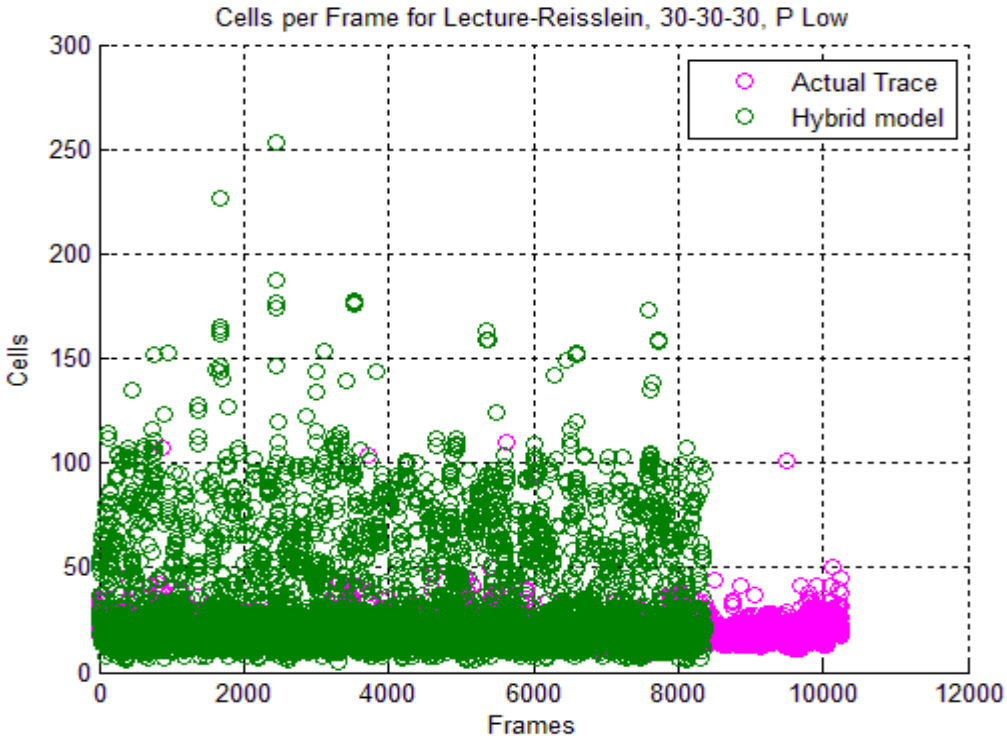

Figure 3.44 *Cells per Frame for trace deteriorating with the increase in the number of sources (5 sources)*

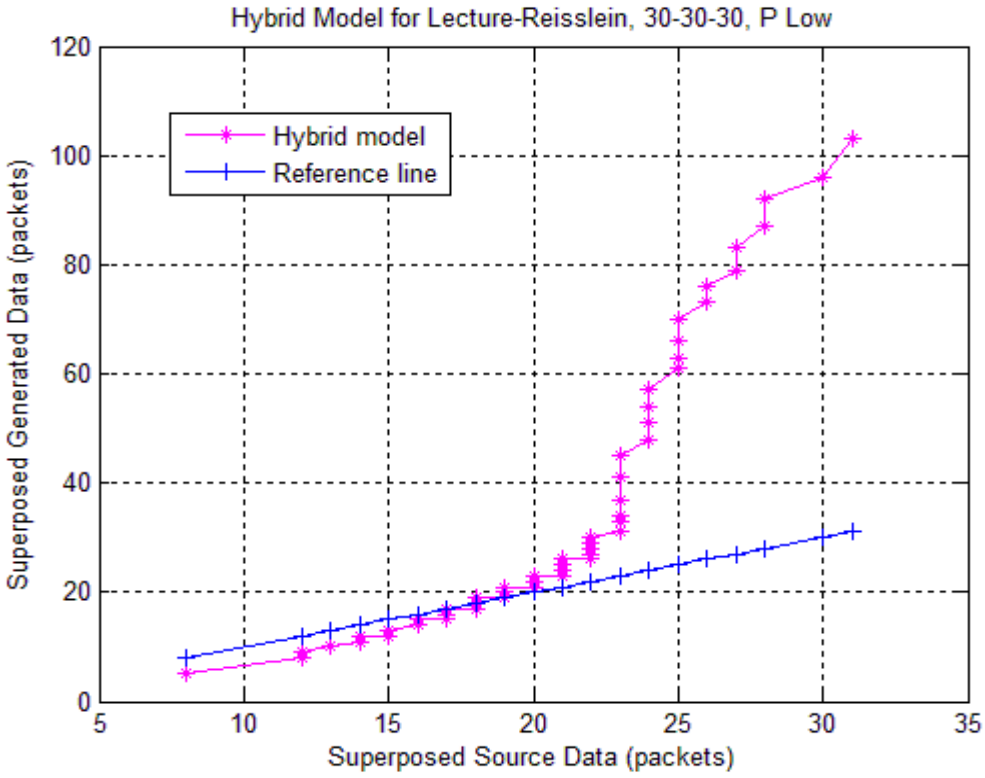

Figure 3.45 *Hybrid modeling result for trace deteriorating with the increase in the number of sources (5 sources)*

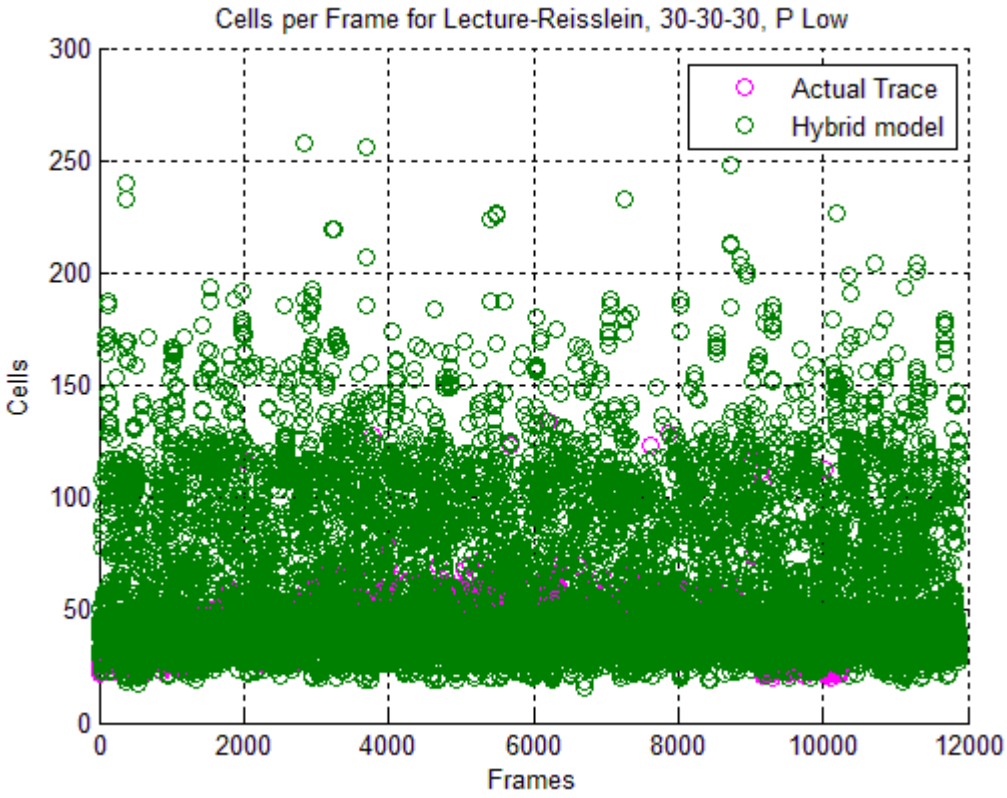

Figure 3.46 *Cells per Frame for trace deteriorating with the increase in the number of sources (10 sources)*

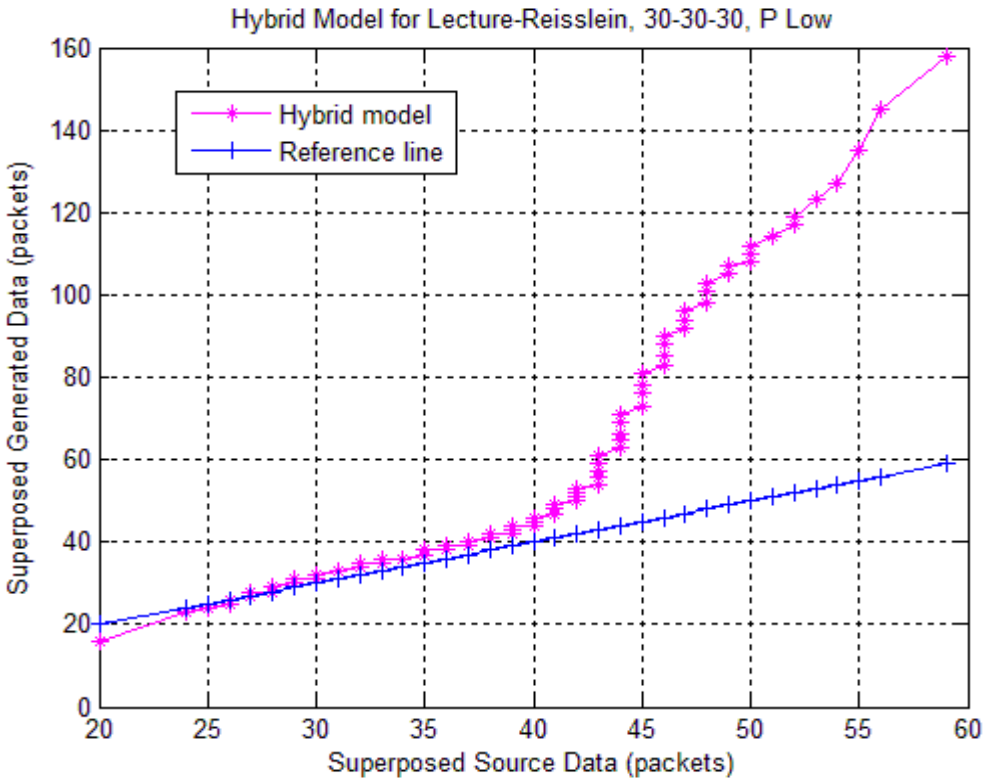

Figure 3.47 *Hybrid modeling result for trace deteriorating with the increase in the number of sources (10 sources)*

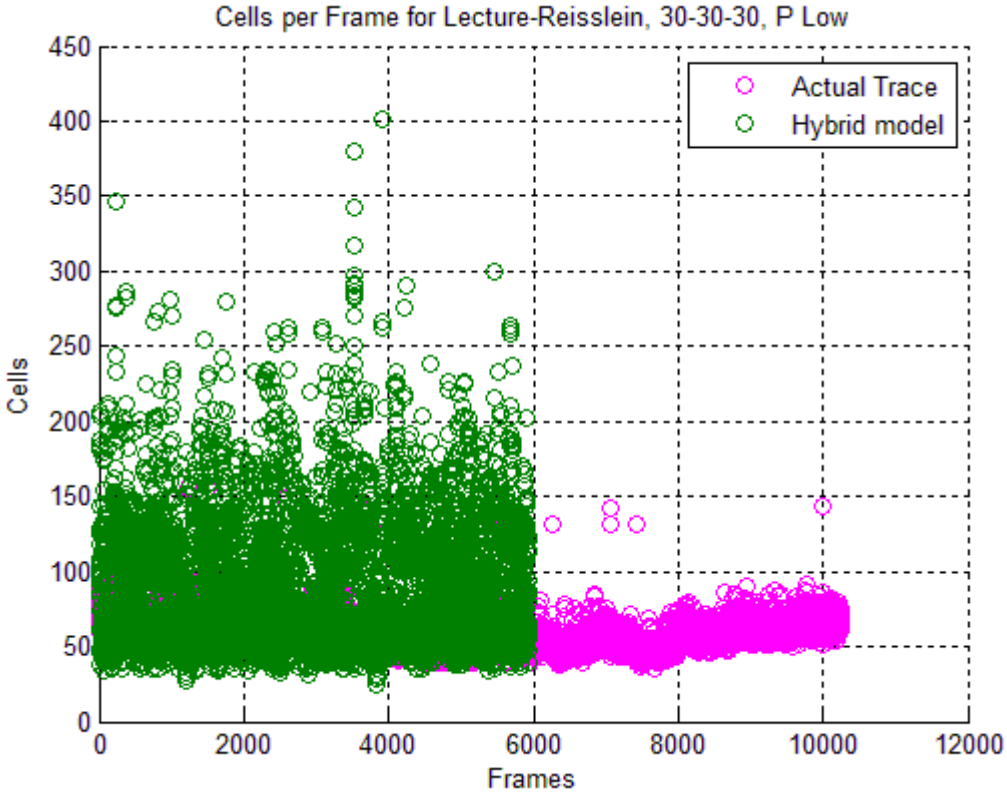

Figure 3.48 *Cells per Frame for trace deteriorating with the increase in the number of sources (15 sources)*

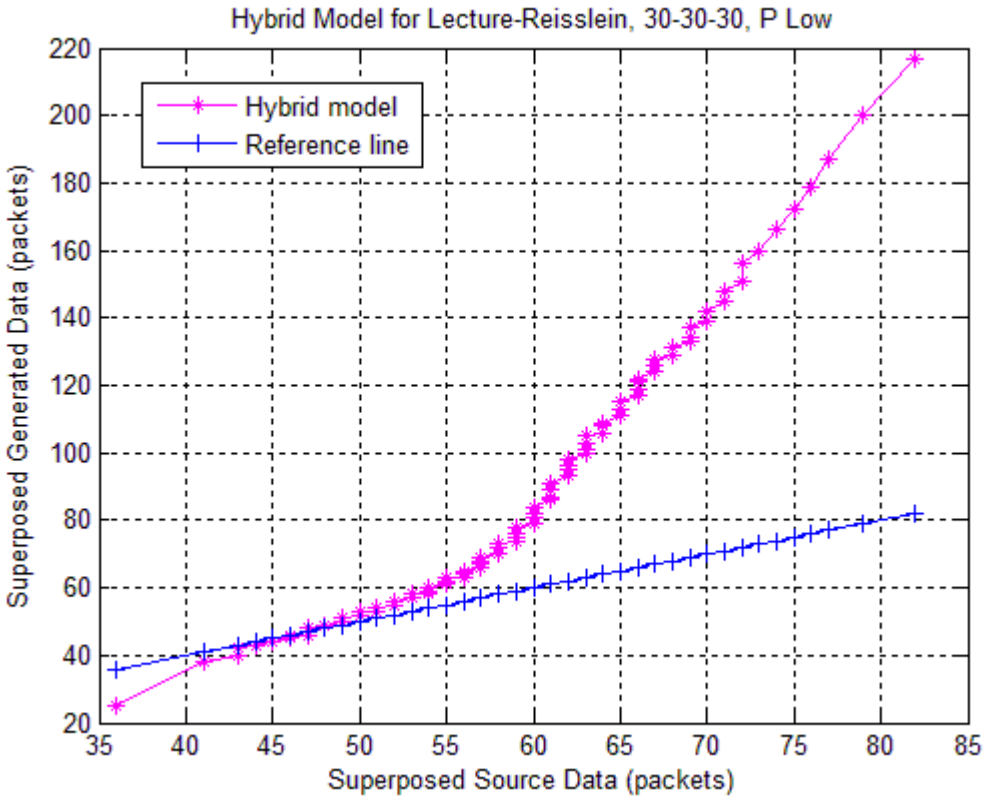

Figure 3.49 *Hybrid modeling result for trace deteriorating with the increase in the number of sources (15 sources)*

3.9 Lag-1 Autocorrelation Coefficient of Modeled Sources

In this section, we compare the autocorrelation of the actual and the modeled superposed sources. Hence, we calculate the lag-1 autocorrelation coefficient for every Low and High I, P and B actual and modeled superposition of 5, 10 and 15 sources. Our results indicate that the hybrid model "captures" sufficiently the autocorrelation of the actual sequences, for all frame types, degrees of activity and numbers of superposed sources (see Tables A.2.13-18 of the Appendix). The range of differences between the autocorrelation of the real and the modeled superpositions is shown in Table 3.15.

	5 sources			10 sources			15 sources		
Trace Type	*Min deviation*	*Max deviation*	*Average deviation*	*Min deviation*	*Max deviation*	*Average deviation*	*Min deviation*	*Max deviation*	*Average deviation*
I frames, Low	0.0000	0.0494	0.0163	0.0011	0.0624	0.0177	0.0000	0.0654	0.0160
P frames, Low	0.0007	0.1799	0.0211	0.0009	0.1459	0.0350	0.0008	0.1157	0.0254
B frames, Low	0.0001	0.2012	0.0371	0.0004	0.2640	0.0412	0.0020	0.1723	0.0368
I frames, High	0.0007	0.0525	0.0154	0.0007	0.0546	0.0159	0.0004	0.0940	0.0170
P frames, High	0.0000	0.1125	0.0247	0.0005	0.1288	0.0215	0.0012	0.1341	0.0217
B frames, High	0.0000	0.1085	0.0177	0.0001	0.1015	0.0164	0.0002	0.1682	0.0208

TABLE 3.15 – MIN, MAX AND AVERAGE DIFFERENCES IN LAG-1 AUTOCORRELATION COEFFICIENT VALUES PER TRACE TYPE AND NUMBER OF SOURCES

By using the actual and generated superposition of indicative traces, as produced by the synthetic hybrid model in section 3.10, we calculate the autocorrelation coefficient for various lags. The traces are chosen on the basis of representing almost every movie genre. Indicative examples follow in Figures 3.50 - 3.59, and will be discussed below.

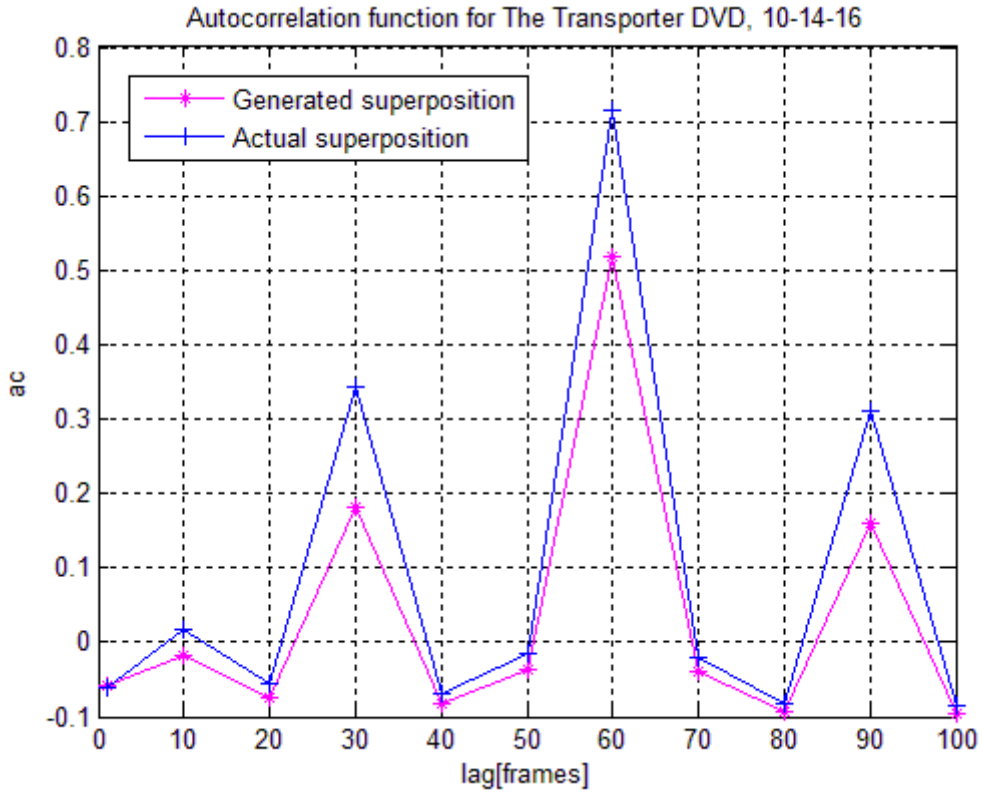

Figure 3.50 *Genre: Action (10 sources) – AC differences between actual and generated sequence less than 0.2*

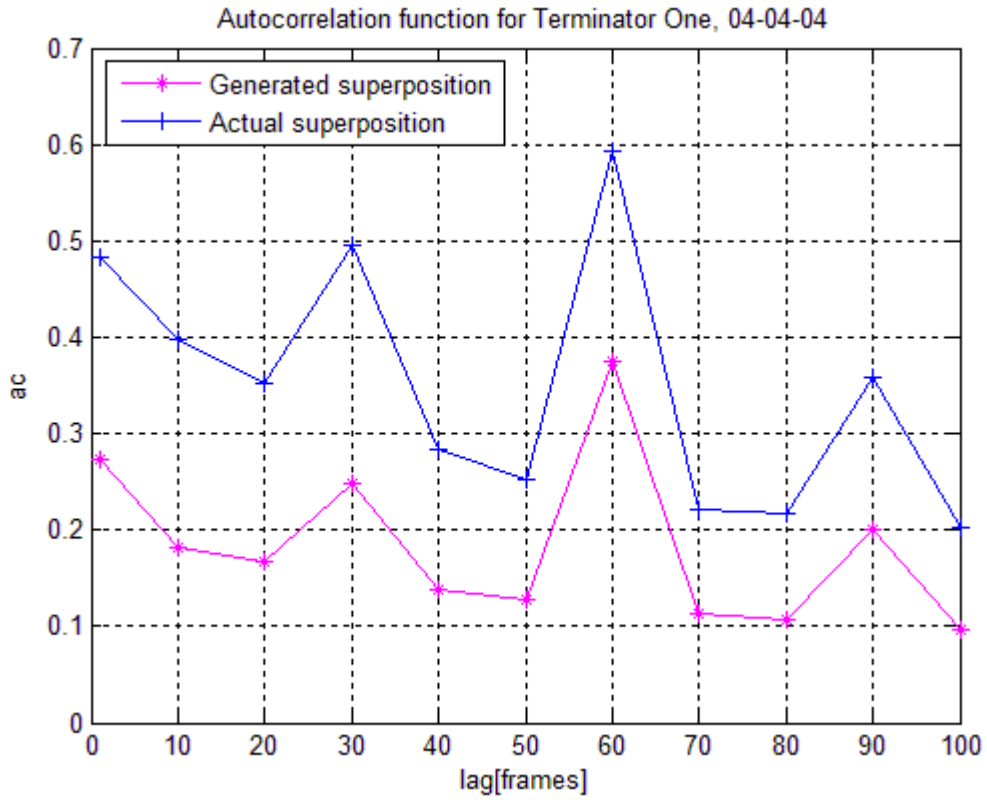

Figure 3.51 *Genre: Sci-Fi, Example: 1 (15 sources) – AC differences between actual and generated sequence less than 0.25*

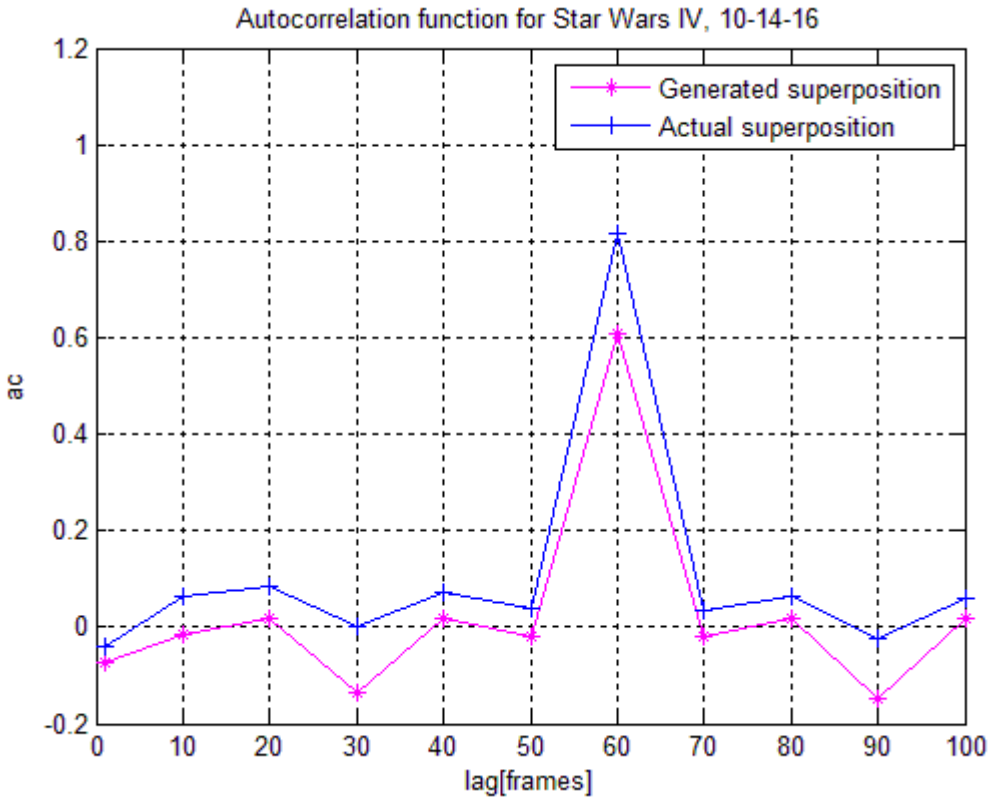

Figure 3.52 *Genre: Sci-Fi, Example: 2 (15 sources) – AC differences between actual and generated sequence less than 0.2*

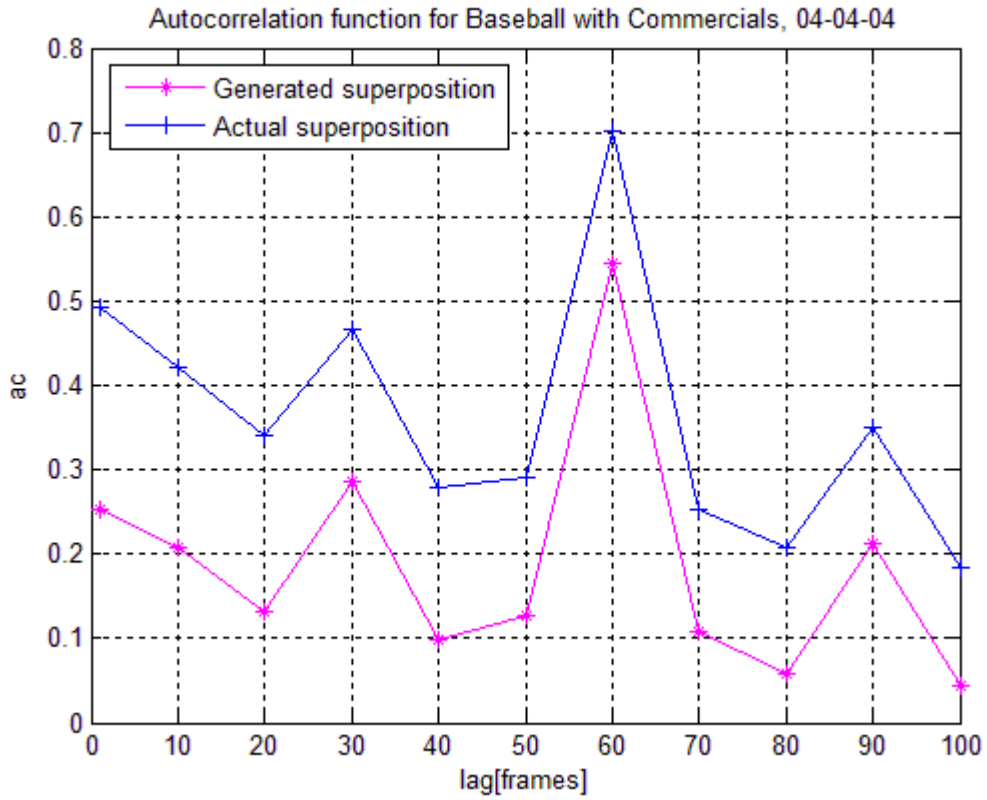

Figure 3.53 *Genre: Sports (5 sources) – AC differences between actual and generated sequence less than 0.25*

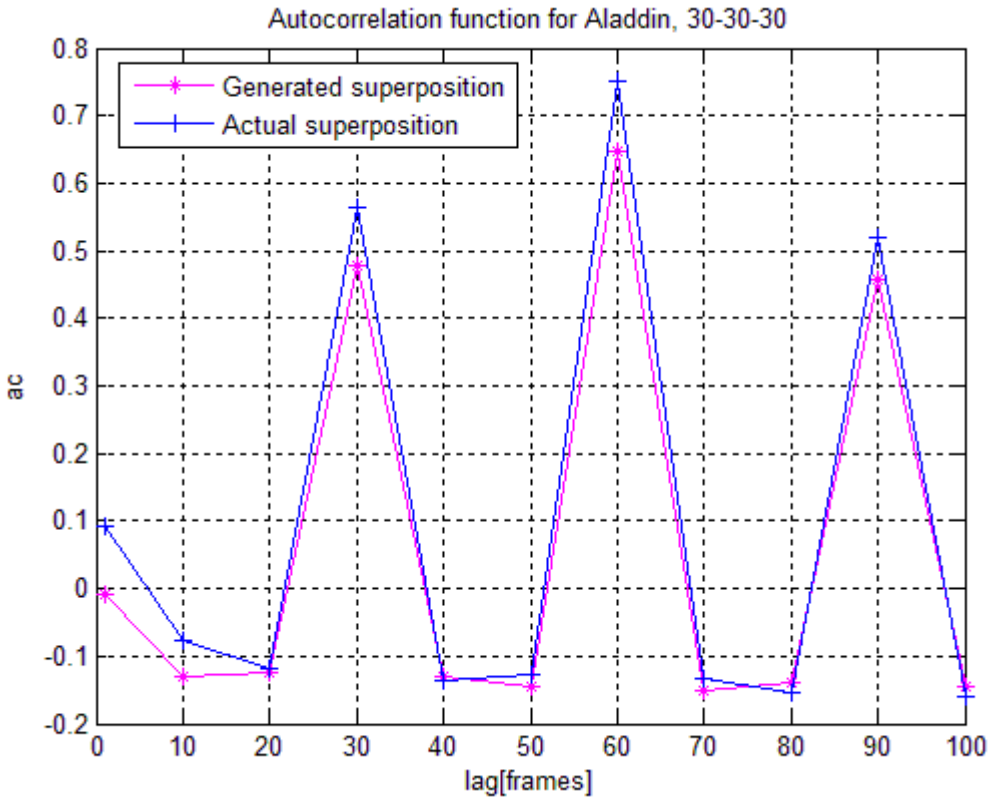

Figure 3.54 *Genre: Cartoon (10 sources) - AC differences between actual and generated sequence less than 0.1*

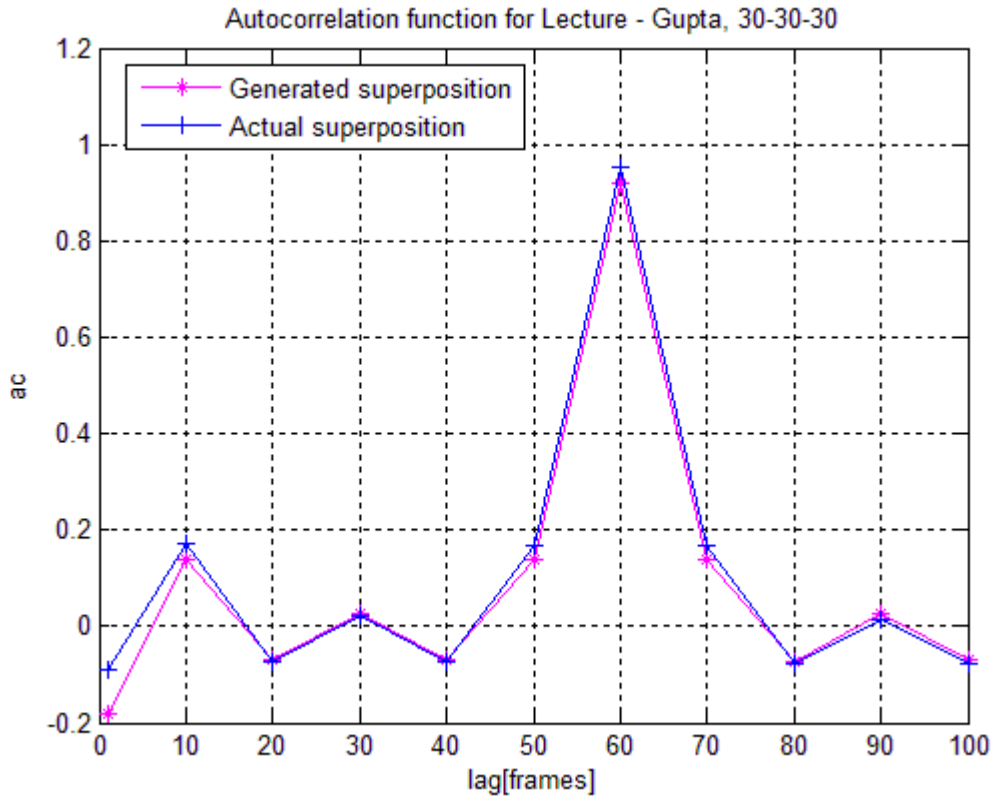

Figure 3.55 *Genre: Lecture (15 sources) - AC differences between actual and generated sequence less than 0.1*

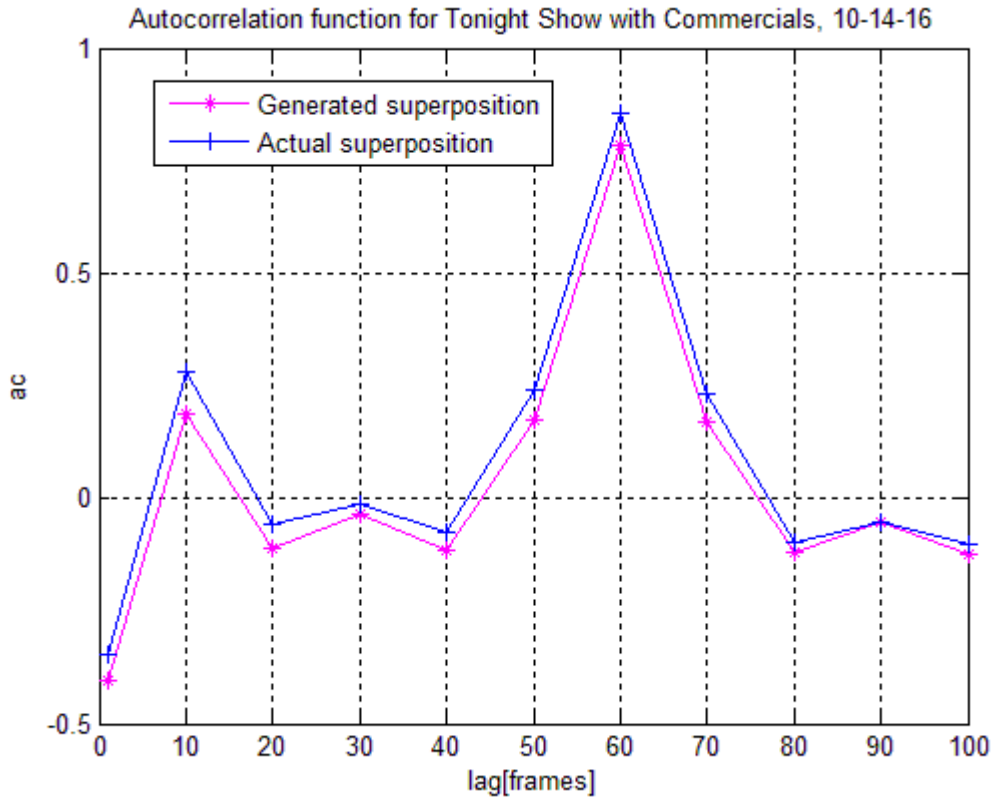

Figure 3.56 *Genre: Talk-Show, Example: 1 (5 sources) - AC differences between actual and generated sequence less than 0.1*

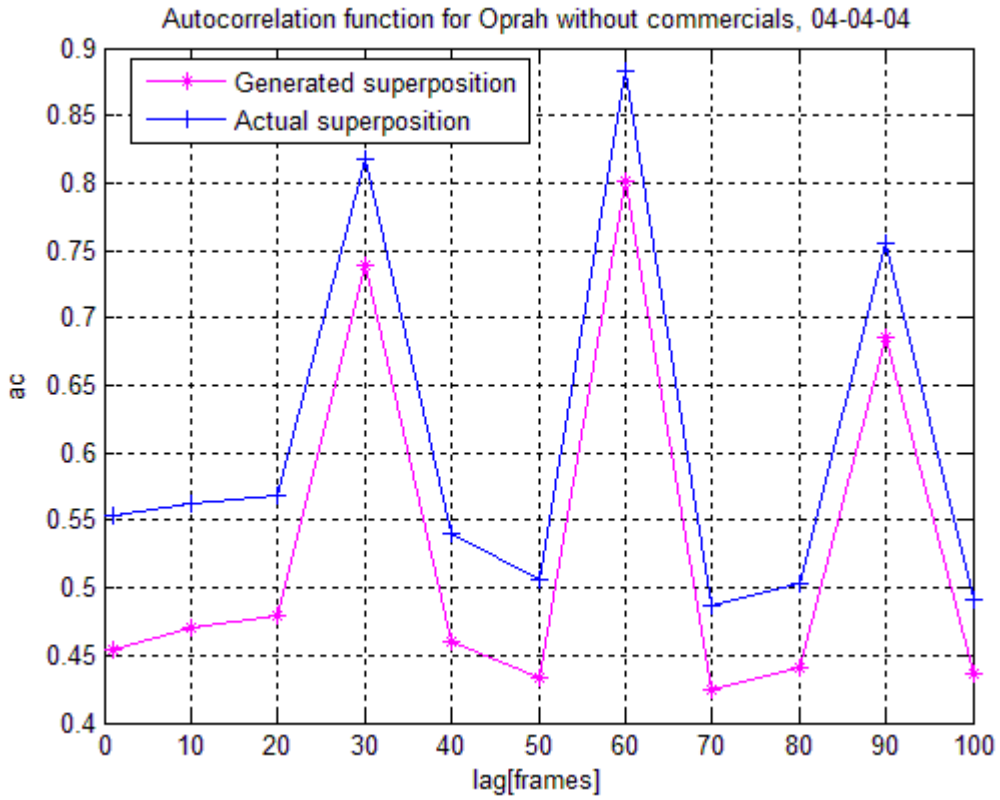

Figure 3.57 *Genre: Talk-Show, Example: 2 (5 sources) - AC differences between actual and generated sequence less than 0.1*

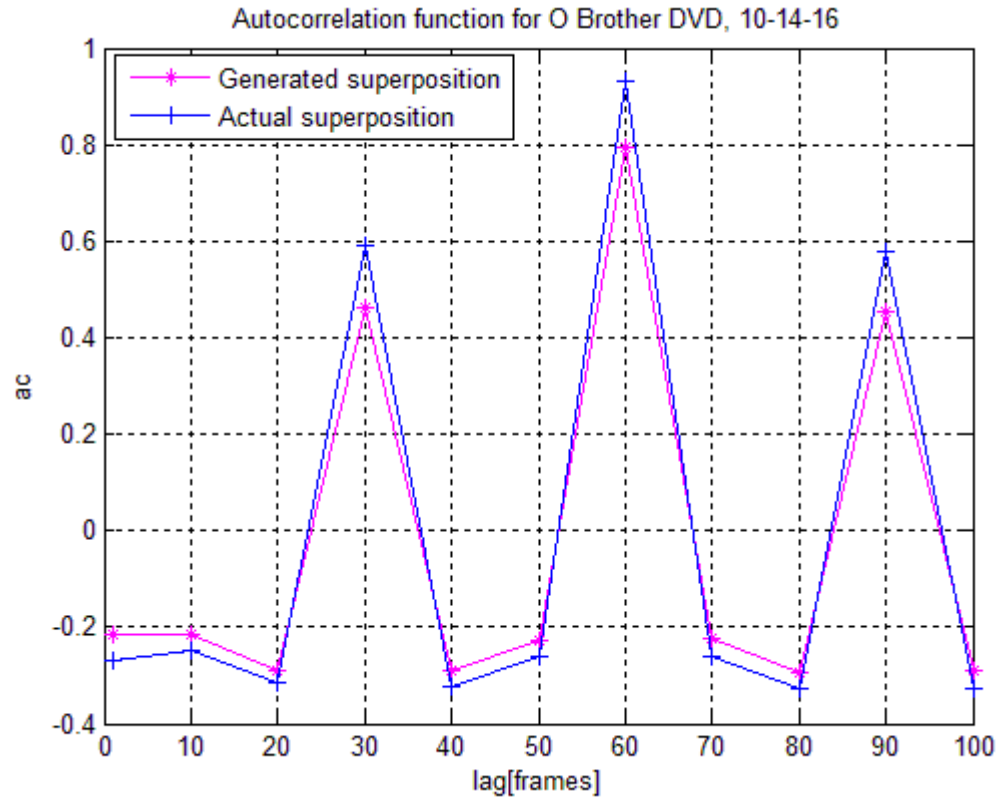

Figure 3.58 *Genre: Comedy, Example: 1 (10 sources) - AC differences between actual and generated sequence less than 0.2*

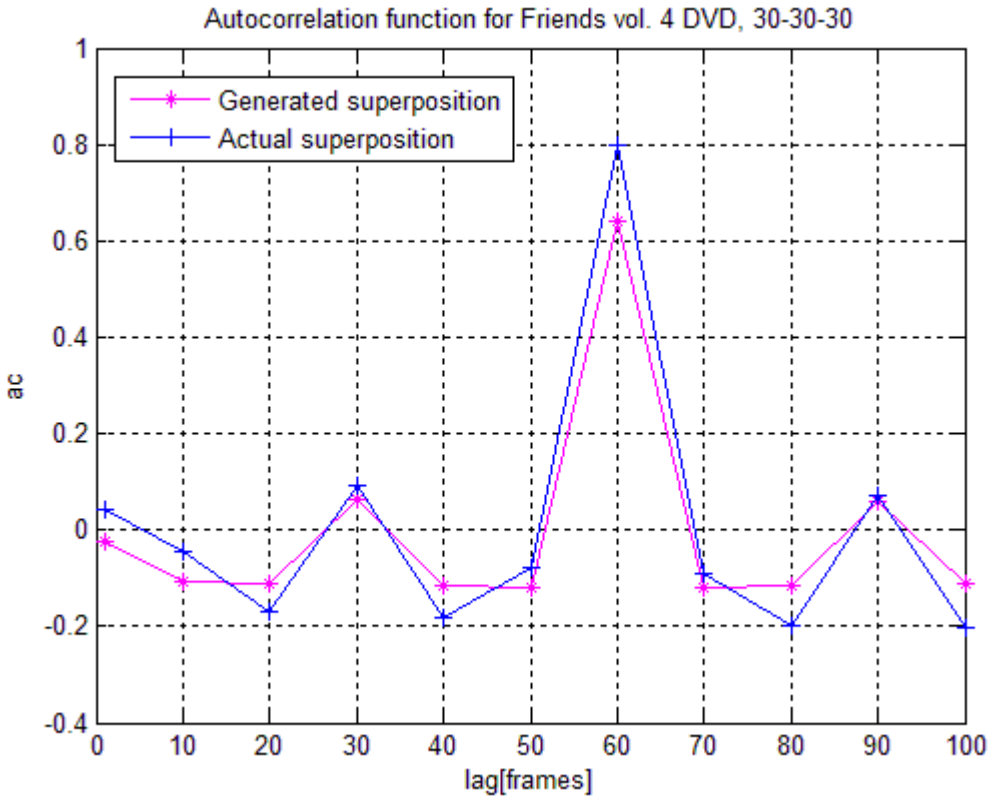

Figure 3.59 *Genre: Comedy, Example: 2 (10 sources) - AC differences between actual and generated sequence less than 0.2*

In the case of sci-fi, talk-shows and comedies, an interesting result is that for lag-30 and lag-90, the two sequences of the same genre behave differently. One sequence has a high autocorrelation coefficient value while the other has a low autocorrelation coefficient value. Also, we need to mention the importance of Long Range Dependence, as shown by the high autocorrelation for large numbers of lags.

Most importantly, the results in Figures 3.50-3.59 clearly show that our proposed model captures accurately the behavior of the autocorrelation of the superposed sources, and often achieves very close or almost identical autocorrelation values regardless of the number of lags.

3.10 Final Hybrid Modeling Results

Our results in section 3.8, on modeling I, P and B frames of Low and High activity from multiplexed sources, were a strong indication of whether the hybrid model can succeed in capturing the behavior of specific traces. However, a clear result on the feasibility of this type of modeling can only be derived by: a) generating Low and High I, P and B frame sizes according to the GoP pattern of each original trace, hence creating a model for a single trace, and b) superposing a number of the generated traces (5, 10 and 15 in our work) and assessing the modeling results via statistical tests (we used Q-Q plots).

In the cases that one or more of the six frame type sequences of a trace was excluded from the modeling of section 3.8, the specific movie was not examined in this part of our work (see Table 3.16).

Excluded Traces
Silence of the Lambs, 10-14-16
Terminator One, 10-14-16
Tonight Show without Commercials, 30-30-30
Tonight Show without Commercials, 10-14-16
Tonight Show without Commercials, 04-04-04
Lecture – Reisslein, 10-14-16
Lecture – Reisslein, 04-04-04
Tokyo Olympics DVD, 10-14-16
O Brother DVD, 30-30-30
Ice Age DVD, 10-14-16
Ice Age DVD, 04-04-04

TABLE 3.16 – TRACES EXCLUDED FROM FINAL HYBRID MODELING

Hence, we evaluated the hybrid model via 52 Q-Q plots (the synthetic model in section 2.4 produced 8 Q-Q plots less). Most of them showed mediocre modeling results (32 in total), along with 17 good and 3 bad ones. Tables 3.17 and 3.18 below confirm the fact that the hybrid model performs better than the DAR(1), as to the number and percentage of its good and bad modeling results. Indicative examples follow in Figures 3.60 - 3.62.

	DAR(1) Model	Hybrid Model
Good Results	7	17
Mediocre Results	25	32
Bad Results	12	3
Total	44	52

TABLE 3.17 – COMPARING THE DAR(1) AND THE HYBRID MODEL WITH PLAIN NUMBERS

	DAR(1) Model	Hybrid Model
Good Results	15.91%	32.69%
Mediocre Results	56.82%	61.54%
Bad Results	27.27%	5.77%
Total	100%	100%

TABLE 3.18 – COMPARING THE DAR(1) AND THE HYBRID MODEL WITH PERCENTAGES

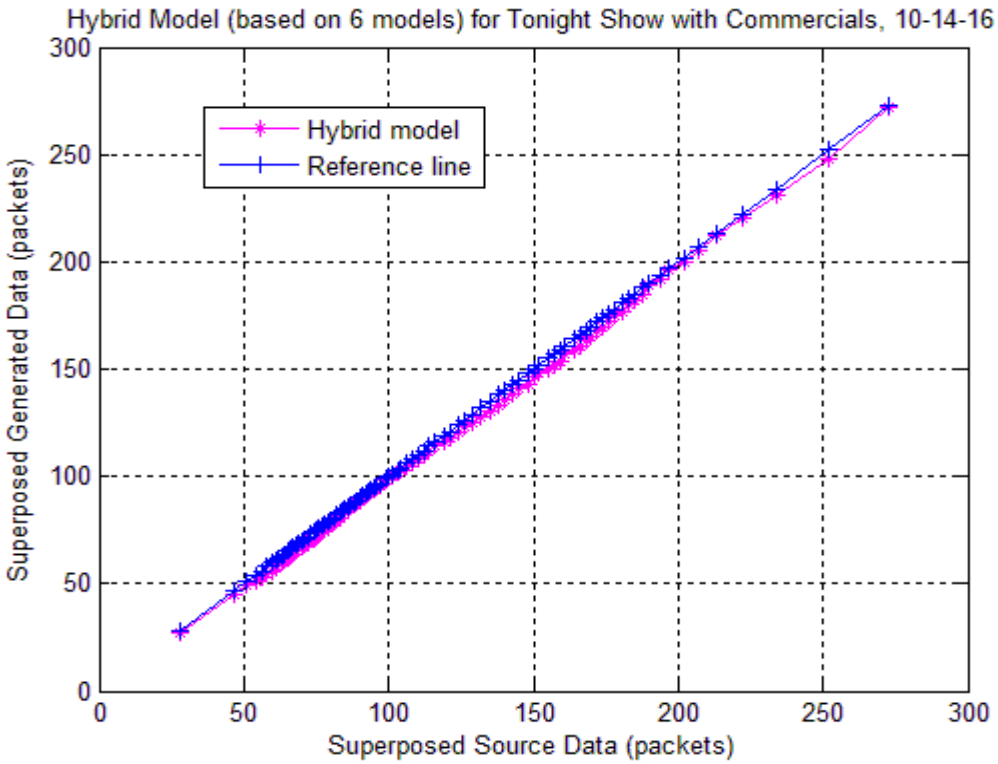

Figure 3.60 *Good hybrid modeling result (5 sources)–*
Movie Burstiness = 9.2541, ρ = -0.0657

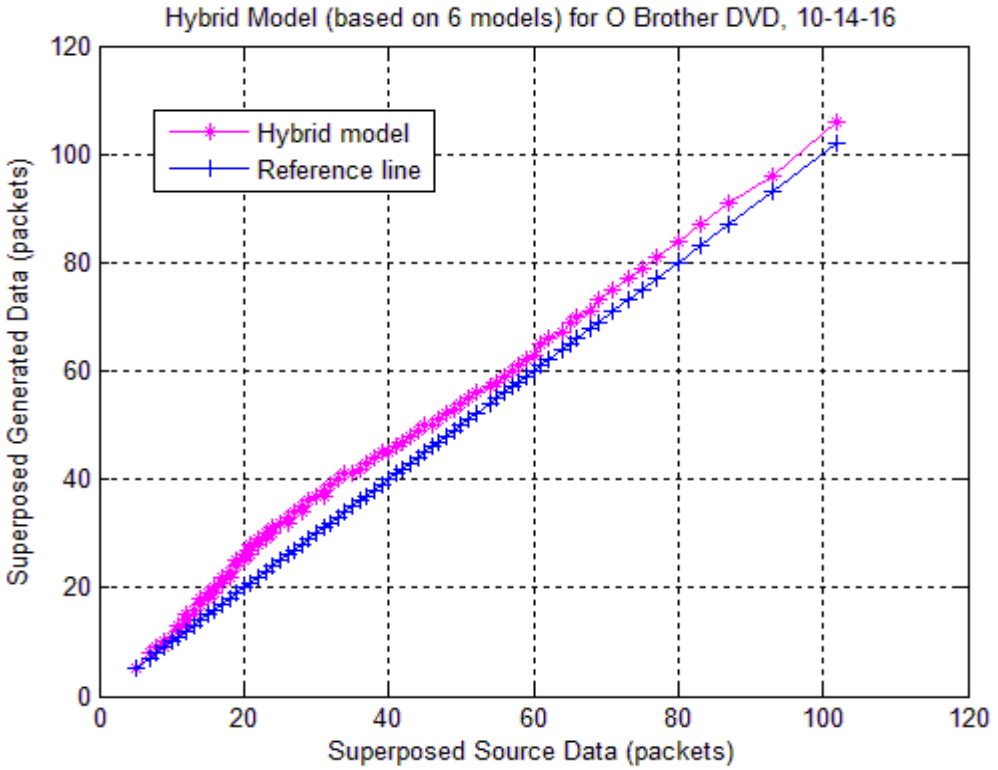

Figure 3.61 *Mediocre hybrid modeling result (5 sources)–*
Movie Burstiness = 16.5323, ρ = -0.0375

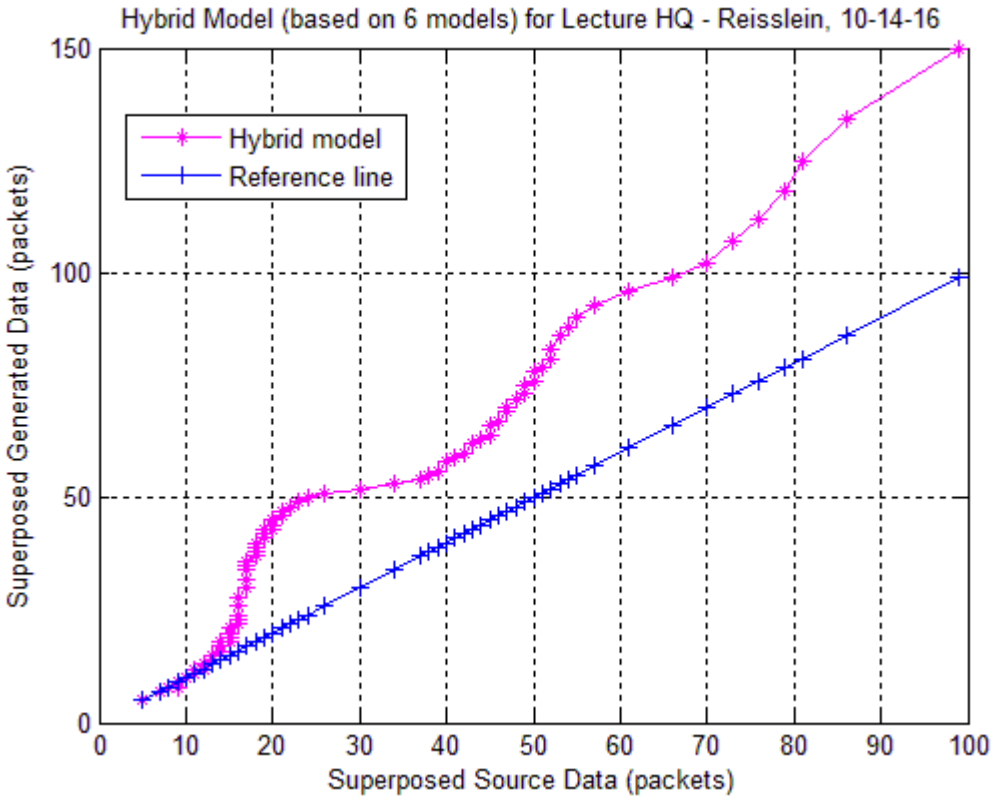

Figure 3.62 *Bad hybrid modeling result (5 sources)–*
Movie Burstiness = 17.3022, ρ = -0.0472

An interesting observation is that the majority of the 30-30-30 quantization scale traces modeled (18 out of 19) are associated with mediocre modeling results. Also, the majority of the 04-04-04 quantization scale traces modeled are classified as good (7 out of 18) and mediocre (9 out of 18) modeling results. Similarly, most of the 10-14-16 quantization scale traces are classified as good (9 out of 15) and mediocre (5 out of 15) hybrid modeling results.

As previously mentioned in section 2.4, in the majority of the cases under study, the 04-04-04 movies have the highest autocorrelation coefficient (between -0.01 and 0.75) while the 10-14-16 movies have the lowest autocorrelation coefficient (between -0.08 and 0.06). The 30-30-30 movies are usually in between (between -0.04 and 0.26). For most of the cases, the 04-04-04 movies present the lowest burstiness (between 2.99 and 12.24) whereas the 10-14-16 movies present the highest burstiness (between 9.25 and 25.39). The 30-30-30 movies are usually in the middle, in terms of burstiness (between 6.41 and 17.33).

To sum up, this model provides relative accuracy for traces with mediocre burstiness and a lag-1 autocorrelation coefficient of moderate value. This is also the case for many traces of low burstiness and high autocorrelation. On the other hand, the synthetic hybrid model provides high accuracy for many traces of high burstiness and low autocorrelation and for some traces of low burstiness and high autocorrelation. As to in which cases the model performs badly, we cannot draw a clear conclusion. However, the cases in which the model provides low accuracy results are very limited (only 3). Hence, the proposed hybrid model seems to be working well for most of the traces, and most importantly, the synthetic model is shown to be much more than the

sum of its parts, given that its results are better than the individual results for I, P and B frames. *This means that the overestimations and underestimations that take place in most of the "mediocre" separate results for I, P, and B frames even each other out to provide a synthetic trace of multiplexed traffic quite close to the real one.*

Finally, we need to mention that when the number of superposed sources increases (from 5 to 10 and from 10 to 15), most of the initial results for 5 sources remain unaffected or deteriorate. The majority of the initially good modeling results remain good with the increase of sources in the superposition. For the results initially classified as mediocre or bad, the addition of sources undermines the model's accuracy in most cases. Improvements in the modeling results are rare to observe. Even for the initially good modeling cases, one cannot generally claim that the model constantly improves for a superposition of more sources and this is a result that does not coincide with the DAR(1) results in [2]; there are cases (for instance, Terminator One 30-30-30, Lecture - HQ Reisslein 04-04-04 and Die Another Day DVD 10-14-16) where the opposite occurs. Indicative examples are displayed below.

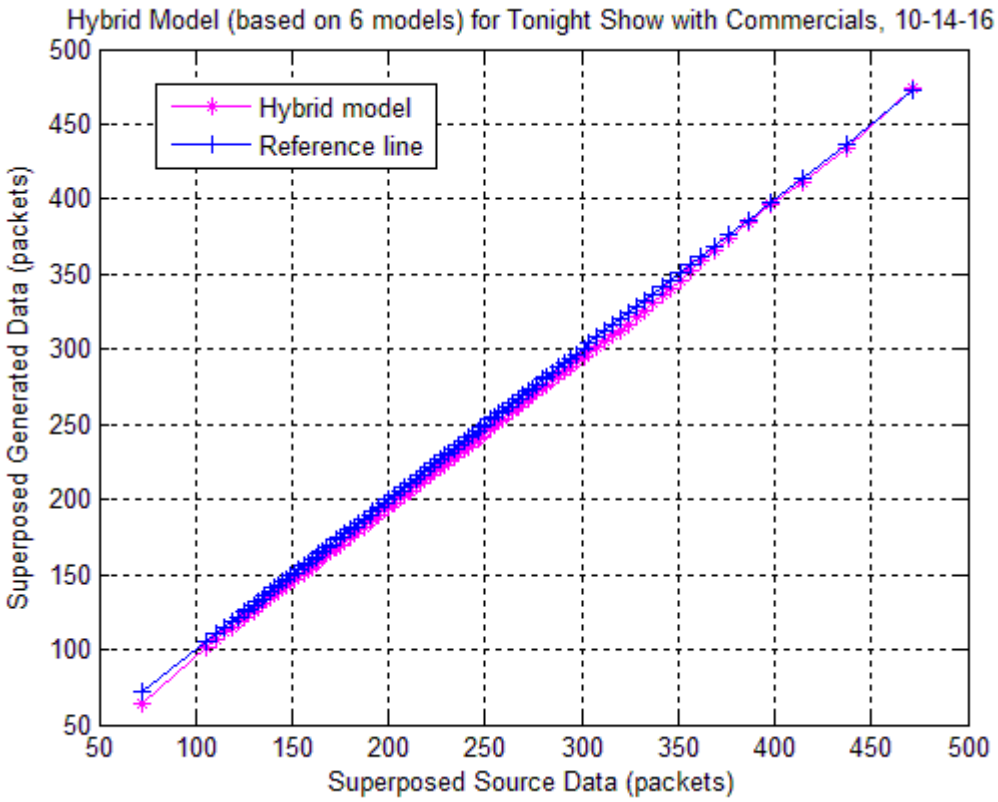

Figure 3.63 *Initially good hybrid modeling result remains unaffected (10 sources)– Movie Burstiness = 9.2541, ρ = -0.0657*

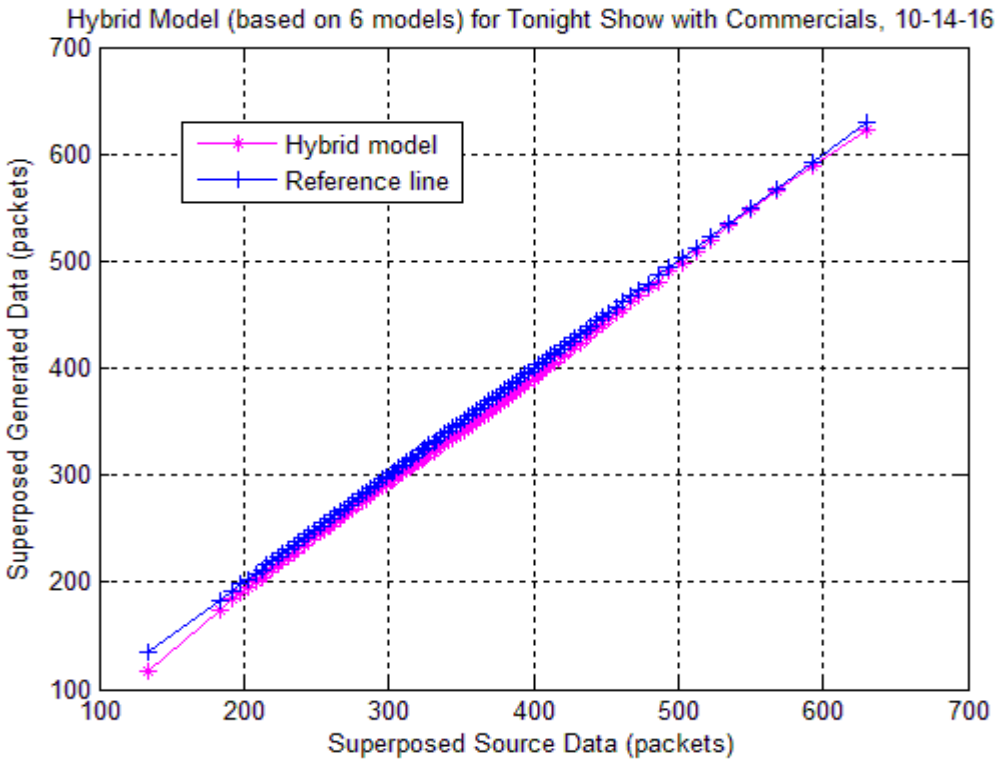

Figure 3.64 *Initially good hybrid modeling result remains unaffected (15 sources)– Movie Burstiness = 9.2541, ρ = -0.0657*

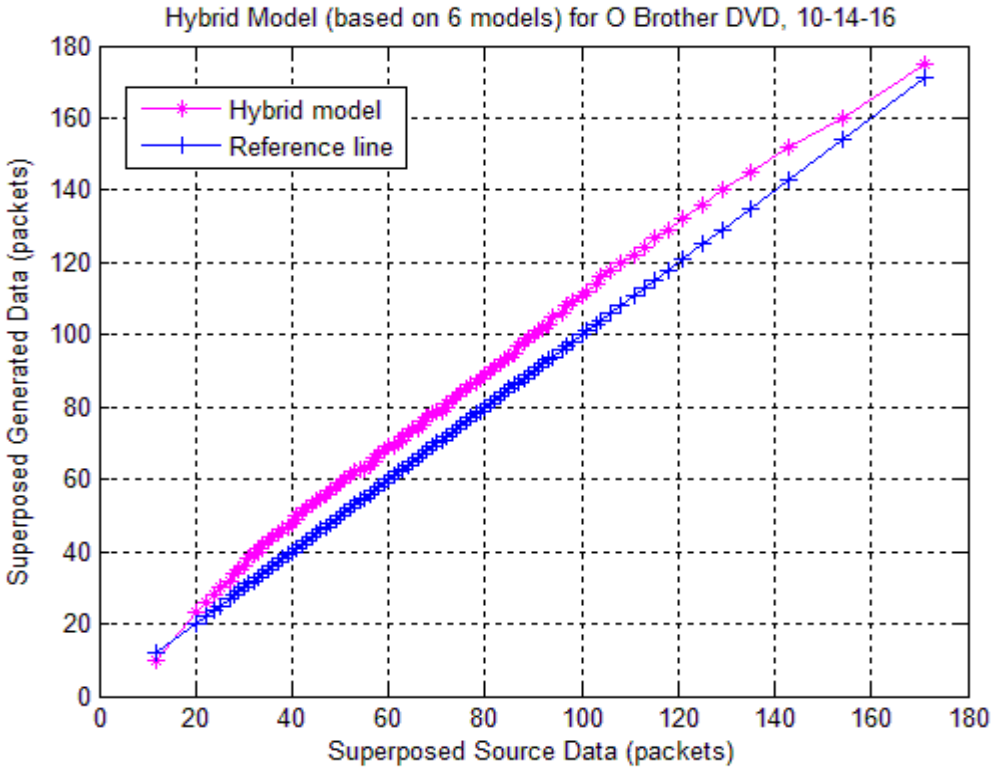

Figure 3.65 *Initially mediocre hybrid modeling result deteriorates (10 sources)– Movie Burstiness = 16.5323, ρ = -0.0375*

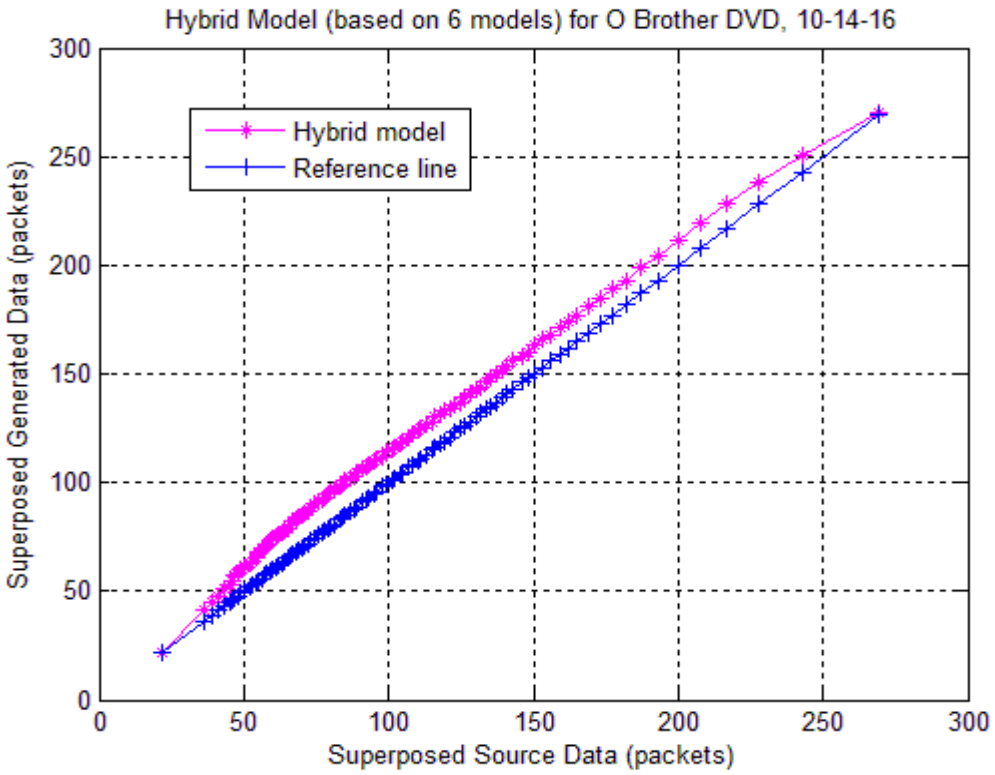

Figure 3.66 *Initially mediocre hybrid modeling result deteriorates (15 sources)– Movie Burstiness = 16.5323, ρ = -0.0375*

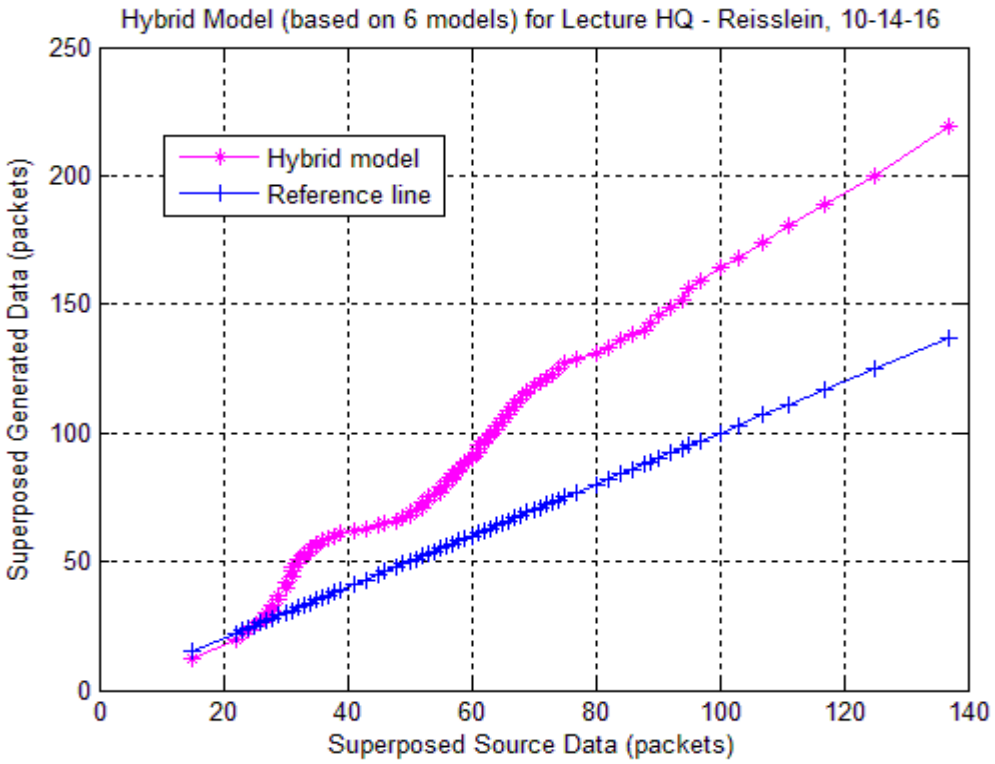

Figure 3.67 *Initially bad hybrid modeling result deteriorates (10 sources)– Movie Burstiness = 17.3022, ρ = -0.0472*

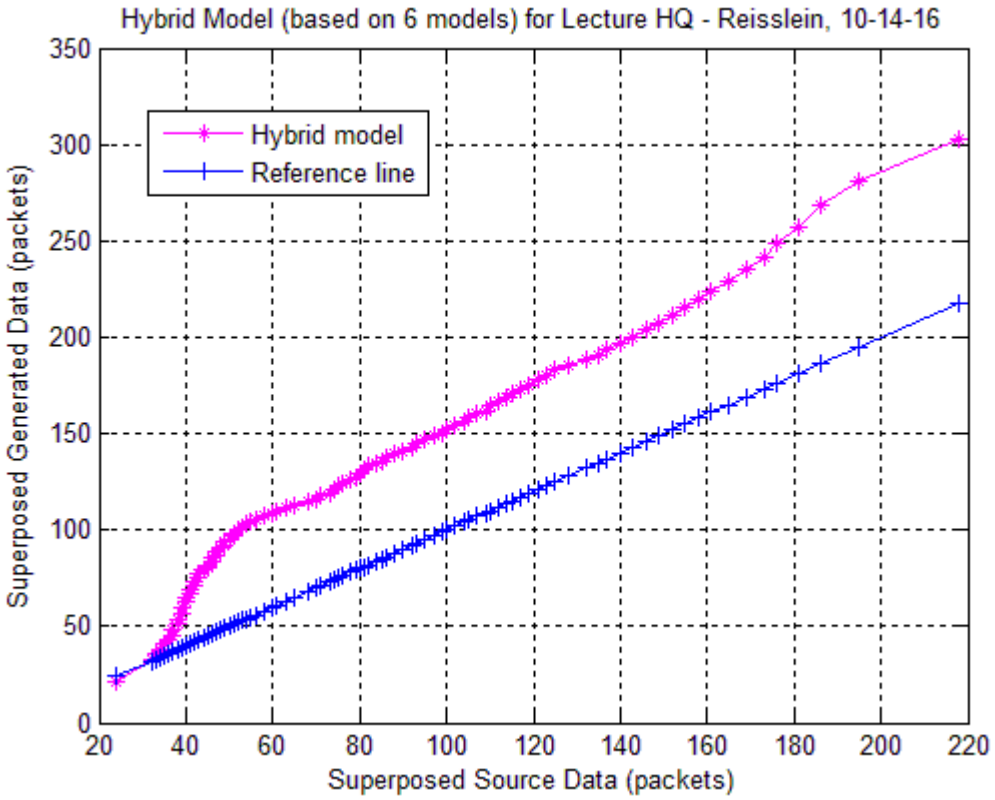

Figure 3.68 *Initially bad hybrid modeling result deteriorates (15 sources)– Movie Burstiness = 17.3022, ρ = -0.0472*

4. A VARIATION OF THE HYBRID MODEL

In this section, we present a variation of the hybrid model introduced in 3. Here, we do not study the P and B frames one by one, as previously done, but instead, we study the sum of their sizes per high or low activity scene. The reason for this approach is that we want to evaluate a possible modeling solution which is of even lower computational complexity than the hybrid model, for possible use in solving networking problems.

4.1 Scene Identification and Scene Classification

The scene identification and scene classification processes are identical to the ones presented in Sections 3.1 and 3.2.

4.2 Determining Best Fit

In order to derive the best distribution fit, we first consult the Q-Q plot test. If a conclusion can be clearly reached, we consider that distribution as the best fit; otherwise we use the respective result of the KL-test.

4.3 The Scene-Based Markov Chain Model

The scene-based Markov chain model, which determines scene succession, i.e. transitions from high to low activity scenes and vice versa, is identical to the one presented in Section 3.4.

4.4 Packets per Scene Generation

In order to determine the number of P and B frames' packets per scene for each high and low activity trace under study, we calculate the DAR(1) transition probabilities based on each trace's best distribution fit, and we run the DAR(1) model. This model generates an average sum of the P and B frames' sizes per scene for each high and low activity trace, which we then multiply by each trace's average number of P and B frames per scene, in order to derive the total sum of the P and B frames' sizes for every scene. This implementation is easily manageable, as opposed to the one generating the total size of P and B frames per high or low activity scene directly (the number of states in the model can be of hundreds of thousands).

Our results are presented in the form of Q-Q plots and correspond to a superposition of 5, 10 and 15 sources. Most traces' frame sizes are modeled in the form of packets of 200 Bytes, however all the 30-30-30 and some 10-14-16 traces are modeled as packets of 48 Bytes.

4.5 Best Fit Results

In this section, we present the statistical data corresponding to the part of our work focusing on finding the best distribution fit. A discussion on the results of this part follows.

Distribution	Corresponding Percentage
Exponential	3.17%
Gamma	7.94%
Lognormal	55.56%
Weibull	19.05%
Pearson V	2.38%
Geometric	4.76%
Negative Binomial	0.79%

TABLE 4.1 - Q-Q PLOTS' CUMULATIVE RESULTS FOR BEST FIT

Distribution	Percentage for *P/B frames, Low*	Percentage for *P/B frames, High*
Exponential	4.76%	1.59%
Gamma	9.52%	6.35%
Lognormal	44.44%	66.67%
Weibull	20.63%	17.46%
Pearson V	0.00%	4.76%
Geometric	7.94%	1.59%
Negative Binomial	1.59%	0.00%

TABLE 4.2 - Q-Q PLOTS' DETAILED RESULTS FOR BEST FIT

Distribution	Corresponding Percentage
Exponential	17.46%
Gamma	0.00%
Lognormal	42.86%
Weibull	2.38%
Pearson V	0.00%
Geometric	11.11%
Negative Binomial	26.19%

TABLE 4.3 – KL TESTS' CUMULATIVE RESULTS FOR BEST FIT

Distribution	Percentage for *P/B frames, Low*	Percentage for *P/B frames, High*
Exponential	20.63%	14.29%
Gamma	0.00%	0.00%
Lognormal	44.44%	41.27%
Weibull	3.17%	1.59%
Pearson V	0.00%	0.00%
Geometric	6.35%	15.87%
Negative Binomial	25.40%	26.98%

TABLE 4.4 – KL TESTS' DETAILED RESULTS FOR BEST FIT

Distribution	Percentage for *P/B frames, Low*	Percentage for *P/B frames, High*	Cumulative Percentage
Exponential	7.94%	1.59%	4.76%
Gamma	9.52%	6.35%	7.94%
Lognormal	50.79%	68.25%	59.52%
Weibull	22.22%	17.46%	19.84%
Pearson V	0.00%	4.76%	2.38%
Geometric	7.94%	1.59%	4.76%
Negative Binomial	1.59%	0.00%	0.79%

TABLE 4.5 – BEST DISTRIBUTION FIT PERCENTAGES PER TRACE TYPE

	Percentage for *P/B frames, Low*	Percentage for *P/B frames, High*	Cumulative Percentage
Q-Q plot	88.89%	98.41%	93.65%
KL test	11.11%	1.59%	6.35%

TABLE 4.6 – PERCENTAGE PER TRACE TYPE OF TEST CHOSEN TO DETERMINE THE BEST DISTRIBUTION FIT

4.5.1 Low Activity Scenes

In this section, we focus on the Q-Q plot fittings corresponding to the P/B frames of the low-activity scenes of the traces examined. The negative binomial distribution is the worst fit among all distributions used. The same applies to the case of the high-activity scene traces, as well. We present indicatively some of our results in Figures 4.1, 4.2 and 4.3.

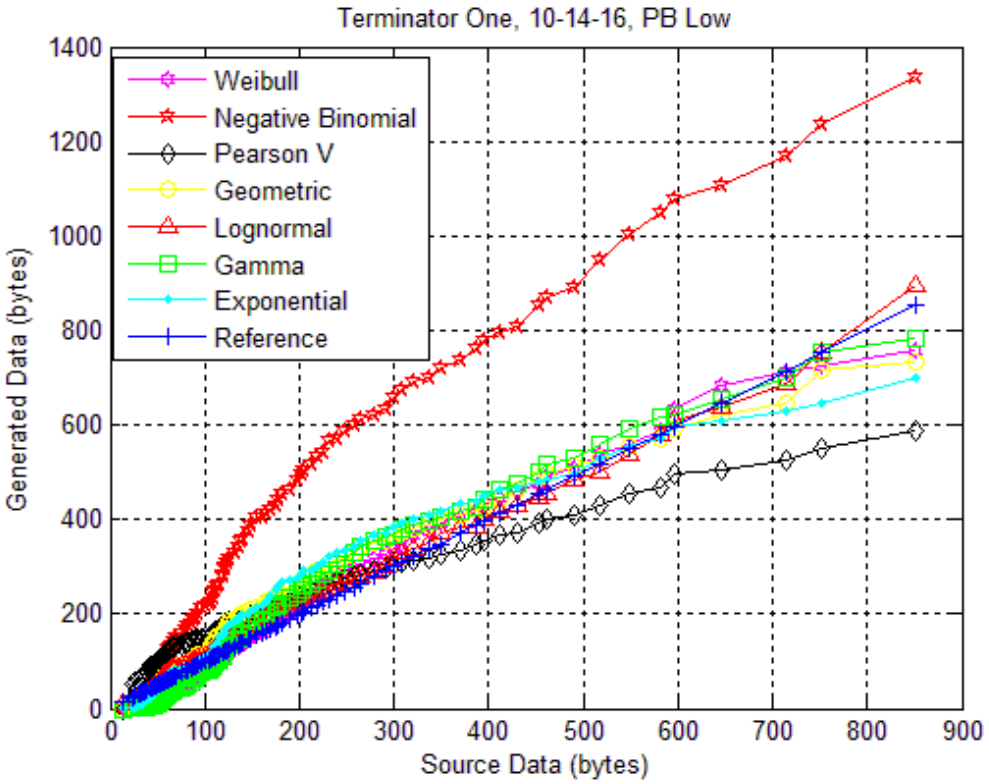

Figure 4.1 *Good fitting, P/B frames, Low activity*

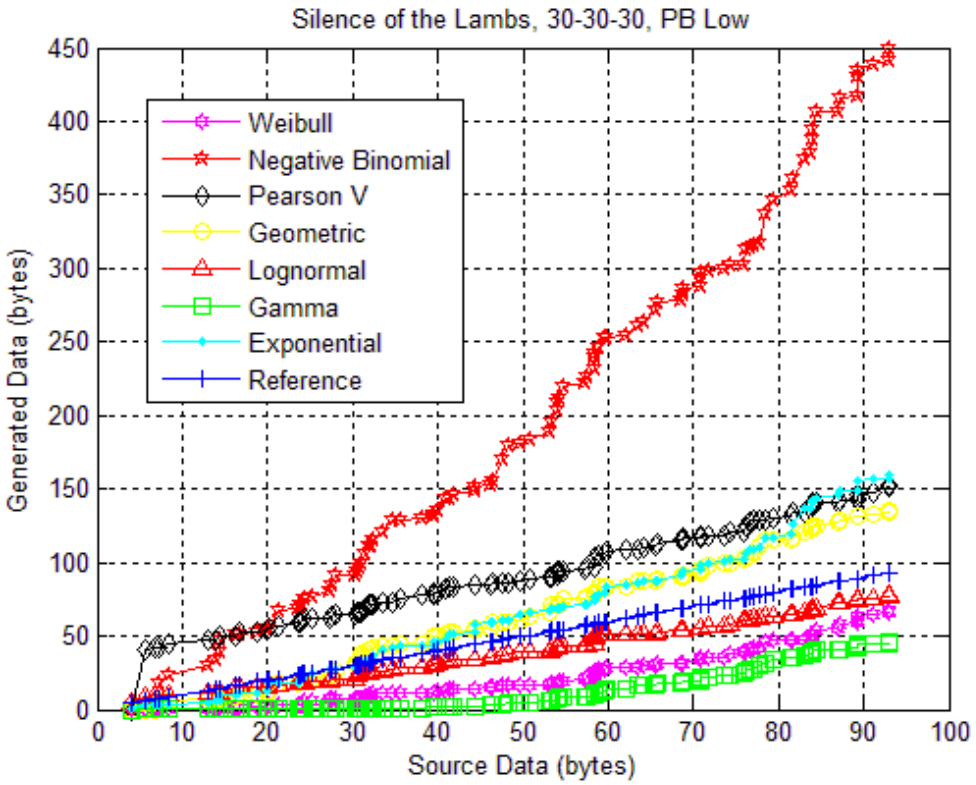

Figure 4.2 *Mediocre fitting, P/B frames, Low activity*

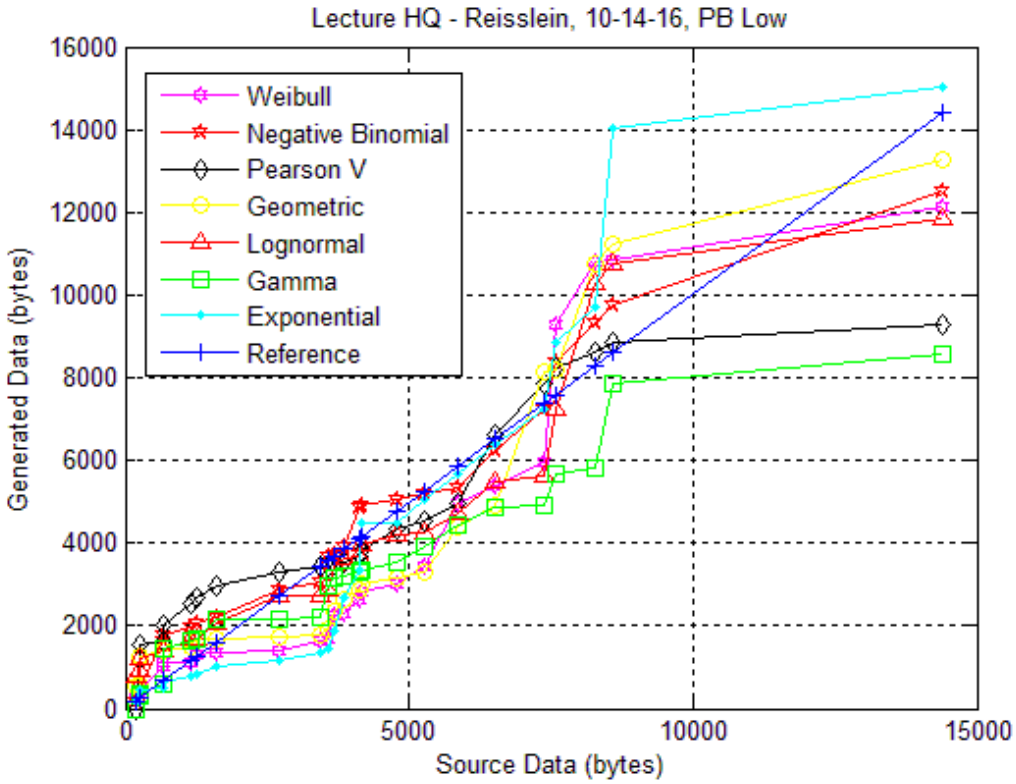

Figure 4.3 *Bad fitting, P/B frames, Low activity*

The cases where the accuracy of the fittings clearly increases with movie quality are limited in number (examples: Tokyo Olympics DVD, O Brother DVD, Charlie's Angels DVD, Ice Age DVD). In the cases where fittings are bad for all three qualities of a movie, the improvement or deterioration with quality is hard to observe (examples: Lecture – Reisslein, Lecture HQ - Reisslein). There are cases where the accuracy of the fittings diminishes as quality increases (examples: Aladdin, Cinderella, Friends vol.4 DVD). A common case is that the accuracy of the fittings increases on the transition from the 30-30-30 to the 10-14-16 quantization scale and diminishes on the transition from the 10-14-16 to the 04-04-04quantization scale (examples: Silence of the Lambs, Star Wars IV, Terminator One, Oprah without Commercials).

The worst fittings, in terms of deviation from the reference line, were associated with all the qualities of the traces Tonight Show without Commercials, Lecture – Reisslein, Lecture HQ – Reisslein and Lecture Gupta. In other words, the movies with the worst behavior here included a talk show and three lectures.

Lastly, as expected, no distribution was able of perfectly "capturing" the behavior of a trace under study even though the majority of the plots examined provided good to mediocre fitting results.

4.5.2 High Activity Scenes

In this section, we focus on the Q-Q plot fittings corresponding to the P/B frames of the high-activity scenes of the traces examined. We present indicatively some of our results in Figures 4.4, 4.5 and 4.6.

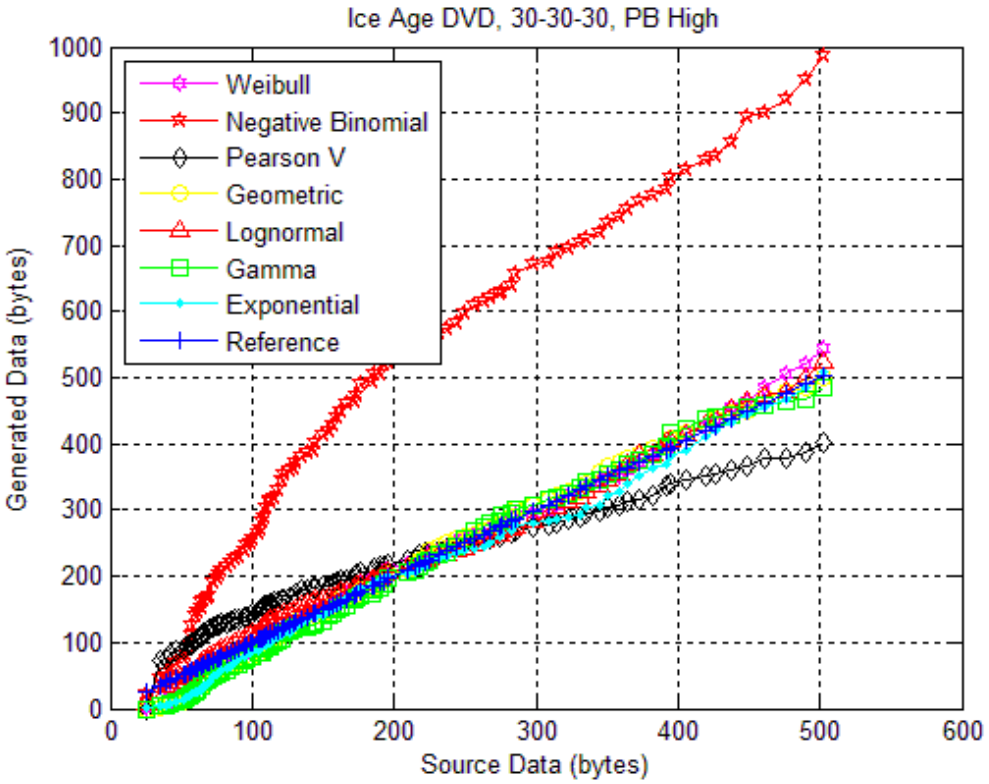

Figure 4.4 *Good fitting, P/B frames, High activity*

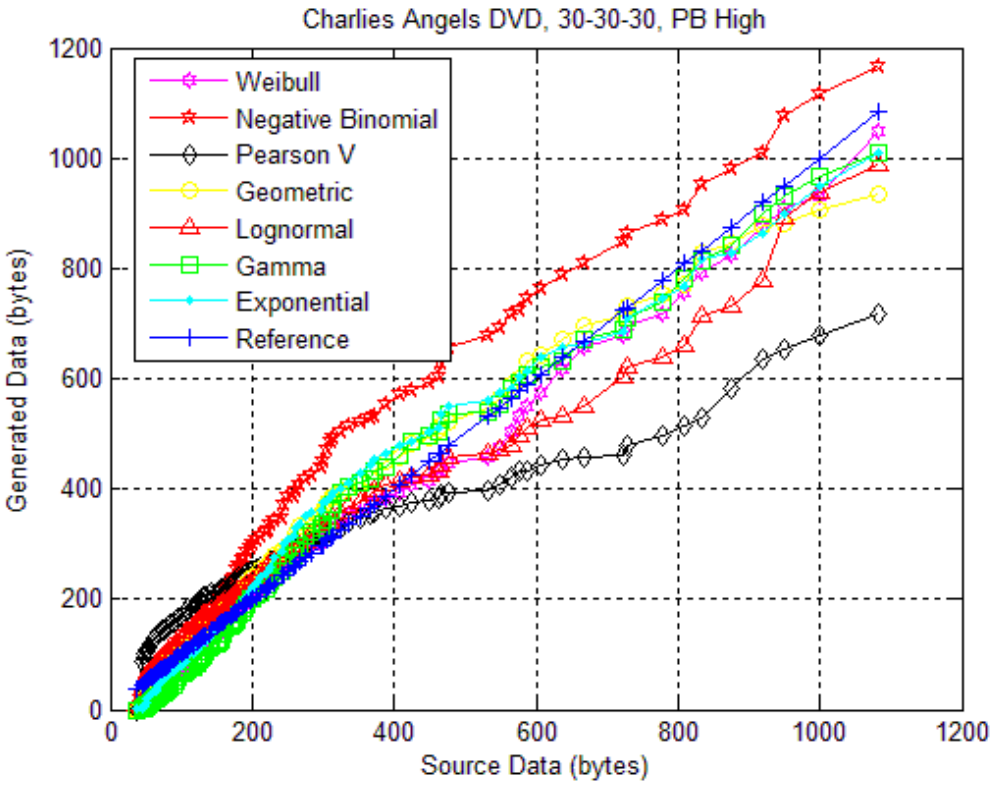

Figure 4.5 *Mediocre fitting, P/B frames, High activity*

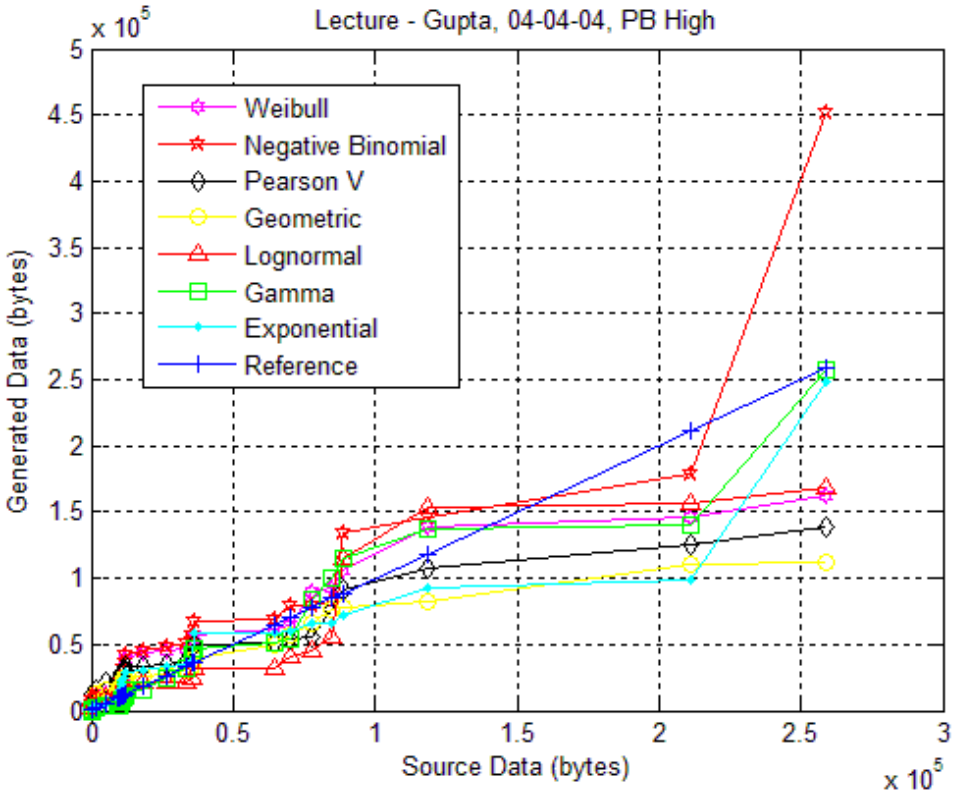

Figure 4.6 *Bad fitting, P/B frames, High activity*

The cases where the accuracy of the fittings clearly increases with movie quality are hard to find. In the cases where fittings are bad for all three qualities of a movie, the improvement or deterioration with quality is hard to observe (examples: Lecture – Reisslein, Lecture HQ - Reisslein). There are cases where the accuracy of the fittings diminishes as quality increases (examples: Aladdin, Cinderella, The Transporter DVD, Tokyo Olympics DVD, Oprah without Commercials). A common case is that the accuracy of the fittings increases on the transition from the 30-30-30 to the 10-14-16 quantization scale and diminishes on the transition from the 10-14-16 to the 04-04-04quantization scale (examples: Silence of the Lambs, Star Wars IV, Baseball with Commercials, Friends vol.4 DVD).

The worst fittings, in terms of deviation from the reference line, were associated with all the qualities of the traces Lecture – Reisslein, Lecture HQ – Reisslein and Lecture Gupta. In other words, the movies with the worst behavior here included three lectures.

Again, no distribution perfectly "captured" the behavior of a trace under study.

4.6 Multiplexed MPEG-4 Traffic Modeling

As far as the lag-1 autocorrelation coefficient, ρ, is concerned, we observe that the autocorrelation of P/B frames of both Low and High activity traces is in most cases quite low. Even though the maximum ρ for the High activity traces is larger, we have

to mention that ρ is lower than 0.3 for the majority of Low and High activity traces. The range of autocorrelation values is shown in Table 4.7 below.

Trace Type	Min ρ	Max ρ
P/B frames, Low	-0.2575	0.3455
P/B frames, High	-0.2667	0.6105

TABLE 4.7 – MIN AND MAX AUTOCORRELATION COEFFICIENT VALUES PER TRACE TYPE

- *P/B frames, Low activity*

We evaluated the hybrid model via 63 Q-Q plots. Most of them showed bad modeling results, along with 10 mediocre ones. In this section, the hybrid model did not produce any good results. A rough conclusion would be that a mediocre modeling result comes after a good or mediocre initial fitting. A bad modeling result usually follows a mediocre initial fitting. However, there are 9 cases (i.e., Baseball with Commercials 04-04-04, Terminator One 30-30-30) where a good initial fitting is followed by a bad modeling result and 12 cases (i.e., Lecture HQ - Reisslein 30-30-30, 10-14-16 and 04-04-04) where a bad initial fitting is followed by a bad modeling result. Some indicative results are presented in Figures 4.7 and 4.8.

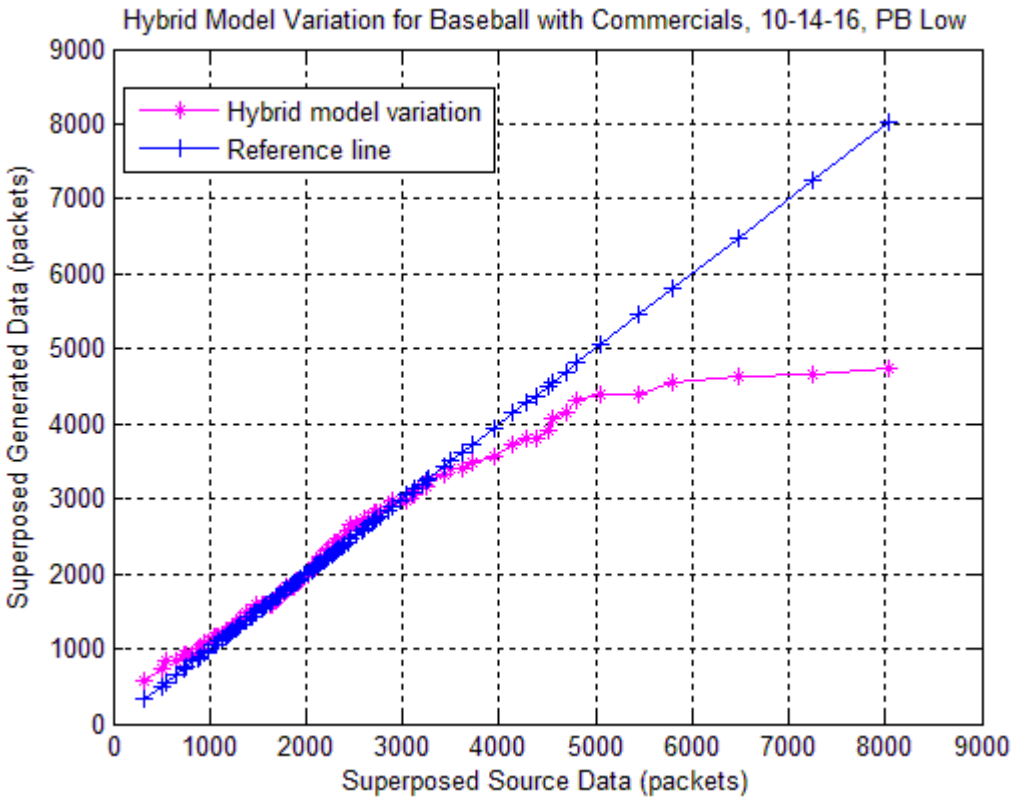

Figure 4.7 *Mediocre Modeling Result (5 sources) for P/B frames of Low activity*

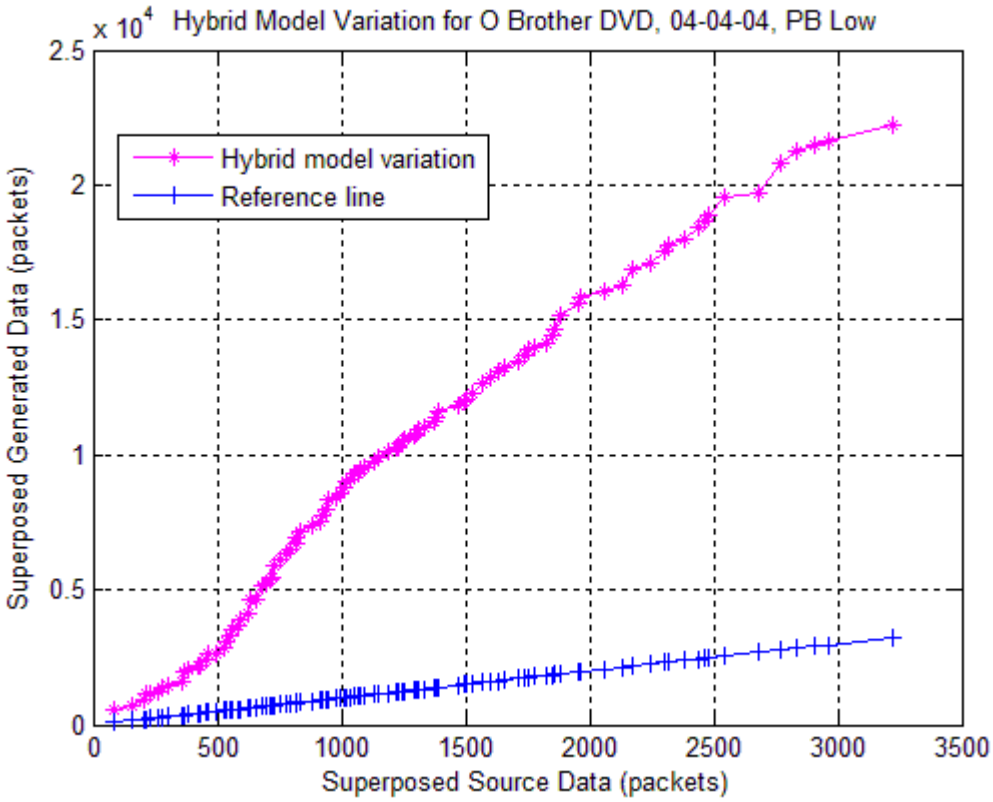

Figure 4.8 *Bad Modeling Result (5 sources) for P/B frames of Low activity*

- *P/B frames, High activity*

We evaluated the hybrid model via 63 Q-Q plots. Most of them showed bad modeling results, along with 10 good and 17 mediocre ones. In most of these cases, a rough conclusion would be that a good or mediocre modeling result comes after a good or mediocre initial fitting. A bad modeling result can follow a good, mediocre or bad initial fitting. There are 8 cases (i.e., Baseball with Commercials 10-14-16, Citizen Kane 30-30-30, Terminator One 10-14-16) where a good initial fitting is followed by a bad modeling result and 9 cases (i.e., Lecture HQ - Reisslein 30-30-30, 10-14-16 and 04-04-04) where a bad initial fitting is followed by a bad modeling result. Finally, there are 19 cases (i.e., Charlie's Angels DVD 30-30-30, Cinderella 10-14-16 and Citizen Kane 10-14-16) where a mediocre initial fitting is followed by a bad modeling result. Some indicative results are presented in Figures 4.9 - 4.11.

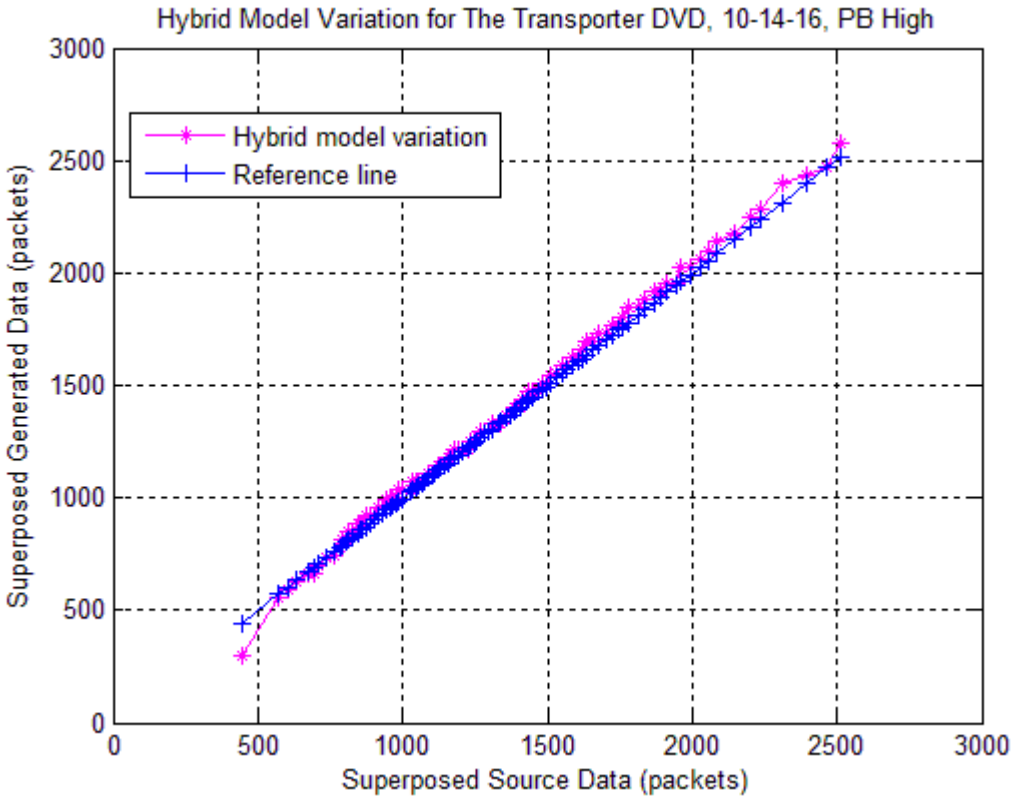

Figure 4.9 *Good Modeling Result (5 sources) for P/B frames of High activity*

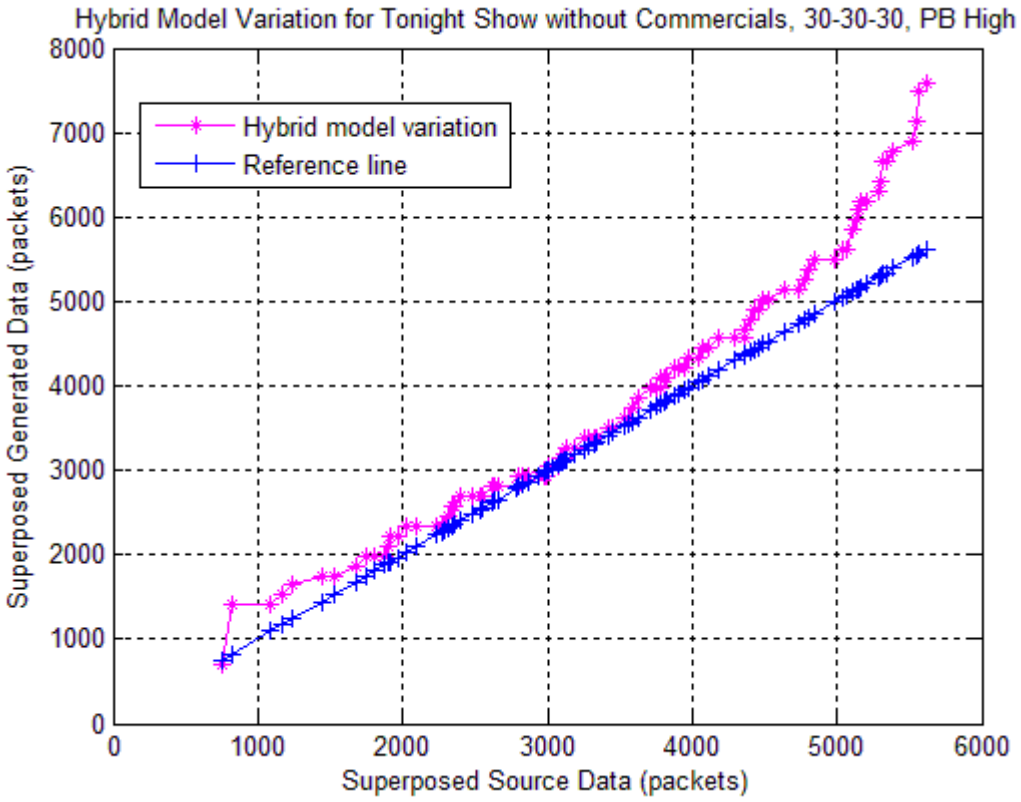

Figure 4.10 *Mediocre Modeling Result (5 sources) for P/B frames of High activity*

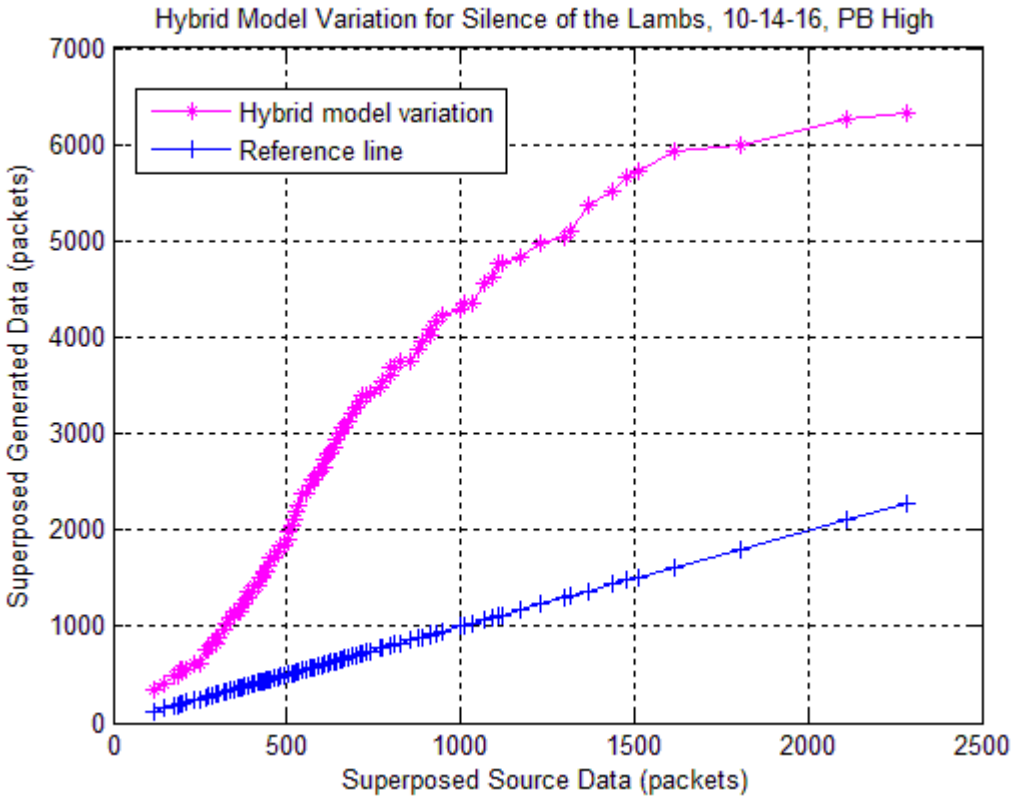

Figure 4.11 *Bad Modeling Result (5 sources) for P/B frames of High activity*

An interesting result of this modeling approach is that the P/B frames of low activity scenes had a lower number of good and mediocre modeling results and a higher number of bad modeling results, in comparison to high activity ones.

As the number of the superposed sources increases from 5 to 10 and then to 15, the majority of the results, regardless of the degree of activity, deteriorate. The cases where the modeling results remain unaffected are just a few. Improvements can be observed in a very limited number of cases and they usually last for only one transition, i.e., from 5 to 10 or 10 to 15 sources. The number of improvements for the High activity traces is larger than the respective one for the Low activity traces. Indicative examples are presented below in Figures 4.12 – 4.23.

- Improvement Example – Cinderella 04-04-04, P/B frames High activity

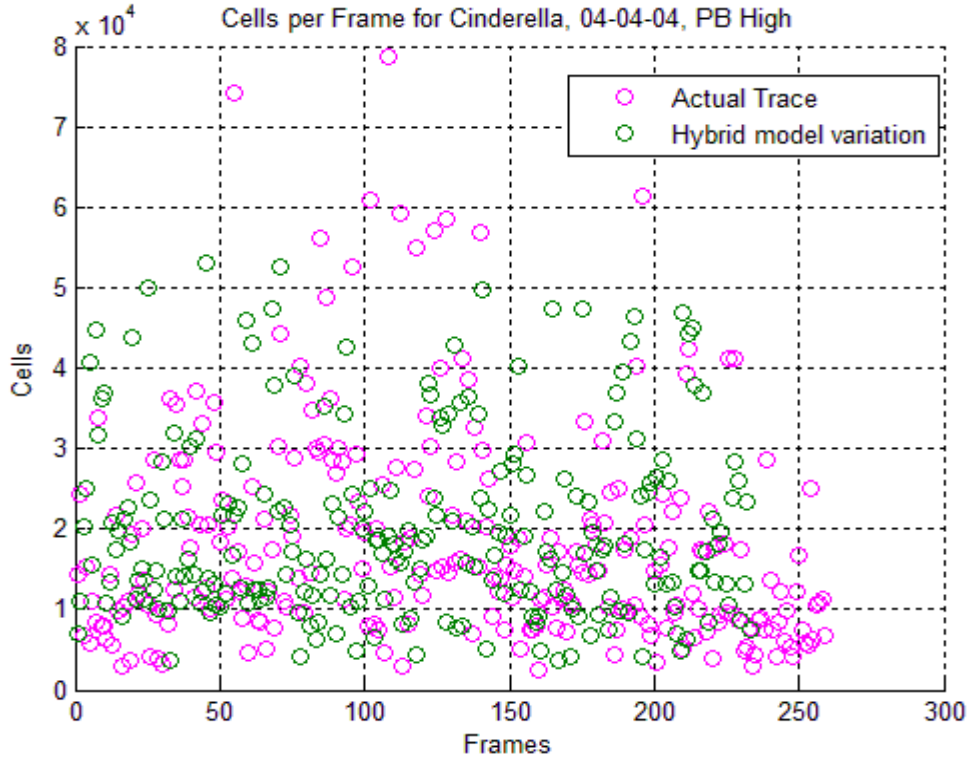

Figure 4.12 *Cells per Frame for trace improving with the increase in the number of sources (5 sources)*

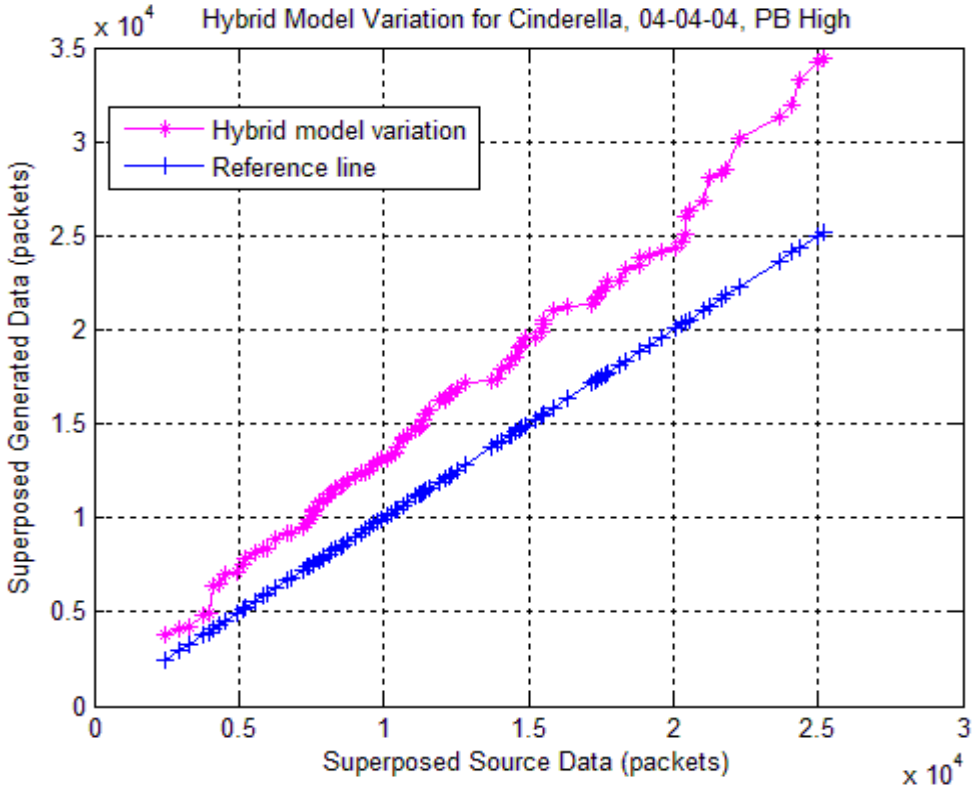

Figure 4.13 *Hybrid modeling result for trace improving with the increase in the number of sources (5 sources)*

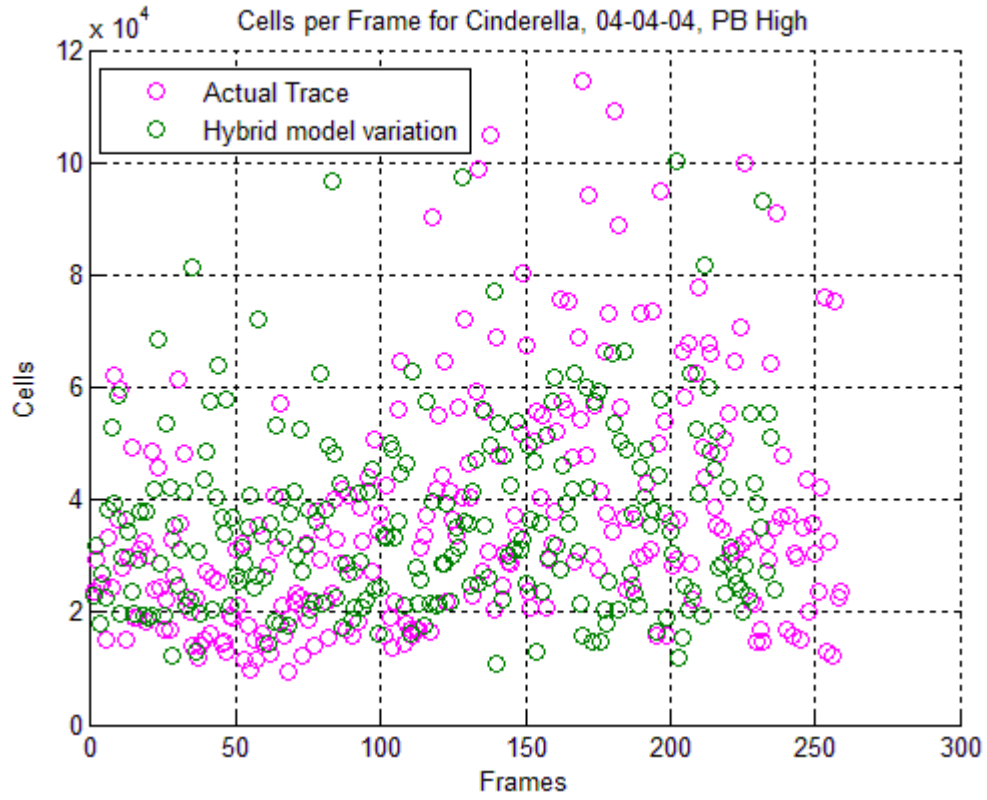

Figure 4.14 *Cells per Frame for trace improving with the increase in the number of sources (10 sources)*

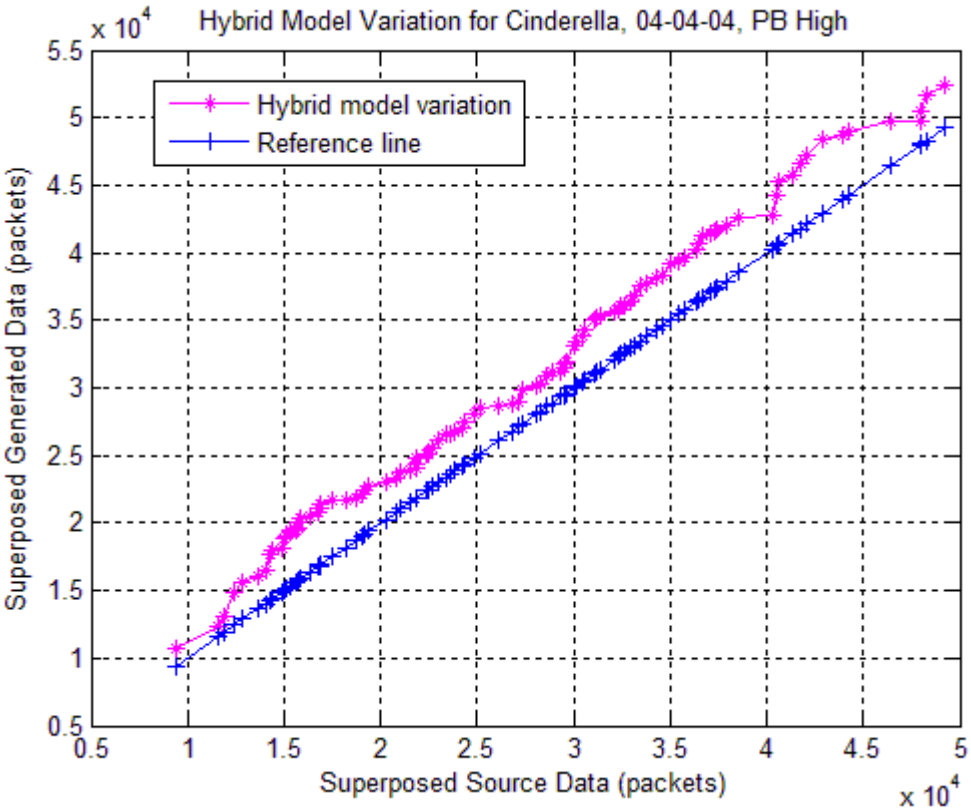

Figure 4.15 *Hybrid modeling result for trace improving with the increase in the number of sources (10 sources)*

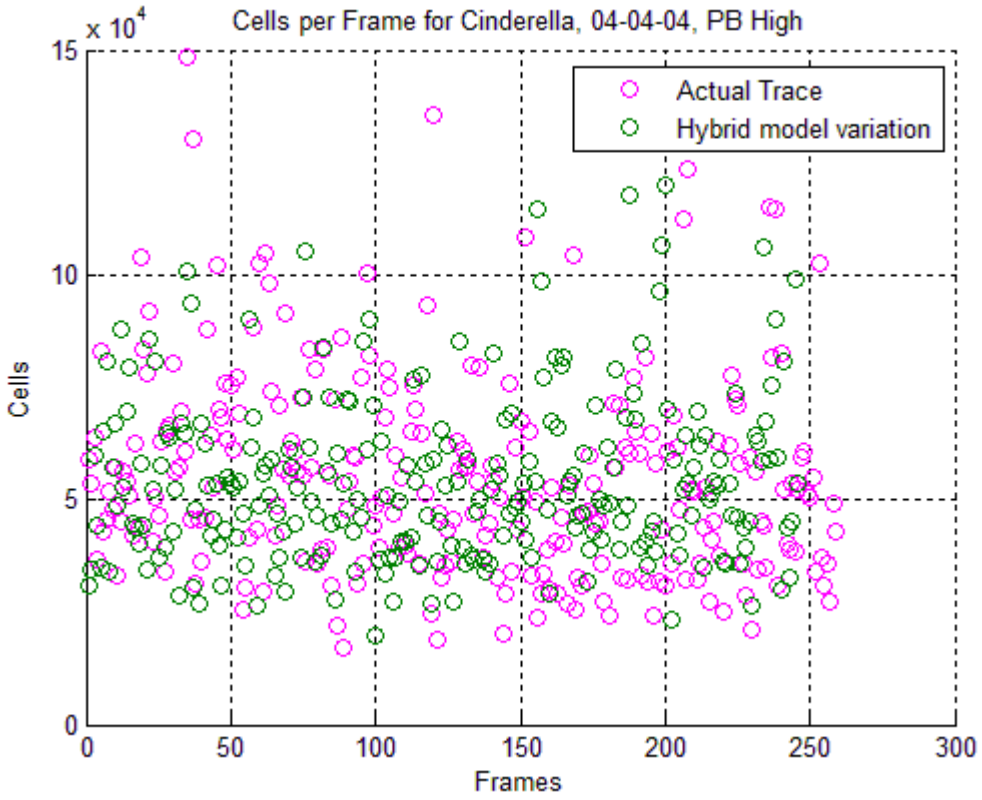

Figure 4.16 *Cells per Frame for trace improving with the increase in the number of sources (15 sources)*

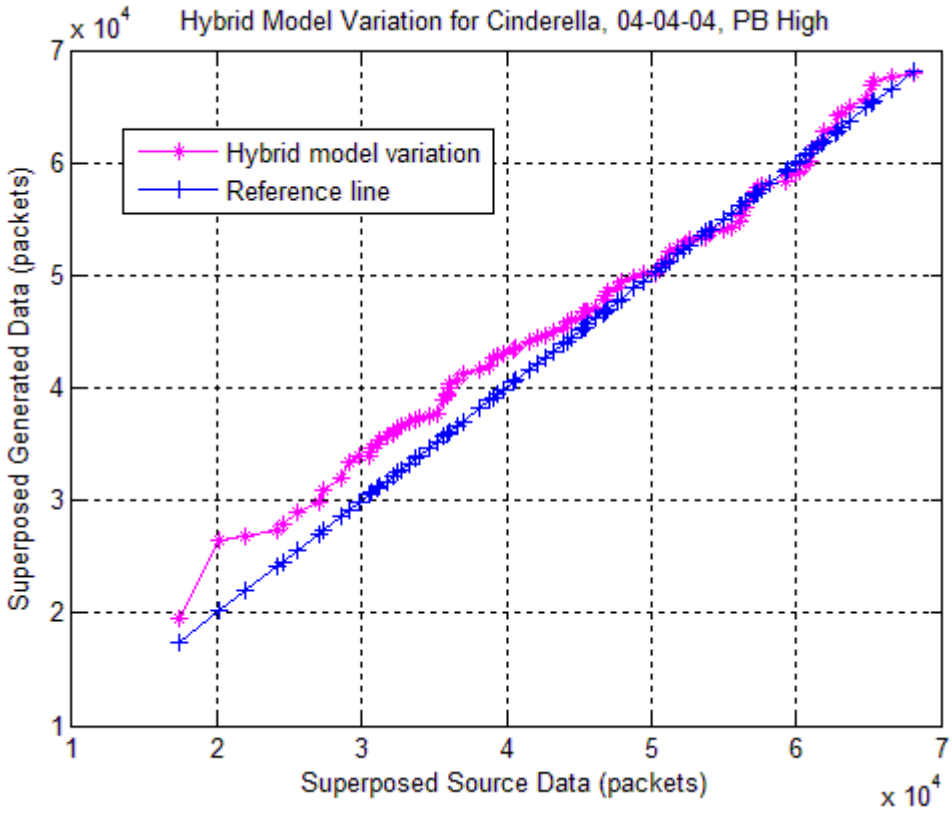

Figure 4.17 *Hybrid modeling result for trace improving with the increase in the number of sources (15 sources)*

- Deterioration Example – Star Wars IV 04-04-04, P/B frames High activity

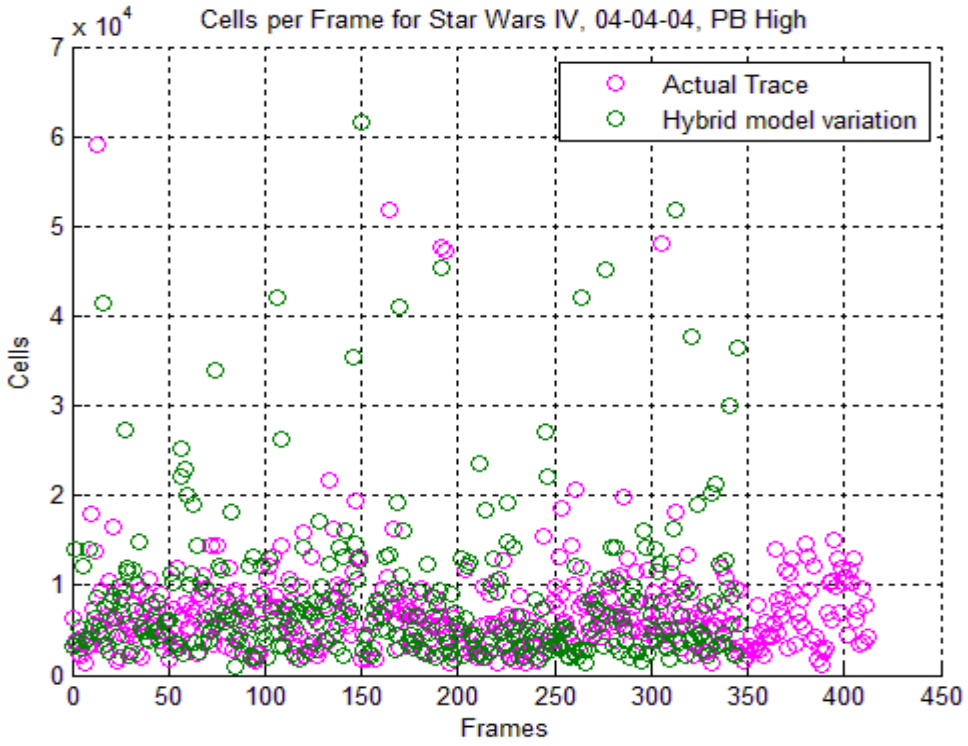

Figure 4.18 *Cells per Frame for trace deteriorating with the increase in the number of sources (5 sources)*

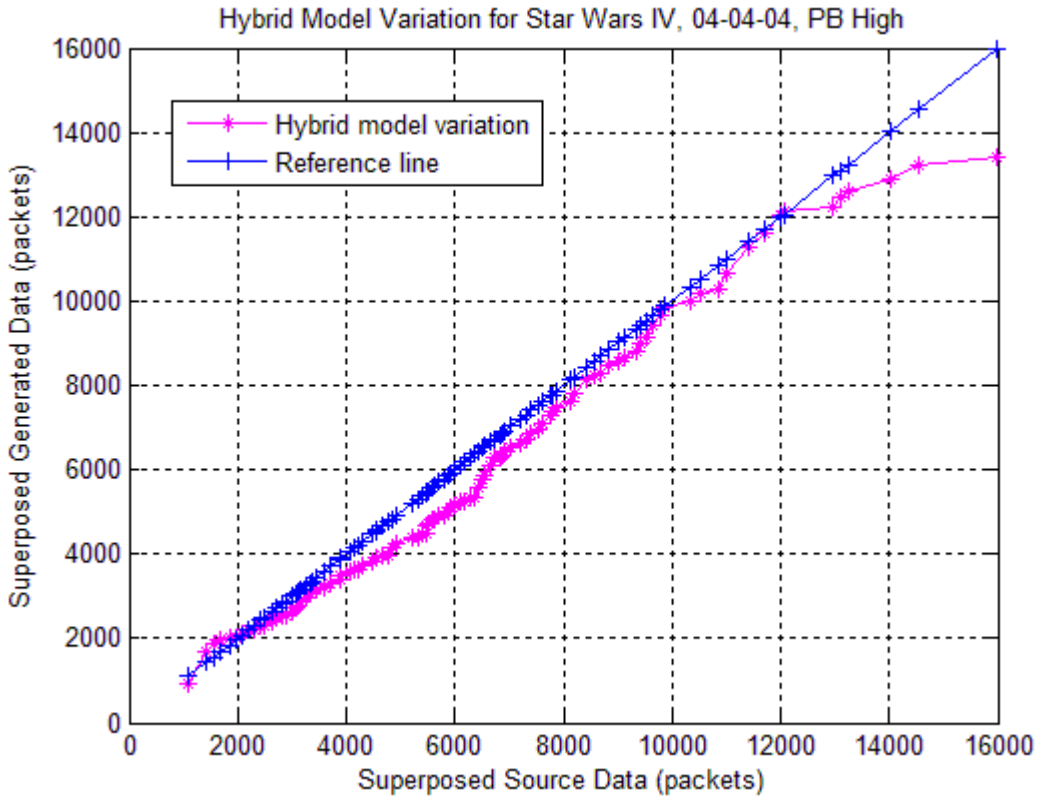

Figure 4.19 *Hybrid modeling result for trace deteriorating with the increase in the number of sources (5 sources)*

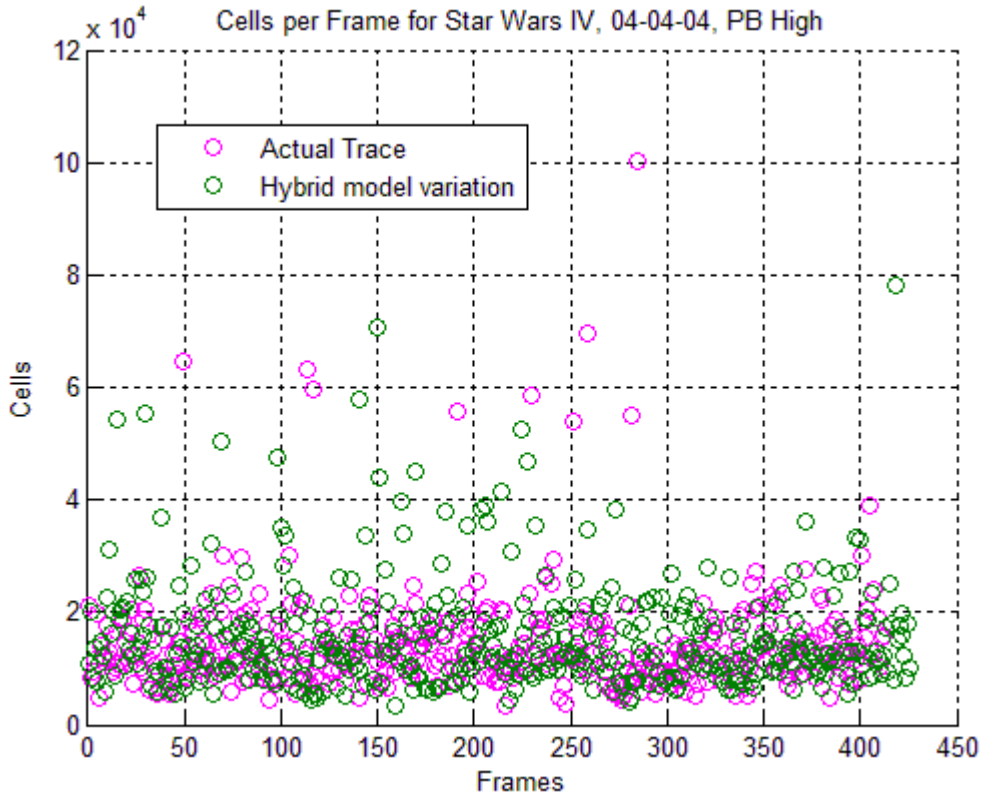

Figure 4.20 *Cells per Frame for trace deteriorating with the increase in the number of sources (10 sources)*

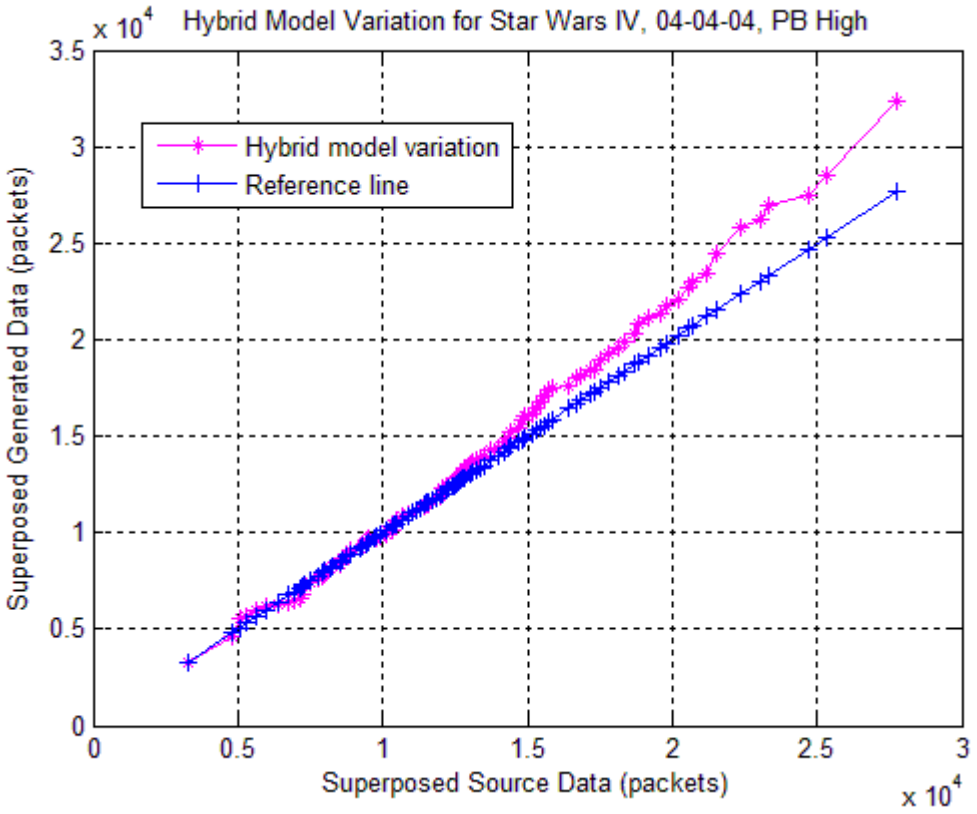

Figure 4.21 *Hybrid modeling result for trace deteriorating with the increase in the number of sources (10 sources)*

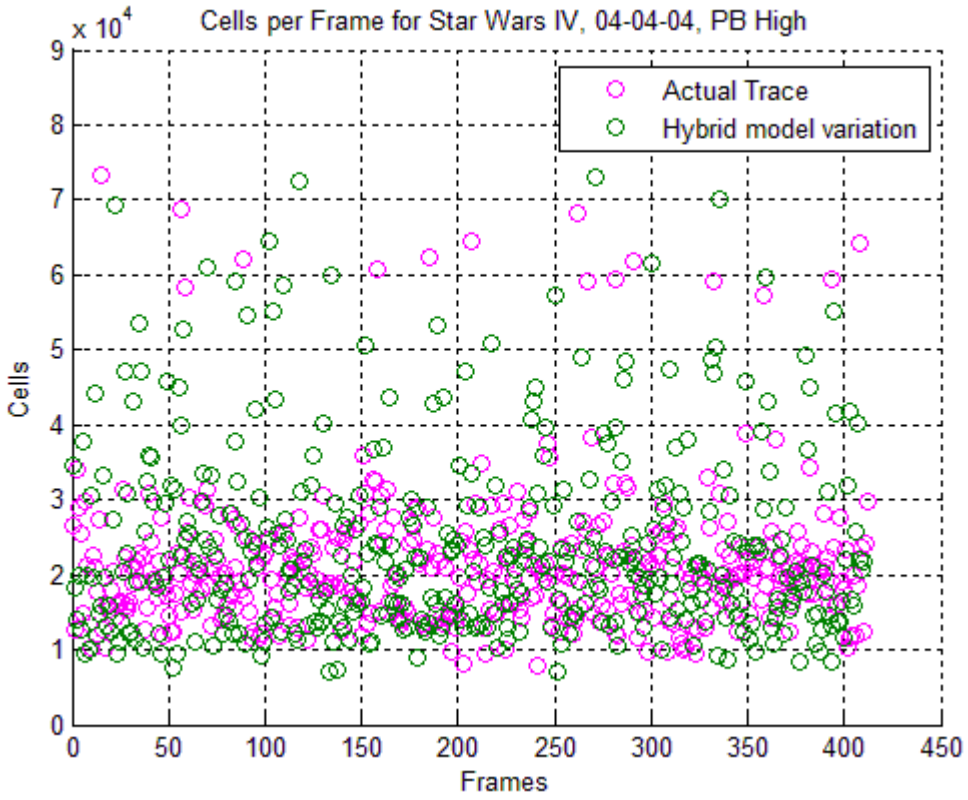

Figure 4.22 *Cells per Frame for trace deteriorating with the increase in the number of sources (15 sources)*

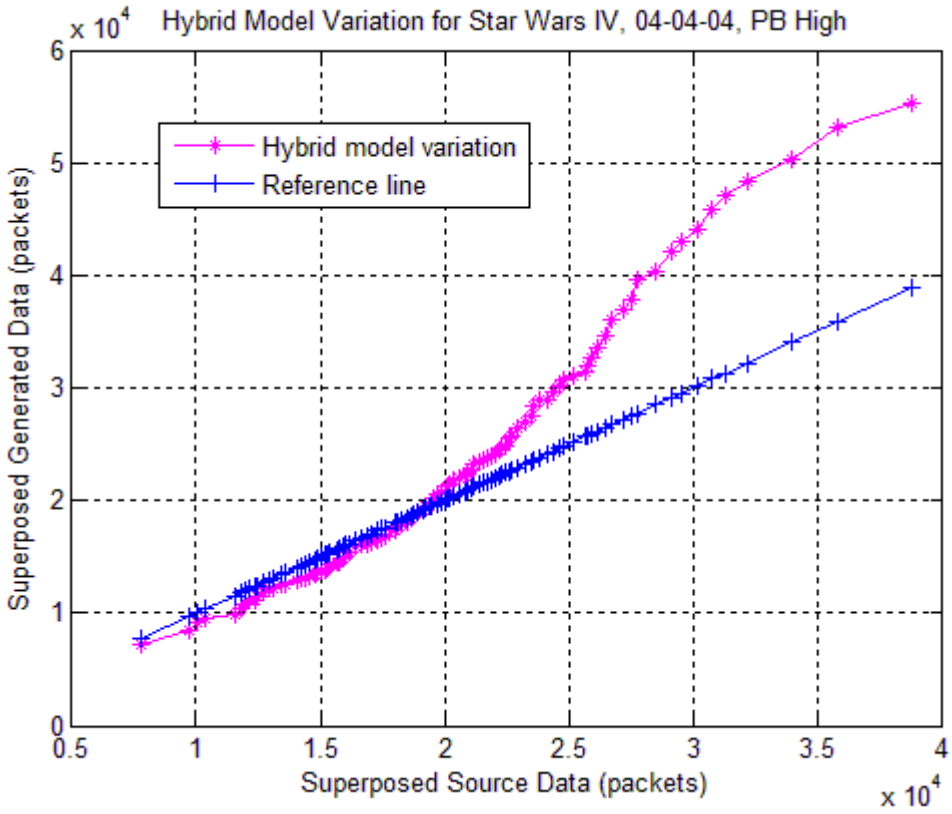

Figure 4.23 *Hybrid modeling result for trace deteriorating with the increase in the number of sources (15 sources)*

4.7 Lag-1 Autocorrelation Coefficient of Modeled Sources

In this section, we compare the autocorrelation of the actual and the modeled superposed sources. Hence, we calculate the lag-1 autocorrelation coefficient for every Low and High P/B actual and modeled superposition of 5, 10 and 15 sources. Our results indicate that the variation of the hybrid model "captures" relatively the autocorrelation of the actual sequences (see Tables A.3.5-6 of the Appendix). The range of differences between the autocorrelation of the real and the modeled superpositions is shown in Table 4.8.

	5 sources			10 sources			15 sources		
Trace Type	*Min deviation*	*Max deviation*	*Average deviation*	*Min deviation*	*Max deviation*	*Average deviation*	*Min deviation*	*Max deviation*	*Average deviation*
PB frames, Low	0.0001	0.4850	0.0816	0.0005	0.4683	0.0854	0.0002	0.5545	0.1017
PB frames, High	0.0009	0.5434	0.0794	0.0048	0.5126	0.0921	0.0002	0.6172	0.0982

TABLE 4.8 – MIN, MAX AND AVERAGE DIFFERENCES IN LAG-1 AUTOCORRELATION COEFFICIENT VALUES PER TRACE TYPE AND NUMBER OF SOURCES

By using the actual and generated superposition of traces, as produced by the synthetic variation of the hybrid model in section 4.8, we calculate the autocorrelation coefficient for various lags. The traces are chosen on the basis of representing almost every movie genre. Indicative examples follow in Figures 4.24 - 4.35.

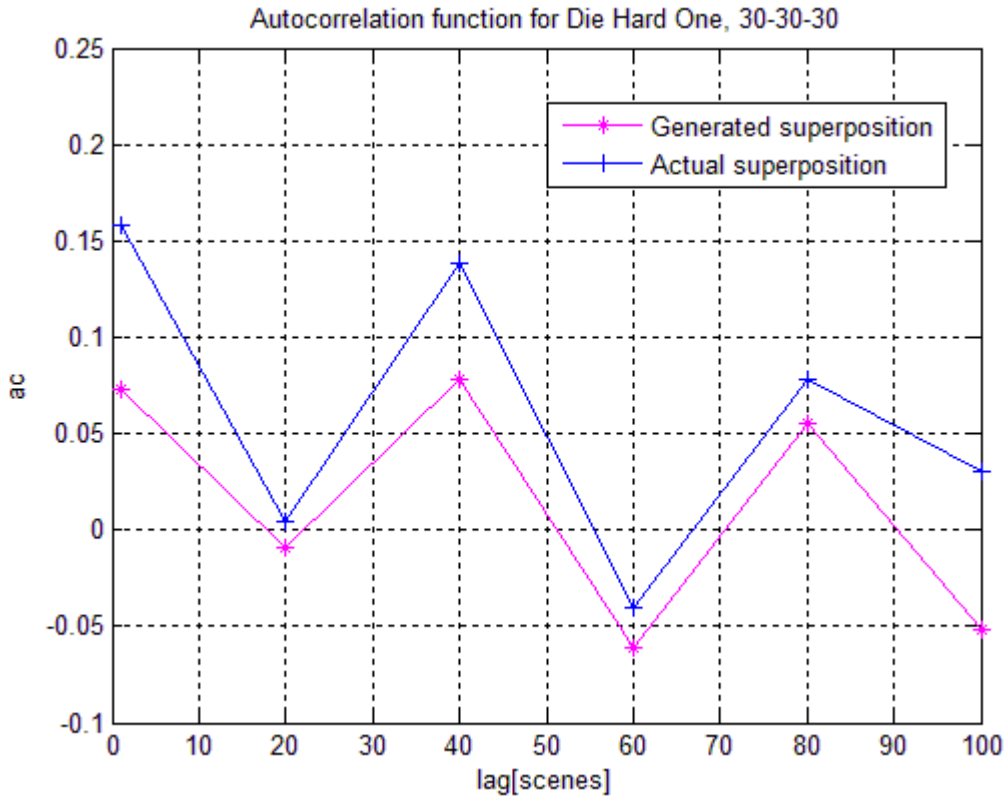

Figure 4.24 *Genre: Action, Example: 1 (10 sources) – AC differences between actual and generated sequence less than 0.1*

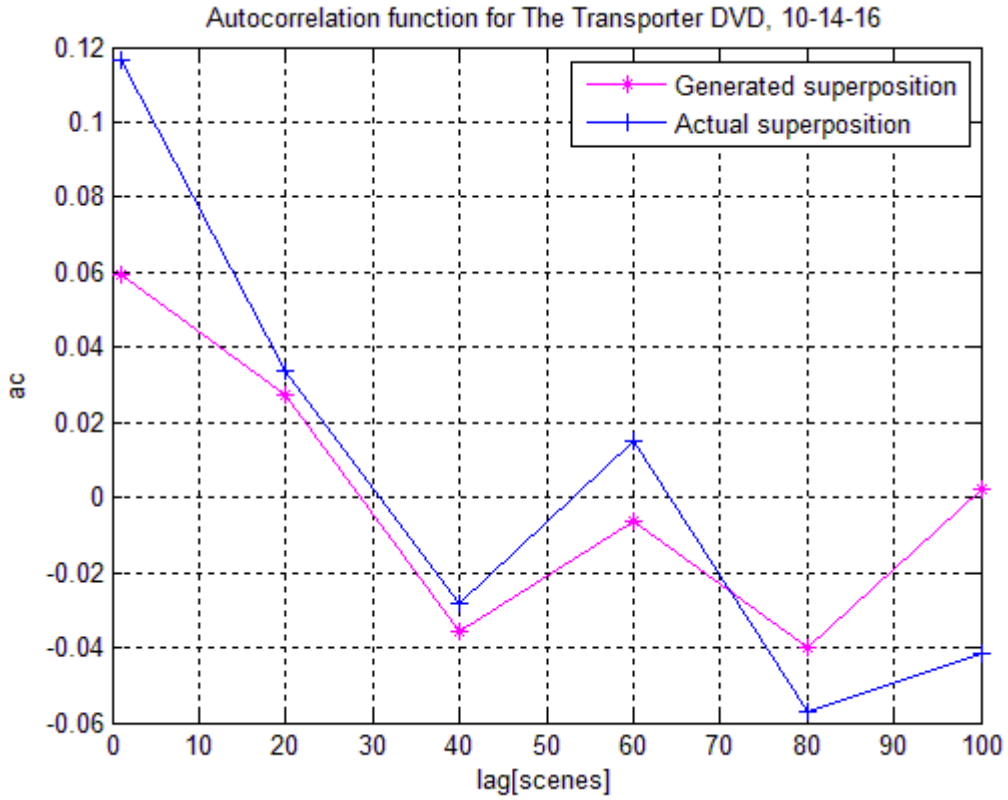

Figure 4.25 *Genre: Action, Example: 2 (10 sources) – AC differences between actual and generated sequence less than 0.06*

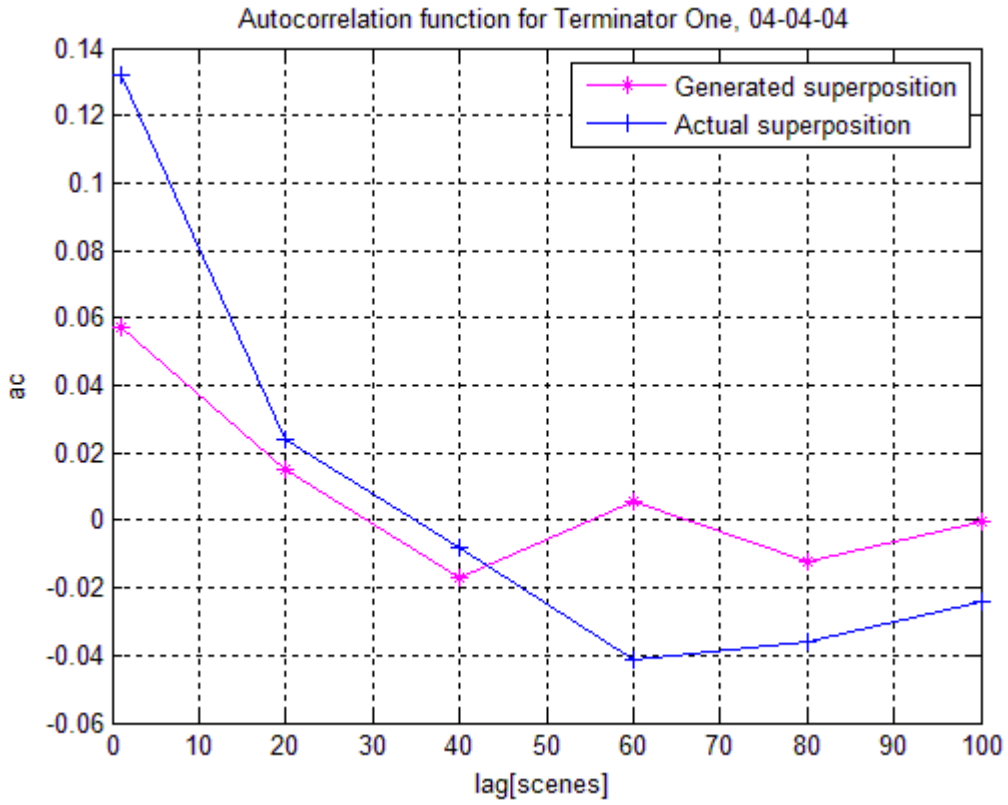

Figure 4.26 *Genre: Sci-Fi (15 sources) – AC differences between actual and generated sequence less than 0.08*

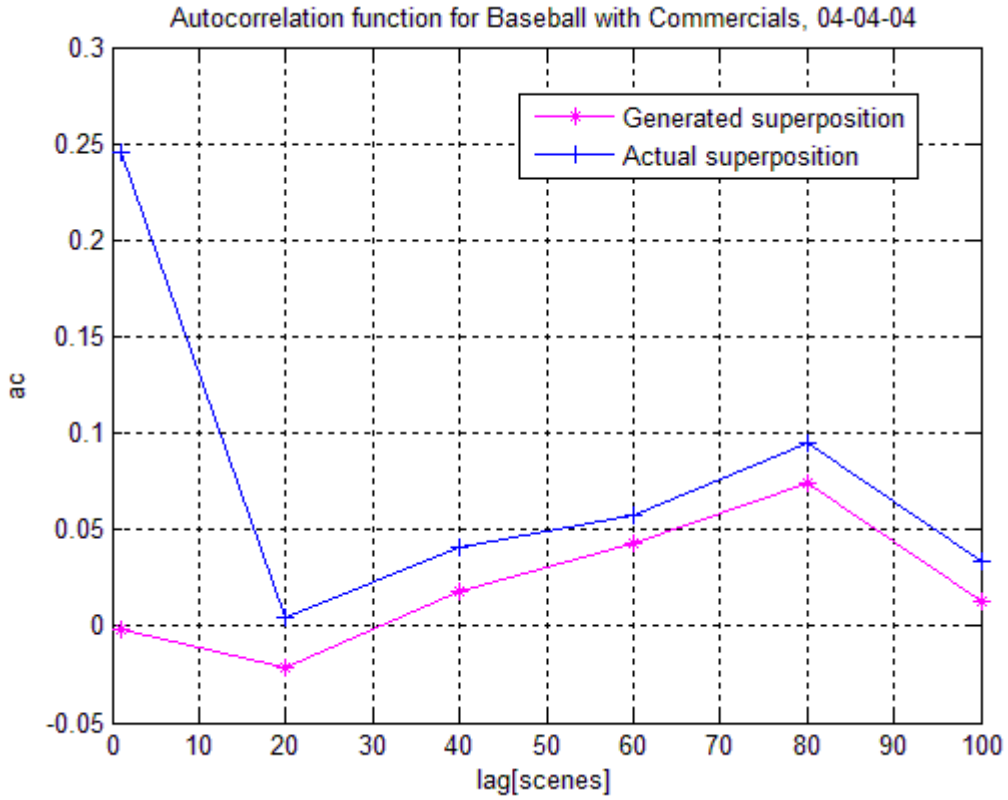

Figure 4.27 *Genre: Sports, Example: 1 (5 sources) – AC differences between actual and generated sequence less than 0.25*

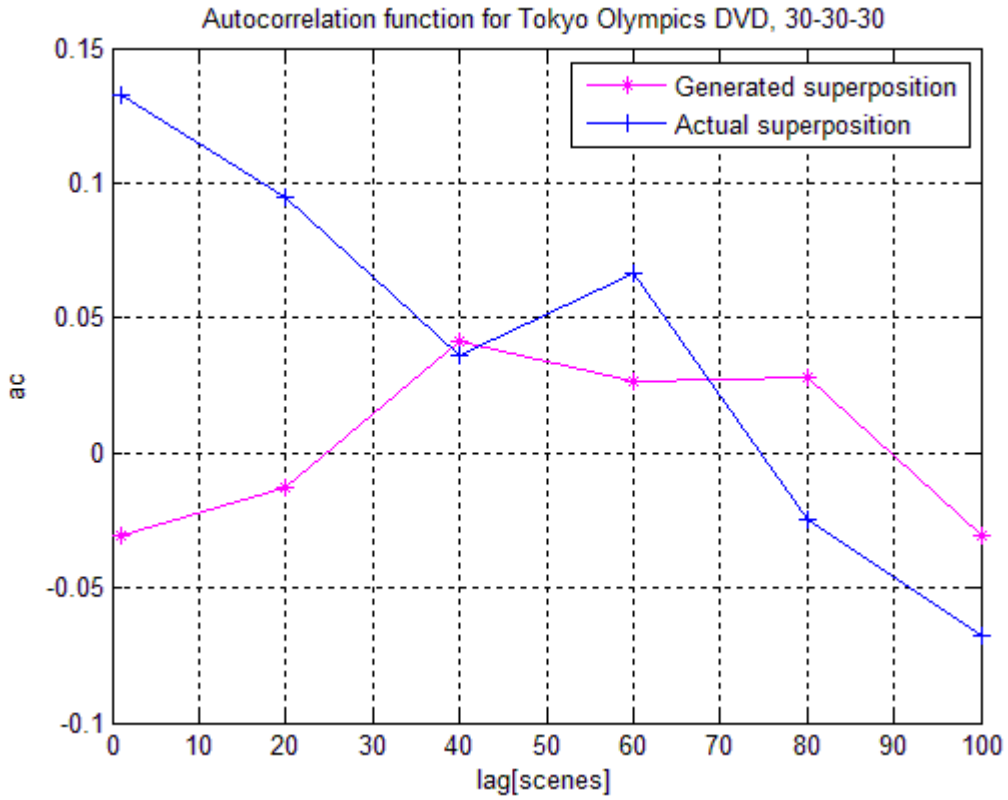

Figure 4.28 *Genre: Sports, Example: 2 (5 sources) – AC differences between actual and generated sequence less than 0.2*

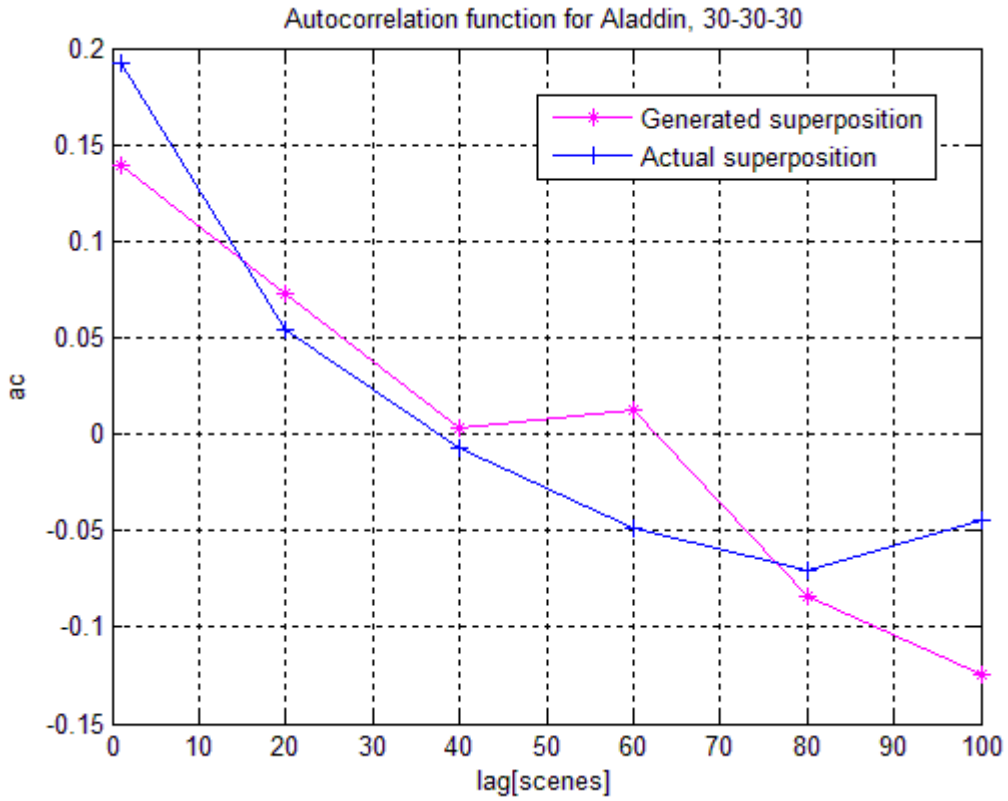

Figure 4.29 *Genre: Cartoon, Example: 1 (10 sources) - AC differences between actual and generated sequence less than 0.1*

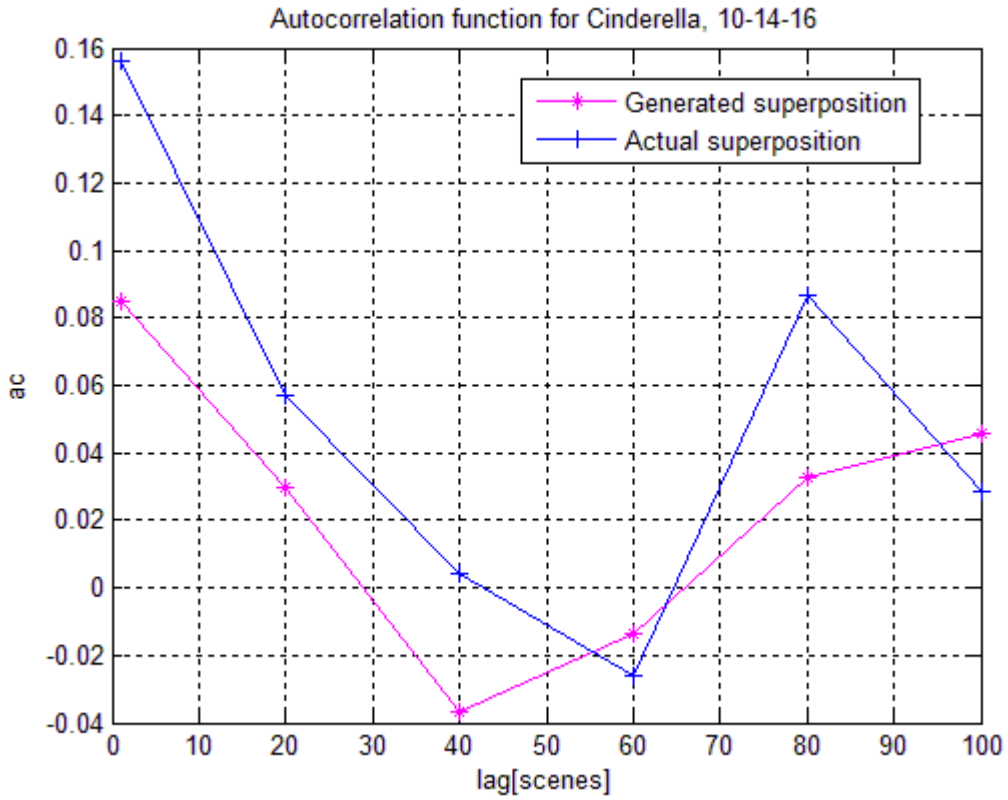

Figure 4.30 *Genre: Cartoon, Example: 2 (10 sources) - AC differences between actual and generated sequence less than 0.08*

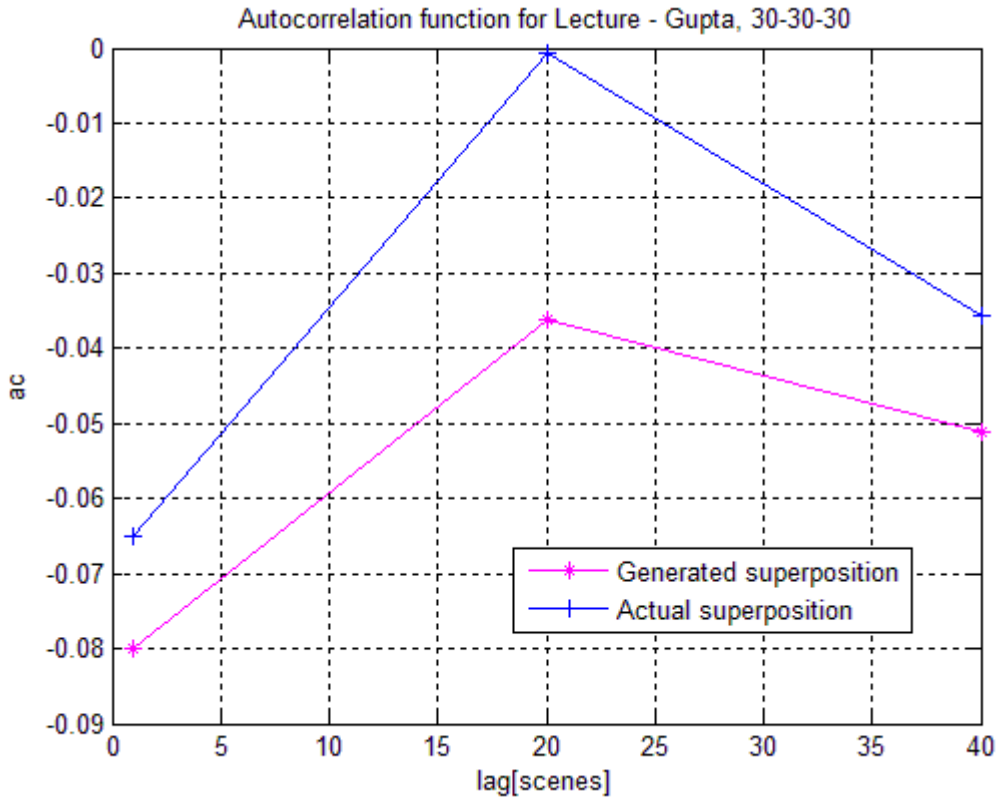

Figure 4.31 *Genre: Lecture (15 sources) - AC differences between actual and generated sequence less than 0.04*

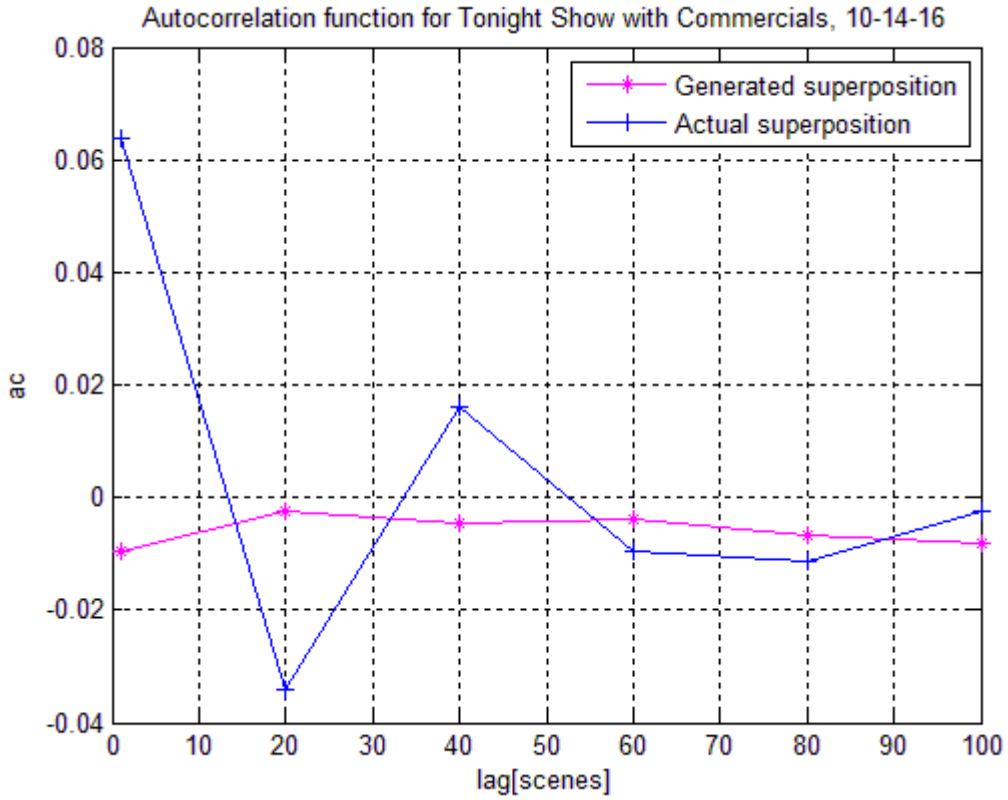

Figure 4.32 *Genre: Talk-Show, Example: 1 (5 sources) - AC differences between actual and generated sequence less than 0.08*

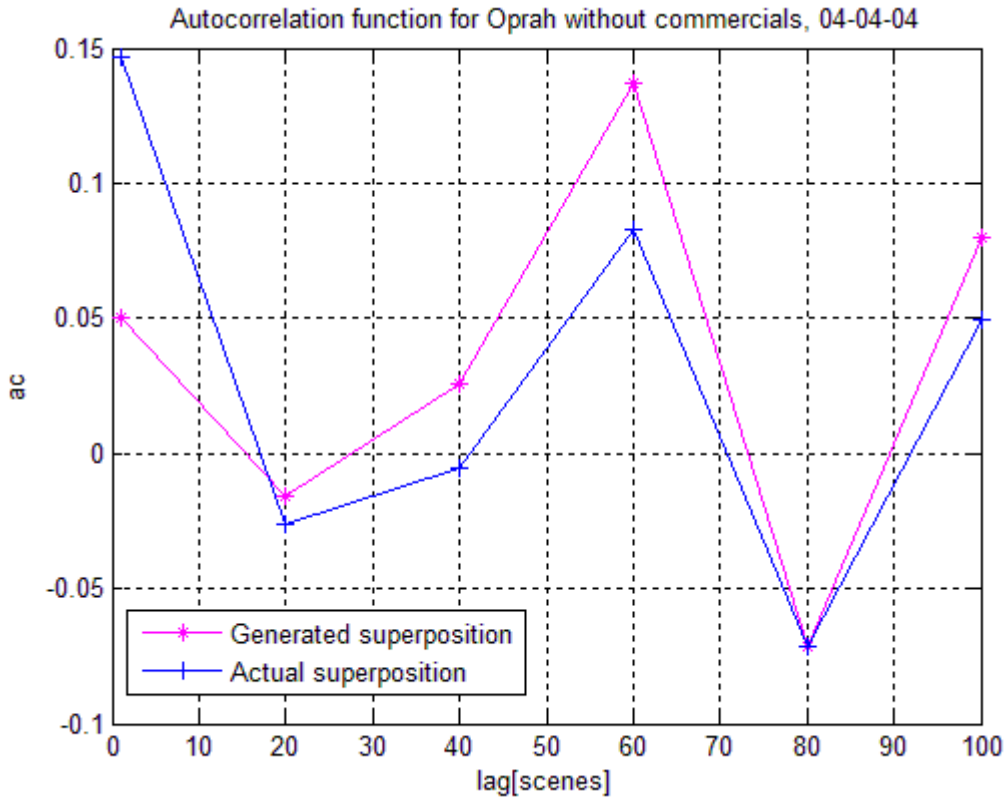

Figure 4.33 *Genre: Talk-Show, Example: 2 (5 sources) - AC differences between actual and generated sequence less than 0.1*

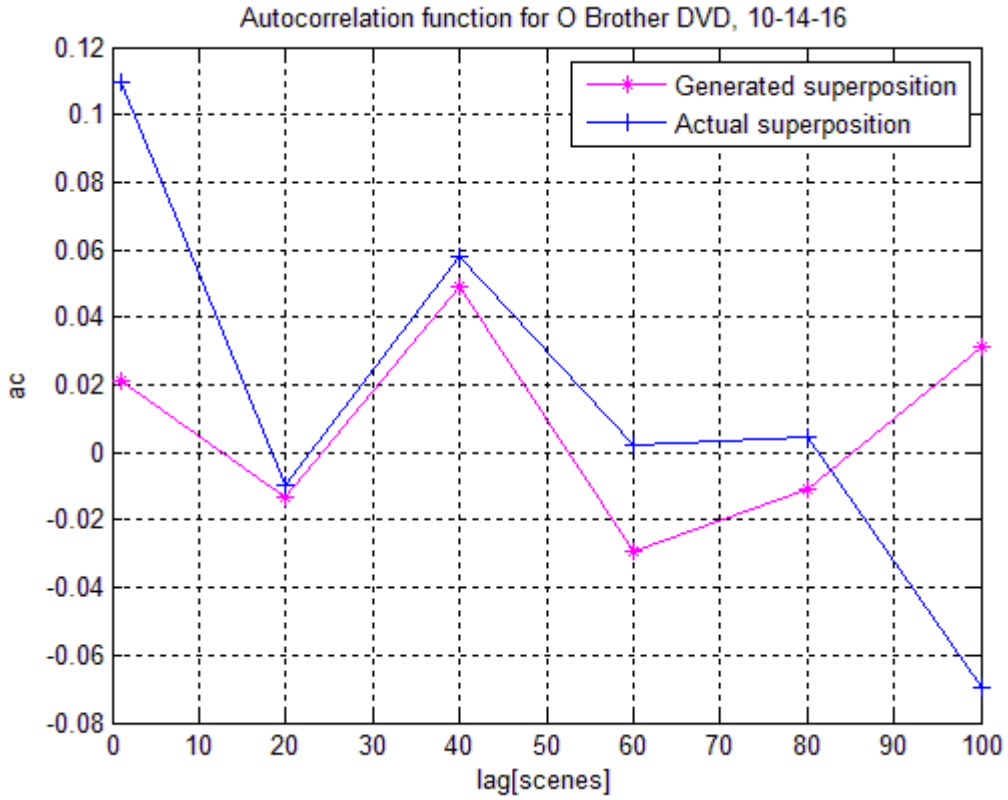

Figure 4.34 *Genre: Comedy, Example: 1 (10 sources) - AC differences between actual and generated sequence less than 0.1*

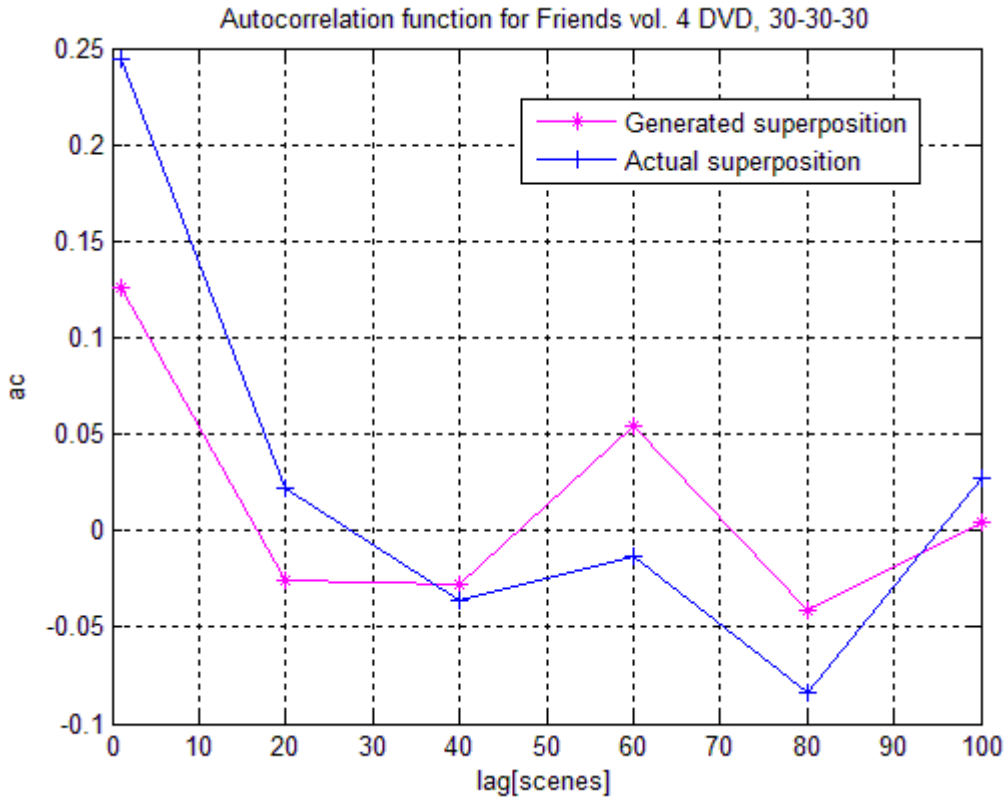

Figure 4.35 *Genre: Comedy, Example: 2 (10 sources) - AC differences between actual and generated sequence less than 0.15*

As shown in the Figures, the peak in the value of the autocorrelation coefficient of the actual sequences is reached for lag-1 for all traces studied, except for lectures (for which the peak is reached for lag-20).

Most importantly, the results in Figures 4.24-4.35 clearly show that the variation of the hybrid model captures in just a few cases accurately the behavior of the autocorrelation of the superposed sources, and clearly underperforms in comparison to the original hybrid model (Figures 3.50 - 3.59).

4.8 Final Modeling Results with the Variation of the Hybrid Model

Our results in Sections 4.6 and 3.8, on modeling the P/B frames and the I frames of Low and High activity from multiplexed sources, respectively, were a strong indication of whether this variation of the hybrid model can succeed in capturing the behavior of specific traces. However, a clear result on the feasibility of this type of modeling can only be derived by: a) generating Low and High activity scene sizes for each original trace (i.e., by generating I and P/B frame sizes per scene), hence creating a model for a single trace, and b) superposing a number of the generated traces (5, 10 and 15 in our work) and assessing the modeling results via statistical tests (we used Q-Q plots).

In the cases that one or more of the four frame type sequences of a trace was excluded from the modeling of section 4.6 and 3.8, the specific movie was not examined in this part of our work (see Table 4.9).

Excluded Traces
Lecture – Reisslein, 10-14-16
Lecture – Reisslein, 04-04-04
Tokyo Olympics DVD, 10-14-16
Ice Age DVD, 10-14-16
Ice Age DVD, 04-04-04

TABLE 4.9 – TRACES EXCLUDED FROM FINAL HYBRID MODELING

Hence, we evaluated the variation of the hybrid model via 58 Q-Q plots. Most of them showed bad modeling results (36 in total), along with 3 good and 19 mediocre ones. Tables 4.10 and 4.11 below confirm the fact that this variation of the hybrid model performs worse than the DAR(1) and the initial hybrid model, as to the number and percentage of its good, mediocre and bad modeling results. More specifically, this variation of the hybrid produces the highest number of bad modeling results and the lowest number of good and mediocre modeling results among the three models. Indicative examples are follow in Figures 4.36-4.38.

	DAR(1) Model	Hybrid Model	Variation of the Hybrid Model
Good Results	7	17	3
Mediocre Results	25	32	19
Bad Results	12	3	36
Total	44	52	58

TABLE 4.10 – COMPARING THE DAR(1) MODEL, THE HYBRID MODEL AND THE VARIATION OF THE HYBRID WITH PLAIN NUMBERS

	DAR(1) Model	Hybrid Model	Variation of the Hybrid Model
Good Results	15.91%	32.69%	5.17%
Mediocre Results	56.82%	61.54%	32.76%
Bad Results	27.27%	5.77%	62.07%
Total	100%	100%	100%

TABLE 4.11 – COMPARING THE DAR(1) MODEL, THE HYBRID MODEL AND THE VARIATION OF THE HYBRID WITH PERCENTAGES

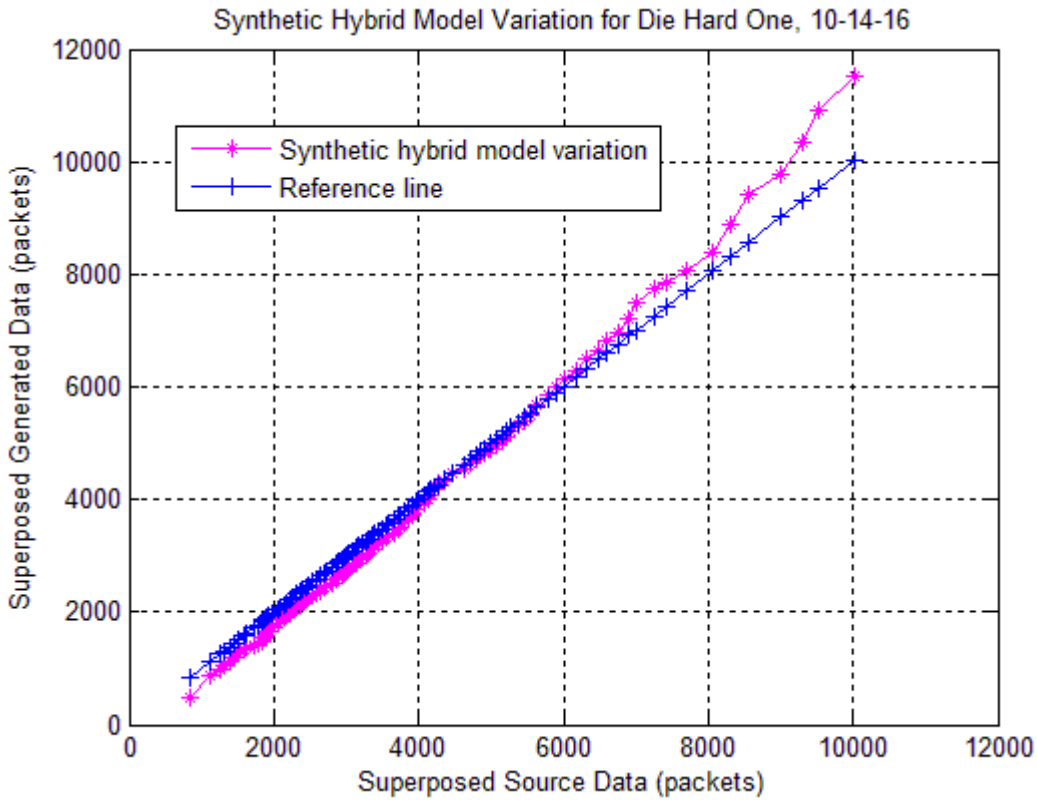

Figure 4.36 *Good hybrid modeling result (5 sources)– Movie Burstiness = 13.6137, ρ =-0.0568*

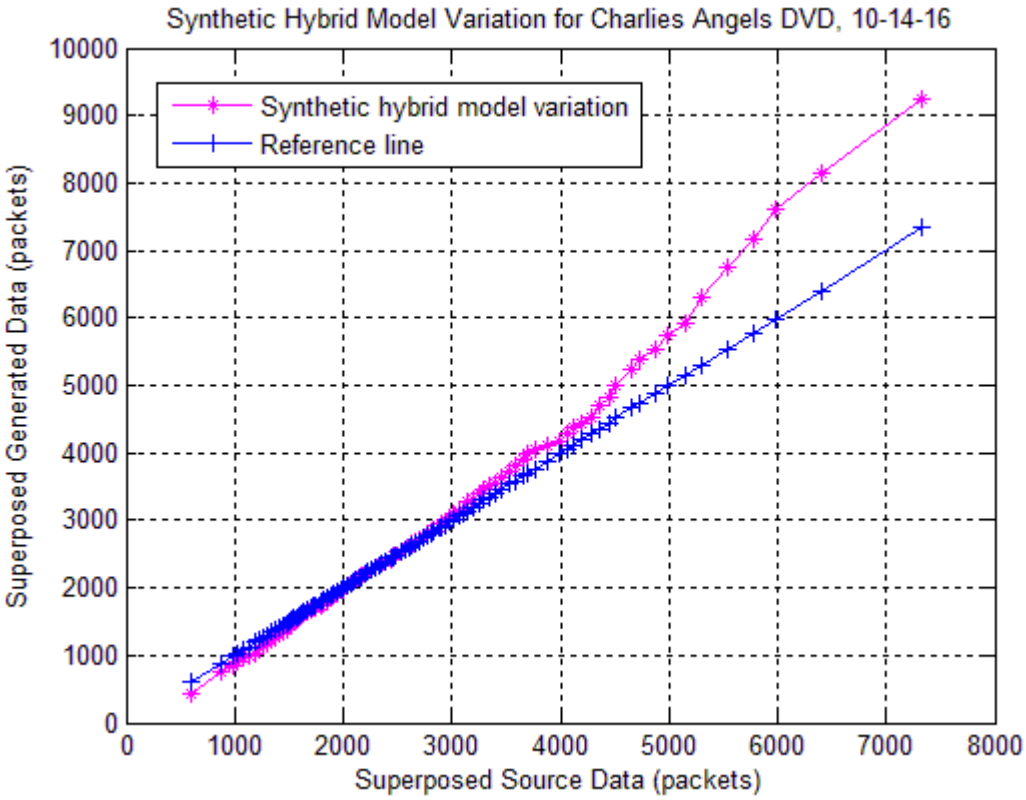

Figure 4.37 *Mediocre hybrid modeling result (5 sources)–*
Movie Burstiness = 15.2836, ρ = -0.0097

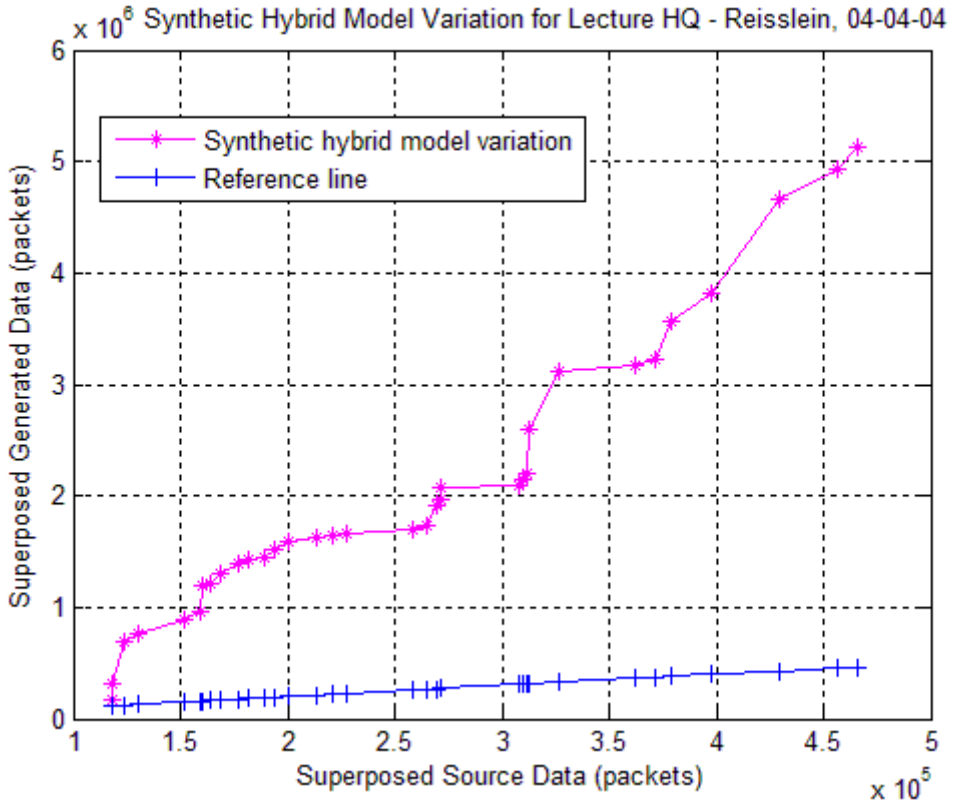

Figure 4.38 *Bad hybrid modeling result (5 sources)–*
Movie Burstiness = 6.2630, ρ = 0.0265

5. CONCLUSIONS

The importance of video traffic modeling is growing, as networks are required to handle video traffic competently. Network providers need to be able to guarantee the strict QoS requirements of video traffic.

Hence, in this work we investigate the possibility of modeling 21 MPEG-4 video traces, in 3 different quantization scales, with well-known distributions. The results show that there is not one distribution that is most suitable for all traces, but rather that the best distribution fit depends on the trace. Also, the behavior of video traffic is never perfectly "captured" by a distribution generating frame sizes independently, according to a declared mean and standard deviation. Thus, none of the fitting attempts used in the modeling part achieves perfect accuracy.

We first build a simple DAR(1) model and study the I, P and B frames of the traces separately. We then evaluate the synthetic model for multiplexed sources that stems from the respective frame type sequences. In most cases, the synthetic DAR(1) model produces results of mediocre accuracy.

Next, we build a new hybrid model which combines the DAR(1) model with scene change detection and scene classification techniques. The traces are split into Low activity and High activity ones and I, P and B frames are studied separately. Again, we evaluate the synthetic model for multiplexed sources that stems from the respective frame type sequences. In most cases, the synthetic hybrid model produces results of high accuracy. This model is shown to be the best out of the 3 models investigated in this work.

Finally, we build a variation of the hybrid model. Here, we do not study the P and B frames one by one, but instead, we study the sum of their sizes per High or Low activity scene. In most cases, the synthetic variation of the hybrid model produces results of low accuracy and thus, is proven to be the worst out of the 3 models studied.

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7. APPENDIX

PART 1: MPEG-4 VIDEO TRAFFIC MODELING

TABLE A.1.1 BURSTINESS AND AUTOCORRELATION OF TRACES

Video Trace	QL	Burstiness	Whole traces ρ	I framesρ	P frames ρ	B frames ρ
Die Hard One	30-30-30	9,1472	0,0899	0,8615	0,6613	0,7441
Die Hard One	10-14-16	13,6137	-0,0568	0,8636	0,6383	0,6674
Die Hard One	04-04-04	4,6747	0,1890	0,8586	0,7202	0,7026
Citizen Kane	30-30-30	12,6011	0,0726	0,9438	0,6641	0,7151
Citizen Kane	10-14-16	21,3502	-0,0381	0,9445	0,7716	0,7189
Citizen Kane	04-04-04	8,7353	0,3079	0,9458	0,8756	0,7714
Silence of the Lambs	30-30-30	13,3556	0,2516	0,9445	0,6833	0,7233
Silence of the Lambs	10-14-16	25,3863	0,0649	0,9486	0,7915	0,7792
Silence of the Lambs	04-04-04	8,7208	0,4860	0,9487	0,8946	0,8874
Star Wars IV	30-30-30	17,2887	0,0640	0,9230	0,5648	0,7176
Star Wars IV	10-14-16	24,1747	-0,0429	0,9261	0,6026	0,6898
Star Wars IV	04-04-04	7,6146	0,2636	0,9187	0,7545	0,7880
Terminator One	30-30-30	10,6104	0,1433	0,8941	0,6913	0,6969
Terminator One	10-14-16	11,8727	-0,0043	0,8890	0,7079	0,6313
Terminator One	04-04-04	8,3181	0,3504	0,8806	0,8051	0,6432
Aladdin	30-30-30	8,7022	0,1338	0,8898	0,6475	0,6831
Aladdin	10-14-16	10,6880	0,0062	0,8833	0,7314	0,6482
Aladdin	04-04-04	4,1148	0,4338	0,8655	0,8207	0,7575
Cinderella	30-30-30	14,8314	0,1574	0,8837	0,6112	0,7503
Cinderella	10-14-16	17,7077	0,0034	0,8967	0,6957	0,7190
Cinderella	04-04-04	6,8162	0,4489	0,9143	0,8300	0,8374
Tonight Show with Commercials	30-30-30	10,8904	0,0663	0,8741	0,6821	0,8951
Tonight Show with Commercials	10-14-16	9,2541	-0,0657	0,8825	0,7331	0,9168
Tonight Show with Commercials	04-04-04	3,1375	0,4439	0,8879	0,8380	0,9550
Tonight Show without Commercials	30-30-30	17,2279	0,1582	0,9768	0,7594	0,8655
Tonight Show without Commercials	10-14-16	20,0224	-0,0003	0,9875	0,7868	0,9357
Tonight Show without Commercials	04-04-04	7,2301	0,5721	0,9917	0,9345	0,9844
Lecture-Reisslein	30-30-30	13,7650	0,0155	0,9883	0,8095	0,7997
Lecture-Reisslein	10-14-16	12,7412	-0,0286	0,9905	0,9239	0,8949
Lecture-Reisslein	04-04-04	4,8860	0,7492	0,9926	0,9794	0,9905
Lecture HQ-	30-30-30	17,3268	0,1055	0,9891	0,4533	0,4692

Reisslein						
Lecture HQ-Reisslein	10-14-16	17,3022	-0,0472	0,9863	0,7072	0,5319
Lecture HQ-Reisslein	04-04-04	6,2630	0,0265	0,9856	0,8117	0,8533
Lecture-Gupta	30-30-30	11,8763	-0,0357	0,9794	0,5167	0,6622
Lecture-Gupta	10-14-16	12,2179	-0,0831	0,9805	0,8161	0,8189
Lecture-Gupta	04-04-04	3,2719	0,4167	0,9789	0,9310	0,9620
Baseball with Commercials	30-30-30	7,7539	0,1041	0,8811	0,7272	0,8308
Baseball with Commercials	10-14-16	12,8458	-0,0454	0,8858	0,7242	0,8619
Baseball with Commercials	04-04-04	4,3682	0,4102	0,8732	0,8332	0,9323
Friends vol.4 DVD	30-30-30	7,7106	0,0370	0,8744	0,4750	0,7384
Friends vol.4 DVD	10-14-16	13,8511	-0,0048	0,8794	0,4365	0,7513
Friends vol.4 DVD	04-04-04	7,8653	-0,0144	0,8851	0,5301	0,7598
Tokyo Olympics DVD	30-30-30	6,4080	0,0940	0,9466	0,7849	0,8358
Tokyo Olympics DVD	10-14-16	15,6132	0,0133	0,9495	0,8082	0,8288
Tokyo Olympics DVD	04-04-04	8,4844	0,4786	0,9480	0,8998	0,8234
O Brother DVD	30-30-30	7,1644	-0,0030	0,9510	0,6096	0,8089
O Brother DVD	10-14-16	16,5323	-0,0375	0,9521	0,6451	0,8497
O Brother DVD	04-04-04	9,1212	0,2542	0,9529	0,7897	0,8671
Die Another Day DVD	30-30-30	7,7205	0,0964	0,8719	0,5796	0,8173
Die Another Day DVD	10-14-16	13,7289	0,0074	0,8637	0,5822	0,8285
Die Another Day DVD	04-04-04	10,5521	0,3077	0,8554	0,6948	0,8295
The Transporter DVD	30-30-30	6,9980	0,2596	0,8473	0,5743	0,7987
The Transporter DVD	10-14-16	13,7398	0,0108	0,8503	0,5437	0,8096
The Transporter DVD	04-04-04	9,3042	0,2904	0,8481	0,6733	0,7895
Charlie's Angels DVD	30-30-30	6,6861	0,0523	0,8997	0,5930	0,8175
Charlie's Angels DVD	10-14-16	15,2836	-0,0097	0,8978	0,6189	0,8350
Charlie's Angels DVD	04-04-04	8,9197	0,3210	0,8939	0,7543	0,8323
Ice Age DVD	30-30-30	8,2625	0,2308	0,9159	0,4767	0,6982
Ice Age DVD	10-14-16	16,0508	-0,0012	0,9132	0,4399	0,7638
Ice Age DVD	04-04-04	12,2389	0,1519	0,9122	0,5510	0,8197
Oprah without Commercials	30-30-30	8,3512	0,0225	0,9046	0,6355	0,8745
Oprah without Commercials	10-14-16	10,0012	-0,0715	0,9107	0,7080	0,9587
Oprah without Commercials	04-04-04	2,9926	0,5668	0,9257	0,8897	0,9892

TABLE A.1.2 BEST DISTRIBUTION FIT CONCLUSIONS FOR WHOLE TRACES

Video Trace	QL	Q-Q plot	KL test	KS test	Conclusion
1. Die Hard One	30-30-30	-	-	-	Split into I, P, B
2. Die Hard One	10-14-16	-	-	-	Split into I, P, B
3. Die Hard One	04-04-04	-	-	-	Split into I, P, B
4. Citizen Kane	30-30-30	-	-	-	Split into I, P, B
5. Citizen Kane	10-14-16	-	-	-	Split into I, P, B
6. Citizen Kane	04-04-04	-	-	-	Split into I, P, B
7. Silence of the Lambs	30-30-30	-	-	-	Split into I, P, B
8. Silence of the Lambs	10-14-16	-	-	-	Split into I, P, B
9. Silence of the Lambs	04-04-04	-	-	-	Split into I, P, B
10. Star Wars IV	30-30-30	-	-	-	Split into I, P, B
11. Star Wars IV	10-14-16	-	-	-	Split into I, P, B
12. Star Wars IV	04-04-04	-	-	-	Split into I, P, B
13. Terminator One	30-30-30	-	-	-	Split into I, P, B
14. Terminator One	10-14-16	-	-	-	Split into I, P, B
15. Terminator One	04-04-04	Gamma	Lognormal	Gamma	Gamma
16. Aladdin	30-30-30	-	-	-	Split into I, P, B
17. Aladdin	10-14-16	-	-	-	Split into I, P, B
18. Aladdin	04-04-04	Lognormal	Negative Binomial	Pearson V	Split into I, P, B
19. Cinderella	30-30-30	-	-	-	Split into I, P, B
20. Cinderella	10-14-16	-	-	-	Split into I, P, B
21. Cinderella	04-04-04	Gamma	Lognormal	Lognormal	Lognormal
22. Tonight Show with Commercials	30-30-30	-	-	-	Split into I, P, B
23. Tonight Show with Commercials	10-14-16	-	-	-	Split into I, P, B
24. Tonight Show with Commercials	04-04-04	Pearson V	Lognormal	Lognormal	Lognormal
25. Tonight Show without Commercials	30-30-30	-	-	-	Split into I, P, B

26. Tonight Show without Commercials	10-14-16	-	-	-	Split into I, P, B
27. Tonight Show without Commercials	04-04-04	-	-	-	Split into I, P, B
28. Lecture-Reisslein	30-30-30	-	-	-	Split into I, P, B
29. Lecture-Reisslein	10-14-16	-	-	-	Split into I, P, B
30. Lecture-Reisslein	04-04-04	-	-	-	Split into I, P, B
31. Lecture HQ-Reisslein	30-30-30	-	-	-	Split into I, P, B
32. Lecture HQ-Reisslein	10-14-16	-	-	-	Split into I, P, B
33. Lecture HQ-Reisslein	04-04-04	-	-	-	Split into I, P, B
34. Lecture-Gupta	30-30-30	-	-	-	Split into I, P, B
35. Lecture-Gupta	10-14-16	-	-	-	Split into I, P, B
36. Lecture-Gupta	04-04-04	-	-	-	Split into I, P, B
37. Baseball with Commercials	30-30-30	-	-	-	Split into I, P, B
38. Baseball with Commercials	10-14-16	-	-	-	Split into I, P, B
39. Baseball with Commercials	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
40. Friends vol.4 DVD	30-30-30	-	-	-	Split into I, P, B
41. Friends vol.4 DVD	10-14-16	-	-	-	Split into I, P, B
42. Friends vol.4 DVD	04-04-04	-	-	-	Split into I, P, B
43. Tokyo Olympics DVD	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
44. Tokyo Olympics DVD	10-14-16	-	-	-	Split into I, P, B
45. Tokyo Olympics DVD	04-04-04	Gamma	Negative Binomial	Weibull	Split into I, P, B
46. O Brother DVD	30-30-30	-	-	-	Split into I, P, B
47. O Brother DVD	10-14-16	-	-	-	Split into I, P, B
48. O Brother DVD	04-04-04	-	-	-	Split into I, P, B
49. Die Another Day DVD	30-30-30	-	-	-	Split into I, P, B
50. Die Another Day DVD	10-14-16	-	-	-	Split into I, P, B
51. Die Another Day DVD	04-04-04	-	-	-	Split into I, P, B
52. The Transporter DVD	30-30-30	Gamma	Lognormal	Weibull	Lognormal
53. The Transporter DVD	10-14-16	-	-	-	Split into I, P, B

54. The Transporter DVD	04-04-04	-	-	-	Split into I, P, B
55. Charlie's Angels DVD	30-30-30	-	-	-	Split into I, P, B
56. Charlie's Angels DVD	10-14-16	-	-	-	Split into I, P, B
57. Charlie's Angels DVD	04-04-04	-	-	-	Split into I, P, B
58. Ice Age DVD	30-30-30	-	-	-	Split into I, P, B
59. Ice Age DVD	10-14-16	-	-	-	Split into I, P, B
60. Ice Age DVD	04-04-04	-	-	-	Split into I, P, B
61. Oprah without Commercials	30-30-30	-	-	-	Split into I, P, B
62. Oprah without Commercials	10-14-16	-	-	-	Split into I, P, B
63. Oprah without Commercials	04-04-04	-	-	-	Split into I, P, B

TABLE A.1.3 BEST DISTRIBUTION FIT CONCLUSIONS FOR I FRAME TRACES

Video Trace	QL	Q-Q plot	KL test	KS test	Conclusion
1. Die Hard One	30-30-30	Lognormal	Negative Binomial	Pearson V	Exclude from DAR(1) modeling
2. Die Hard One	10-14-16	Gamma	Lognormal	Gamma	Gamma
3. Die Hard One	04-04-04	Weibull	Lognormal	Gamma	Exclude from DAR(1) modeling
4. Citizen Kane	30-30-30	Pearson V	Negative Binomial	Pearson V	Pearson V
5. Citizen Kane	10-14-16	Lognormal	Lognormal	Gamma	Lognormal
6. Citizen Kane	04-04-04	Lognormal	Lognormal	Negative Binomial	Lognormal
7. Silence of the Lambs	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
8. Silence of the Lambs	10-14-16	Pearson V	Lognormal	Pearson V	Pearson V
9. Silence of the Lambs	04-04-04	Lognormal	Lognormal	Pearson V	Lognormal
10. Star Wars IV	30-30-30	Lognormal	Lognormal	Pearson V	Lognormal
11. Star Wars IV	10-14-16	Gamma	Lognormal	Lognormal	Lognormal
12. Star Wars IV	04-04-04	Weibull	Negative Binomial	Weibull	Weibull
13. Terminator One	30-30-30	Lognormal	Negative Binomial	Lognormal	Lognormal
14. Terminator One	10-14-16	Gamma	Negative Binomial	Gamma	Gamma

15. Terminator One	*04-04-04*				
16. Aladdin	30-30-30	Weibull	Negative Binomial	Weibull	Weibull
17. Aladdin	10-14-16	Weibull	Lognormal	Weibull	Weibull
18. Aladdin	04-04-04	Gamma	Lognormal	Gamma	Gamma
19. Cinderella	30-30-30	Lognormal	Lognormal	Gamma	Lognormal
20. Cinderella	10-14-16	Gamma	Lognormal	Gamma	Gamma
21. Cinderella	*04-04-04*				
22. Tonight Show with Commercials	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
23. Tonight Show with Commercials	10-14-16	Weibull	Negative Binomial	Weibull	Weibull
24. Tonight Show with Commercials	*04-04-04*				
25. Tonight Show without Commercials	30-30-30	Weibull	Negative Binomial	Weibull	Weibull
26. Tonight Show without Commercials	10-14-16	Weibull	Lognormal	Weibull	Weibull
27. Tonight Show without Commercials	04-04-04	Weibull	Lognormal	Weibull	Weibull
28. Lecture-Reisslein	30-30-30	Gamma	Lognormal	Weibull	Lognormal
29. Lecture-Reisslein	10-14-16	Weibull	Negative Binomial	Weibull	Weibull
30. Lecture-Reisslein	04-04-04	Gamma	Lognormal	Negative Binomial	Lognormal
31. Lecture HQ-Reisslein	30-30-30	Pearson V	Negative Binomial	Pearson V	Pearson V
32. Lecture HQ-Reisslein	10-14-16	Pearson V	Negative Binomial	Pearson V	Pearson V
33. Lecture HQ-Reisslein	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
34. Lecture-Gupta	30-30-30	Pearson V	Lognormal	Lognormal	Lognormal
35. Lecture-Gupta	10-14-16	Pearson V	Negative Binomial	Pearson V	Pearson V
36. Lecture-Gupta	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
37. Baseball with Commercials	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
38. Baseball with Commercials	10-14-16	Weibull	Negative Binomial	Weibull	Weibull
39. Baseball with Commercials	*04-04-04*				
40. Friends vol.4 DVD	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
41. Friends vol.4 DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma

42. Friends vol.4 DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
43. Tokyo Olympics DVD	*30-30-30*				
44. Tokyo Olympics DVD	10-14-16	Lognormal	Negative Binomial	Lognormal	Lognormal
45. Tokyo Olympics DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
46. O Brother DVD	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
47. O Brother DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
48. O Brother DVD	04-04-04	Weibull	Lognormal	Weibull	Weibull
49. Die Another Day DVD	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
50. Die Another Day DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
51. Die Another Day DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
52. The Transporter DVD	*30-30-30*				
53. The Transporter DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
54. The Transporter DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
55. Charlie's Angels DVD	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
56. Charlie's Angels DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
57. Charlie's Angels DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
58. Ice Age DVD	30-30-30	Gamma	Lognormal	Gamma	Gamma
59. Ice Age DVD	10-14-16	Weibull	Lognormal	Weibull	Weibull
60. Ice Age DVD	04-04-04	Weibull	Lognormal	Weibull	Weibull
61. Oprah without Commercials	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
62. Oprah without Commercials	10-14-16	Weibull	Lognormal	Weibull	Weibull
63. Oprah without Commercials	04-04-04	Gamma	Negative Binomial	Negative Binomial	Negative Binomial

TABLE A.1.4 BEST DISTRIBUTION FIT CONCLUSIONS FOR P FRAME TRACES

Video Trace	QL	Q-Q plot	KL test	KS test	Conclusion
1. Die Hard One	30-30-30	Gamma	Lognormal	Gamma	Gamma
2. Die Hard One	10-14-16	Gamma	Lognormal	Gamma	Gamma
3. Die Hard One	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
4. Citizen Kane	30-30-30	Lognormal	Negative Binomial	Lognormal	Lognormal
5. Citizen Kane	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
6. Citizen Kane	04-04-04	Lognormal	Lognormal	Lognormal	Lognormal
7. Silence of the Lambs	30-30-30	Lognormal	Negative Binomial	Gamma	Exclude from DAR(1) modeling
8. Silence of the Lambs	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
9. Silence of the Lambs	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
10. Star Wars IV	30-30-30	Lognormal	Lognormal	Gamma	Lognormal
11. Star Wars IV	10-14-16	Lognormal	Negative Binomial	Lognormal	Lognormal
12. Star Wars IV	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
13. Terminator One	30-30-30	Gamma	Lognormal	Gamma	Gamma
14. Terminator One	10-14-16	Gamma	Lognormal	Weibull	Lognormal
15. Terminator One	*04-04-04*				
16. Aladdin	30-30-30	Lognormal	Negative Binomial	Lognormal	Lognormal
17. Aladdin	10-14-16	Lognormal	Lognormal	Negative Binomial	Lognormal
18. Aladdin	04-04-04	Lognormal	Negative Binomial	Lognormal	Lognormal
19. Cinderella	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
20. Cinderella	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
21. Cinderella	*04-04-04*				
22. Tonight Show with Commercials	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
23. Tonight Show with Commercials	10-14-16	Pearson V	Lognormal	Pearson V	Pearson V
24. Tonight Show with Commercials	*04-04-04*				
25. Tonight Show without	30-30-30	Gamma	Lognormal	Gamma	Gamma

Commercials					
26. Tonight Show without Commercials	10-14-16	Gamma	Lognormal	Gamma	Gamma
27. Tonight Show without Commercials	04-04-04	Lognormal	Lognormal	Geometric	Lognormal
28. Lecture-Reisslein	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
29. Lecture-Reisslein	10-14-16	Lognormal	Lognormal	Weibull	Lognormal
30. Lecture-Reisslein	04-04-04	Weibull	Lognormal	Negative Binomial	Exclude from DAR(1) modeling
31. Lecture HQ-Reisslein	30-30-30	Gamma	Lognormal	Gamma	Gamma
32. Lecture HQ-Reisslein	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
33. Lecture HQ-Reisslein	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
34. Lecture-Gupta	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
35. Lecture-Gupta	10-14-16	Pearson V	Lognormal	Lognormal	Lognormal
36. Lecture-Gupta	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
37. Baseball with Commercials	30-30-30	Gamma	Lognormal	Gamma	Gamma
38. Baseball with Commercials	10-14-16	Gamma	Negative Binomial	Gamma	Gamma
39. Baseball with Commercials	*04-04-04*				
40. Friends vol.4 DVD	30-30-30	Pearson V	Negative Binomial	Weibull	Exclude from DAR(1) modeling
41. Friends vol.4 DVD	10-14-16	Lognormal	Lognormal	Geometric	Lognormal
42. Friends vol.4 DVD	04-04-04	Lognormal	Negative Binomial	Lognormal	Lognormal
43. Tokyo Olympics DVD	*30-30-30*				
44. Tokyo Olympics DVD	10-14-16	Weibull	Lognormal	Weibull	Weibull
45. Tokyo Olympics DVD	04-04-04	Weibull	Lognormal	Weibull	Weibull
46. O Brother DVD	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
47. O Brother DVD	10-14-16	Geometric	Lognormal	Negative Binomial	Exclude from DAR(1) modeling
48. O Brother DVD	04-04-04	Weibull	Lognormal	Weibull	Weibull
49. Die Another Day DVD	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
50. Die Another Day DVD	10-14-16	Gamma	Negative Binomial	Gamma	Gamma

51. Die Another Day DVD	04-04-04	Weibull	Lognormal	Gamma	Exclude from DAR(1) modeling
52. The Transporter DVD	*30-30-30*				
53. The Transporter DVD	10-14-16	Gamma	Negative Binomial	Gamma	Gamma
54. The Transporter DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
55. Charlie's Angels DVD	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
56. Charlie's Angels DVD	10-14-16	Lognormal	Negative Binomial	Gamma	Exclude from DAR(1) modeling
57. Charlie's Angels DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
58. Ice Age DVD	30-30-30	Lognormal	Lognormal	Gamma	Lognormal
59. Ice Age DVD	10-14-16	Lognormal	Lognormal	Exponential	Lognormal
60. Ice Age DVD	04-04-04	Gamma	Negative Binomial	Gamma	Gamma
61. Oprah without Commercials	30-30-30	Lognormal	Lognormal	Pearson V	Lognormal
62. Oprah without Commercials	10-14-16	Lognormal	Lognormal	Weibull	Lognormal
63. Oprah without Commercials	04-04-04	Weibull	Negative Binomial	Negative Binomial	Negative Binomial

TABLE A.1.5 BEST DISTRIBUTION FIT CONCLUSIONS FOR B FRAME TRACES

Video Trace	QL	Q-Q plot	KL test	KS test	Conclusion
1. Die Hard One	30-30-30	Gamma	Lognormal	Gamma	Gamma
2. Die Hard One	10-14-16	Gamma	Lognormal	Gamma	Gamma
3. Die Hard One	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
4. Citizen Kane	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
5. Citizen Kane	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
6. Citizen Kane	04-04-04	Lognormal	Lognormal	Pearson V	Lognormal
7. Silence of the Lambs	30-30-30	Weibull	Negative Binomial	Weibull	Weibull
8. Silence of the Lambs	10-14-16	Exponential	Lognormal	Lognormal	Lognormal
9. Silence of the Lambs	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
10. Star Wars IV	30-30-30	Gamma	Lognormal	Gamma	Gamma
11. Star Wars IV	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal

12. Star Wars IV	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
13. Terminator One	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
14. Terminator One	10-14-16	Gamma	Negative Binomial	Gamma	Gamma
15. Terminator One	*04-04-04*				
16. Aladdin	30-30-30	Lognormal	Negative Binomial	Lognormal	Lognormal
17. Aladdin	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
18. Aladdin	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
19. Cinderella	30-30-30	Lognormal	Negative Binomial	Lognormal	Lognormal
20. Cinderella	10-14-16	Lognormal	Negative Binomial	Lognormal	Lognormal
21. Cinderella	*04-04-04*				
22. Tonight Show with Commercials	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
23. Tonight Show with Commercials	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
24. Tonight Show with Commercials	*04-04-04*				
25. Tonight Show without Commercials	30-30-30	Gamma	Lognormal	Geometric	Exclude from DAR(1) modeling
26. Tonight Show without Commercials	10-14-16	Weibull	Lognormal	Weibull	Weibull
27. Tonight Show without Commercials	04-04-04	Lognormal	Lognormal	Weibull	Lognormal
28. Lecture-Reisslein	30-30-30	Weibull	Lognormal	Negative Binomial	Exclude from DAR(1) modeling
29. Lecture-Reisslein	10-14-16	Lognormal	Lognormal	Weibull	Lognormal
30. Lecture-Reisslein	04-04-04	Weibull	Lognormal	Weibull	Weibull
31. Lecture HQ-Reisslein	30-30-30	Weibull	Lognormal	Weibull	Weibull
32. Lecture HQ-Reisslein	10-14-16	Gamma	Negative Binomial	Gamma	Gamma
33. Lecture HQ-Reisslein	04-04-04	Lognormal	Lognormal	Lognormal	Lognormal
34. Lecture-Gupta	30-30-30	Gamma	Lognormal	Lognormal	Lognormal
35. Lecture-Gupta	10-14-16	Pearson V	Lognormal	Lognormal	Lognormal
36. Lecture-Gupta	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
37. Baseball with Commercials	30-30-30	Gamma	Lognormal	Gamma	Gamma

38. Baseball with Commercials	10-14-16	Lognormal	Lognormal	Gamma	Lognormal
39. Baseball with Commercials	*04-04-04*				
40. Friends vol.4 DVD	30-30-30	Weibull	Lognormal	Weibull	Weibull
41. Friends vol.4 DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
42. Friends vol.4 DVD	04-04-04	Gamma	Negative Binomial	Gamma	Gamma
43. Tokyo Olympics DVD	*30-30-30*				
44. Tokyo Olympics DVD	10-14-16	Weibull	Lognormal	Weibull	Weibull
45. Tokyo Olympics DVD	04-04-04	Weibull	Negative Binomial	Geometric	Exclude from DAR(1) modeling
46. O Brother DVD	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
47. O Brother DVD	10-14-16	Gamma	Lognormal	Negative Binomial	Exclude from DAR(1) modeling
48. O Brother DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
49. Die Another Day DVD	30-30-30	Gamma	Lognormal	Gamma	Gamma
50. Die Another Day DVD	10-14-16	Exponential	Lognormal	Exponential	Exponential
51. Die Another Day DVD	04-04-04	Gamma	Lognormal	Geometric	Exclude from DAR(1) modeling
52. The Transporter DVD	*30-30-30*				
53. The Transporter DVD	10-14-16	Weibull	Lognormal	Weibull	Weibull
54. The Transporter DVD	04-04-04	Gamma	Negative Binomial	Gamma	Gamma
55. Charlie's Angels DVD	30-30-30	Gamma	Lognormal	Gamma	Gamma
56. Charlie's Angels DVD	10-14-16	Lognormal	Lognormal	Gamma	Lognormal
57. Charlie's Angels DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
58. Ice Age DVD	30-30-30	Weibull	Negative Binomial	Weibull	Weibull
59. Ice Age DVD	10-14-16	Weibull	Lognormal	Weibull	Weibull
60. Ice Age DVD	04-04-04	Exponential	Lognormal	Weibull	Exclude from DAR(1) modeling
61. Oprah without Commercials	30-30-30	Weibull	Negative Binomial	Weibull	Weibull
62. Oprah without Commercials	10-14-16	Gamma	Lognormal	Weibull	Lognormal
63. Oprah without Commercials	04-04-04	Weibull	Lognormal	Weibull	Weibull

TABLE A.1.6 INFORMATION ON DAR(1) MODELING OF WHOLE TRACES

Video Trace	QL	BEST FIT	Max Frame Size (Bytes)	States In DAR	Autocorrelation
15. Terminator One	04-04-04	Gamma	7367	123	0,3504
21. Cinderella	04-04-04	Lognormal	11283	132	0,4489
24. Tonight Show with Commercials	04-04-04	Lognormal	10281	114	0,4439
39. Baseball with Commercials	04-04-04	Pearson V	7749	91	0,4102
43. Tokyo Olympics DVD	30-30-30	Lognormal	11048	38	0,0940
52. The Transporter DVD	30-30-30	Lognormal	11792	38	0,2596

Packet size = 48 Bytes/packet for the 30-30-30 movie traces and 200 Bytes/packet for the rest

TABLE A.1.7 INFORMATION ON DAR(1) MODELING OF I FRAME TRACES

Video Trace	QL	BEST FIT	Max Frame Size (Bytes)	States In DAR	Autocorrelation
1. Die Hard One	30-30-30				
2. Die Hard One	10-14-16	Gamma	6897	35	0,8636
3. Die Hard One	04-04-04				
4. Citizen Kane	30-30-30	Pearson V	2731	57	0,9438
5. Citizen Kane	10-14-16	Lognormal	8406	43	0,9445
6. Citizen Kane	04-04-04	Lognormal	14495	73	0,9458
7. Silence of the Lambs	30-30-30	Pearson V	2858	60	0,9445
8. Silence of the Lambs	10-14-16	Pearson V	8450	43	0,9486
9. Silence of the Lambs	04-04-04	Lognormal	14938	75	0,9487
10. Star Wars IV	30-30-30	Lognormal	4279	90	0,9230
11. Star Wars IV	10-14-16	Lognormal	9992	50	0,9261
12. Star Wars IV	04-04-04	Weibull	16816	85	0,9187
13. Terminator One	30-30-30	Lognormal	2399	50	0,8941

14. Terminator One	10-14-16	Gamma	6762	34	0,8890
15. Terminator One	*04-04-04*				
16. Aladdin	30-30-30	Weibull	3286	69	0,8898
17. Aladdin	10-14-16	Weibull	9345	47	0,8833
18. Aladdin	04-04-04	Gamma	17364	87	0,8655
19. Cinderella	30-30-30	Lognormal	4598	96	0,8837
20. Cinderella	10-14-16	Gamma	11283	57	0,8967
21. Cinderella	*04-04-04*				
22. Tonight Show with Commercials	30-30-30	Gamma	4143	87	0,8741
23. Tonight Show with Commercials	10-14-16	Weibull	10281	52	0,8825
24. Tonight Show with Commercials	*04-04-04*				
25. Tonight Show without Commercials	30-30-30	Weibull	3261	68	0,9768
26. Tonight Show without Commercials	10-14-16	Weibull	8782	44	0,9875
27. Tonight Show without Commercials	04-04-04	Weibull	16055	81	0,9917
28. Lecture-Reisslein	30-30-30	Lognormal	3011	63	0,9883
29. Lecture-Reisslein	10-14-16	Weibull	8962	45	0,9905
30. Lecture-Reisslein	04-04-04	Lognormal	16705	84	0,9926
31. Lecture HQ-Reisslein	30-30-30	Pearson V	6778	142	0,9891
32. Lecture HQ-Reisslein	10-14-16	Pearson V	18575	93	0,9863
33. Lecture HQ-Reisslein	04-04-04	Pearson V	36853	185	0,9856
34. Lecture-Gupta	30-30-30	Lognormal	3475	73	0,9794
35. Lecture-Gupta	10-14-16	Pearson V	9242	47	0,9805
36. Lecture-Gupta	04-04-04	Pearson V	16668	84	0,9789
37. Baseball with Commercials	30-30-30	Gamma	2397	50	0,8811
38. Baseball with Commercials	10-14-16	Weibull	7749	39	0,8858
39. Baseball with Commercials	*04-04-04*				
40. Friends vol.4 DVD	30-30-30	Lognormal	1598	34	0,8744
41. Friends vol.4 DVD	10-14-16	Gamma	4898	25	0,8794

42. Friends vol.4 DVD	04-04-04	Gamma	10185	51	0,8851
43. Tokyo Olympics DVD	*30-30-30*				
44. Tokyo Olympics DVD	10-14-16	Lognormal	6549	33	0,9495
45. Tokyo Olympics DVD	04-04-04	Gamma	11555	58	0,9480
46. O Brother DVD	30-30-30	Gamma	1539	33	0,9510
47. O Brother DVD	10-14-16	Gamma	5210	27	0,9521
48. O Brother DVD	04-04-04	Weibull	10207	52	0,9529
49. Die Another Day DVD	30-30-30	Pearson V	1321	28	0,8719
50. Die Another Day DVD	10-14-16	Gamma	4039	85	0,8637
51. Die Another Day DVD	04-04-04	Gamma	8276	42	0,8554
52. The Transporter DVD	*30-30-30*				
53. The Transporter DVD	10-14-16	Gamma	4904	25	0,8503
54. The Transporter DVD	04-04-04	Gamma	10768	54	0,8481
55. Charlie's Angels DVD	30-30-30	Lognormal	1670	35	0,8997
56. Charlie's Angels DVD	10-14-16	Gamma	5433	28	0,8978
57. Charlie's Angels DVD	04-04-04	Gamma	10945	55	0,8939
58. Ice Age DVD	30-30-30	Gamma	1170	25	0,9159
59. Ice Age DVD	10-14-16	Weibull	4410	92	0,9132
60. Ice Age DVD	04-04-04	Weibull	10524	53	0,9122
61. Oprah without Commercials	30-30-30	Gamma	2370	50	0,9046
62. Oprah without Commercials	10-14-16	Weibull	7610	39	0,9107
63. Oprah without Commercials	04-04-04				

TABLE A.1.8 INFORMATION ON DAR(1) MODELING OF P FRAME TRACES

Video Trace	QL	BEST FIT	Max Frame Size (Bytes)	States In DAR	Autocorrelation
1. Die Hard One	30-30-30	Gamma	1971	42	0,6613
2. Die Hard One	10-14-16	Gamma	3930	82	0,6383
3. Die Hard One	04-04-04	Pearson V	12952	65	0,7202
4. Citizen Kane	30-30-30	Lognormal	2331	49	0,6641
5. Citizen Kane	10-14-16	Lognormal	5744	29	0,7716
6. Citizen Kane	04-04-04	Lognormal	16633	84	0,8756
7. Silence of the Lambs	30-30-30				
8. Silence of the Lambs	10-14-16	Lognormal	5293	27	0,7915
9. Silence of the Lambs	04-04-04	Pearson V	16406	83	0,8946
10. Star Wars IV	30-30-30	Lognormal	2381	50	0,5648
11. Star Wars IV	10-14-16	Lognormal	5774	29	0,6026
12. Star Wars IV	04-04-04	Pearson V	17518	88	0,7545
13. Terminator One	30-30-30	Gamma	2441	51	0,6913
14. Terminator One	10-14-16	Lognormal	5278	27	0,7079
15. Terminator One	*04-04-04*				
16. Aladdin	30-30-30	Lognormal	3291	69	0,6475
17. Aladdin	10-14-16	Lognormal	7538	38	0,7314
18. Aladdin	04-04-04	Lognormal	22560	113	0,8207
19. Cinderella	30-30-30	Lognormal	3980	83	0,6112
20. Cinderella	10-14-16	Lognormal	9553	48	0,6957
21. Cinderella	*04-04-04*				
22. Tonight Show with Commercials	30-30-30	Lognormal	4047	85	0,6821
23. Tonight Show with Commercials	10-14-16	Pearson V	8728	44	0,7331
24. Tonight Show with Commercials	*04-04-04*				
25. Tonight Show without Commercials	30-30-30	Gamma	3338	70	0,7594
26. Tonight Show without Commercials	10-14-16	Gamma	7356	37	0,7868
27. Tonight Show without	04-04-04	Lognormal	19820	100	0,9345

Commercials					
28. Lecture-Reisslein	30-30-30	Gamma	4099	86	0,8095
29. Lecture-Reisslein	10-14-16	Lognormal	10258	52	0,9239
30. Lecture-Reisslein	04-04-04				
31. Lecture HQ-Reisslein	30-30-30	Gamma	7642	160	0,4533
32. Lecture HQ-Reisslein	10-14-16	Lognormal	14442	73	0,7072
33. Lecture HQ-Reisslein	04-04-04	Pearson V	37267	187	0,8117
34. Lecture-Gupta	30-30-30	Pearson V	2350	49	0,5167
35. Lecture-Gupta	10-14-16	Lognormal	5557	28	0,8161
36. Lecture-Gupta	04-04-04	Pearson V	16968	85	0,9310
37. Baseball with Commercials	30-30-30	Gamma	2338	49	0,7272
38. Baseball with Commercials	10-14-16	Gamma	5704	29	0,7242
39. Baseball with Commercials	*04-04-04*				
40. Friends vol.4 DVD	30-30-30				
41. Friends vol.4 DVD	10-14-16	Lognormal	3337	70	0,4365
42. Friends vol.4 DVD	04-04-04	Lognormal	11048	56	0,5301
43. Tokyo Olympics DVD	*30-30-30*				
44. Tokyo Olympics DVD	10-14-16	Weibull	4135	87	0,8082
45. Tokyo Olympics DVD	04-04-04	Weibull	14114	71	0,8998
46. O Brother DVD	30-30-30	Lognormal	1442	31	0,6096
47. O Brother DVD	10-14-16				
48. O Brother DVD	04-04-04	Weibull	11367	57	0,7897
49. Die Another Day DVD	30-30-30	Lognormal	1853	39	0,5796
50. Die Another Day DVD	10-14-16	Gamma	4246	89	0,5822
51. Die Another Day DVD	04-04-04				
52. The Transporter DVD	*30-30-30*				
53. The Transporter DVD	10-14-16	Gamma	3384	71	0,5437
54. The Transporter DVD	04-04-04	Gamma	11559	58	0,6733
55. Charlie's Angels DVD	30-30-30	Lognormal	1642	35	0,5930
56. Charlie's Angels	10-14-16				

DVD					
57. Charlie's Angels DVD	04-04-04	Gamma	11400	57	0,7543
58. Ice Age DVD	30-30-30	Lognormal	1374	29	0,4767
59. Ice Age DVD	10-14-16	Lognormal	2951	62	0,4399
60. Ice Age DVD	04-04-04	Gamma	10686	54	0,5510
61. Oprah without Commercials	30-30-30	Lognormal	2127	45	0,6355
62. Oprah without Commercials	10-14-16	Lognormal	5375	27	0,7080
63. Oprah without Commercials	04-04-04	Negative Binomial	16771	84	0,8897

TABLE A.1.9 INFORMATION ON DAR(1) MODELING OF B FRAME TRACES

Video Trace	QL	BEST FIT	Max Frame Size (Bytes)	States In DAR	Autocorrelation
1. Die Hard One	30-30-30	Gamma	1649	35	0,7441
2. Die Hard One	10-14-16	Gamma	2795	59	0,6674
3. Die Hard One	04-04-04	Pearson V	10424	53	0,7026
4. Citizen Kane	30-30-30	Gamma	1260	27	0,7151
5. Citizen Kane	10-14-16	Lognormal	2283	48	0,7189
6. Citizen Kane	04-04-04	Lognormal	9910	50	0,7714
7. Silence of the Lambs	30-30-30	Weibull	1654	35	0,7233
8. Silence of the Lambs	10-14-16	Lognormal	3751	79	0,7792
9. Silence of the Lambs	04-04-04	Pearson V	14630	74	0,8874
10. Star Wars IV	30-30-30	Gamma	1954	41	0,7176
11. Star Wars IV	10-14-16	Lognormal	3767	79	0,6898
12. Star Wars IV	04-04-04	Pearson V	14214	72	0,7880
13. Terminator One	30-30-30	Gamma	3455	72	0,6969
14. Terminator One	10-14-16	Gamma	7367	37	0,6313
15. Terminator One	*04-04-04*				
16. Aladdin	30-30-30	Lognormal	2929	62	0,6831
17. Aladdin	10-14-16	Lognormal	6103	31	0,6482
18. Aladdin	04-04-04	Pearson V	21746	109	0,7575

19. Cinderella	30-30-30	Lognormal	3429	72	0,7503
20. Cinderella	10-14-16	Lognormal	7401	38	0,7190
21. Cinderella	*04-04-04*				
22. Tonight Show with Commercials	30-30-30	Lognormal	2336	49	0,8951
23. Tonight Show with Commercials	10-14-16	Lognormal	5237	27	0,9168
24. Tonight Show with Commercials	*04-04-04*				
25. Tonight Show without Commercials	30-30-30				
26. Tonight Show without Commercials	10-14-16	Weibull	3906	82	0,9357
27. Tonight Show without Commercials	04-04-04	Lognormal	16683	84	0,9844
28. Lecture-Reisslein	30-30-30				
29. Lecture-Reisslein	10-14-16	Lognormal	3580	75	0,8949
30. Lecture-Reisslein	04-04-04	Weibull	15419	78	0,9905
31. Lecture HQ-Reisslein	30-30-30	Weibull	11386	238	0,4692
32. Lecture HQ-Reisslein	10-14-16	Gamma	16696	84	0,5319
33. Lecture HQ-Reisslein	04-04-04	Lognormal	40203	202	0,8533
34. Lecture-Gupta	30-30-30	Lognormal	1814	38	0,6622
35. Lecture-Gupta	10-14-16	Lognormal	3444	72	0,8189
36. Lecture-Gupta	04-04-04	Pearson V	13391	67	0,9620
37. Baseball with Commercials	30-30-30	Gamma	1779	38	0,8308
38. Baseball with Commercials	10-14-16	Lognormal	2988	63	0,8619
39. Baseball with Commercials	*04-04-04*				
40. Friends vol.4 DVD	30-30-30	Weibull	1342	28	0,7384
41. Friends vol.4 DVD	10-14-16	Gamma	2630	55	0,7513
42. Friends vol.4 DVD	04-04-04	Gamma	10698	54	0,7598
43. Tokyo Olympics DVD	*30-30-30*				
44. Tokyo Olympics DVD	10-14-16	Weibull	2320	49	0,8288
45. Tokyo Olympics DVD	*04-04-04*				
46. O Brother DVD	30-30-30	Gamma	1266	27	0,8089

47. O Brother DVD	10-14-16				
48. O Brother DVD	04-04-04	Gamma	7798	39	0,8671
49. Die Another Day DVD	30-30-30	Gamma	1357	29	0,8173
50. Die Another Day DVD	10-14-16	Exponential	2240	47	0,8285
51. Die Another Day DVD	04-04-04				
52. The Transporter DVD	*30-30-30*				
53. The Transporter DVD	10-14-16	Weibull	2473	52	0,8096
54. The Transporter DVD	04-04-04	Gamma	9586	48	0,7895
55. Charlie's Angels DVD	30-30-30	Gamma	1341	28	0,8175
56. Charlie's Angels DVD	10-14-16	Lognormal	2799	59	0,8350
57. Charlie's Angels DVD	04-04-04	Gamma	12117	61	0,8323
58. Ice Age DVD	30-30-30	Weibull	1623	34	0,6982
59. Ice Age DVD	10-14-16	Weibull	2342	49	0,7638
60. Ice Age DVD	04-04-04				
61. Oprah without Commercials	30-30-30	Weibull	1193	25	0,8745
62. Oprah without Commercials	10-14-16	Lognormal	2696	57	0,9587
63. Oprah without Commercials	04-04-04	Weibull	13269	67	0,9892

Packet size = 48 Bytes/packet for the 30-30-30 movie traces and the traces highlighted red, 200 Bytes/packet for the rest

TABLE A.1.10 PACKET SIZE USED IN FINAL DAR(1) MODELING (SECTION 2.4)

Movie Trace	Packet Size
Die Hard One, 10-14-16	48 Bytes/Packet
Citizen Kane, 30-30-30	48 Bytes/Packet
Citizen Kane, 10-14-16	48 Bytes/Packet
Citizen Kane, 04-04-04	200 Bytes/Packet
Silence of the Lambs, 10-14-16	48 Bytes/Packet
Silence of the Lambs, 04-04-04	200 Bytes/Packet
Star Wars IV, 30-30-30	48 Bytes/Packet
Star Wars IV, 10-14-16	48 Bytes/Packet
Star Wars IV, 04-04-04	200 Bytes/Packet
Terminator One, 30-30-30	48 Bytes/Packet
Terminator One, 10-14-16	200 Bytes/Packet
Aladdin, 30-30-30	48 Bytes/Packet
Aladdin, 10-14-16	200 Bytes/Packet
Aladdin, 04-04-04	200 Bytes/Packet
Cinderella, 30-30-30	48 Bytes/Packet
Cinderella, 10-14-16	200 Bytes/Packet
Tonight Show with Commercials, 30-30-30	48 Bytes/Packet
Tonight Show with Commercials, 10-14-16	200 Bytes/Packet
Tonight Show without Commercials, 10-14-16	48 Bytes/Packet
Tonight Show without Commercials, 04-04-04	200 Bytes/Packet
Lecture - Reisslein, 10-14-16	48 Bytes/Packet
Lecture HQ - Reisslein, 30-30-30	48 Bytes/Packet
Lecture HQ - Reisslein, 10-14-16	200 Bytes/Packet
Lecture HQ - Reisslein, 04-04-04	200 Bytes/Packet
Lecture - Gupta, 30-30-30	48 Bytes/Packet
Lecture - Gupta, 10-14-16	48 Bytes/Packet
Lecture - Gupta, 04-04-04	200 Bytes/Packet
Baseball with Commercials, 30-30-30	48 Bytes/Packet
Baseball with Commercials, 10-14-16	48 Bytes/Packet
Friends vol.4 DVD, 10-14-16	48 Bytes/Packet
Friends vol.4 DVD, 04-04-04	200 Bytes/Packet
Tokyo Olympics DVD, 10-14-16	48 Bytes/Packet
O Brother DVD, 30-30-30	48 Bytes/Packet
O Brother DVD, 04-04-04	200 Bytes/Packet
Die Another Day DVD, 30-30-30	48 Bytes/Packet
Die Another Day DVD, 10-14-16	48 Bytes/Packet
The Transporter DVD, 10-14-16	48 Bytes/Packet
The Transporter DVD, 04-04-04	200 Bytes/Packet
Charlie's Angels DVD, 30-30-30	48 Bytes/Packet
Charlie's Angels DVD, 04-04-04	200 Bytes/Packet
Ice Age DVD, 30-30-30	48 Bytes/Packet
Ice Age DVD, 10-14-16	48 Bytes/Packet

Oprah without Commercials, 30-30-30	48 Bytes/Packet
Oprah without Commercials, 10-14-16	48 Bytes/Packet

PART 2: DETECTING SCENE CHANGES FOR A NEW HYBRID MODEL

CASE STUDY: FINDING THE BEST FIT FOR SINGLE-SOURCE TRAFFIC

TABLE A.2.1 BEST DISTRIBUTION FIT CONCLUSIONS FOR I FRAMES OF LOW ACTIVITY

Video Trace	QL	Q-Q plot	KL test	KS test	Conclusion
1. Die Hard One	30-30-30	Lognormal	Lognormal	Negative Binomial	Lognormal
2. Die Hard One	10-14-16	Weibull	Negative Binomial	Weibull	Weibull
3. Die Hard One	04-04-04	Weibull	Negative Binomial	Weibull	Weibull
4. Citizen Kane	30-30-30	Gamma	Lognormal	Gamma	Gamma
5. Citizen Kane	10-14-16	Weibull	Lognormal	Weibull	Weibull
6. Citizen Kane	04-04-04	Weibull	Lognormal	Weibull	Weibull
7. Silence of the Lambs	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
8. Silence of the Lambs	10-14-16	Gamma	Lognormal	Gamma	Gamma
9. Silence of the Lambs	04-04-04	Weibull	Lognormal	Weibull	Weibull
10. Star Wars IV	30-30-30	Negative Binomial	Lognormal	Negative Binomial	Negative Binomial
11. Star Wars IV	10-14-16	Weibull	Lognormal	Weibull	Weibull
12. Star Wars IV	04-04-04	Weibull	Lognormal	Weibull	Weibull
13. Terminator One	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
14. Terminator One	10-14-16	Gamma	Lognormal	Gamma	Gamma
15. Terminator One	04-04-04	Weibull	Negative Binomial	Weibull	Weibull
16. Aladdin	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
17. Aladdin	10-14-16	Weibull	Negative Binomial	Weibull	Weibull
18. Aladdin	04-04-04	Weibull	Negative Binomial	Negative Binomial	Negative Binomial
19. Cinderella	30-30-30	Gamma	Lognormal	Gamma	Gamma

20. Cinderella	10-14-16	Weibull	Lognormal	Weibull	Weibull
21. Cinderella	04-04-04	Weibull	Lognormal	Weibull	Weibull
22. Tonight Show with Commercials	30-30-30	Weibull	Lognormal	Weibull	Weibull
23. Tonight Show with Commercials	10-14-16	Weibull	Lognormal	Weibull	Weibull
24. Tonight Show with Commercials	04-04-04	Weibull	Lognormal	Weibull	Weibull
25. Tonight Show without Commercials	30-30-30	Negative Binomial	Negative Binomial	Gamma	Negative Binomial
26. Tonight Show without Commercials	10-14-16	Gamma	Lognormal	Gamma	Gamma
27. Tonight Show without Commercials	04-04-04	Gamma	Lognormal	Lognormal	Lognormal
28. Lecture-Reisslein	30-30-30	Negative Binomial	Negative Binomial	Weibull	Negative Binomial
29. Lecture-Reisslein	10-14-16	Negative Binomial	Lognormal	Geometric	Exclude from DAR(1) modeling
30. Lecture-Reisslein	04-04-04	Lognormal	Negative Binomial	Exponential	Exclude from DAR(1) modeling
31. Lecture HQ-Reisslein	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
32. Lecture HQ-Reisslein	10-14-16	Gamma	Lognormal	Gamma	Gamma
33. Lecture HQ-Reisslein	04-04-04	Weibull	Lognormal	Weibull	Weibull
34. Lecture-Gupta	30-30-30	Weibull	Lognormal	Weibull	Weibull
35. Lecture-Gupta	10-14-16	Weibull	Negative Binomial	Weibull	Weibull
36. Lecture-Gupta	04-04-04	Weibull	Negative Binomial	Weibull	Weibull
37. Baseball with Commercials	30-30-30	Weibull	Negative Binomial	Weibull	Weibull
38. Baseball with Commercials	10-14-16	Weibull	Lognormal	Weibull	Weibull
39. Baseball with Commercials	04-04-04	Weibull	Lognormal	Weibull	Weibull
40. Friends vol.4 DVD	30-30-30	Pearson V	Negative Binomial	Pearson V	Pearson V
41. Friends vol.4 DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
42. Friends vol.4 DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
43. Tokyo Olympics DVD	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
44. Tokyo Olympics DVD	10-14-16	Lognormal	Negative Binomial	Gamma	Exclude from DAR(1) modeling
45. Tokyo Olympics DVD	04-04-04	Gamma	Negative Binomial	Gamma	Gamma

46. O Brother DVD	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
47. O Brother DVD	10-14-16	Weibull	Lognormal	Weibull	Weibull
48. O Brother DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
49. Die Another Day DVD	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
50. Die Another Day DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
51. Die Another Day DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
52. The Transporter DVD	30-30-30	Gamma	Lognormal	Gamma	Gamma
53. The Transporter DVD	10-14-16	Weibull	Lognormal	Weibull	Weibull
54. The Transporter DVD	04-04-04	Weibull	Lognormal	Weibull	Weibull
55. Charlie's Angels DVD	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
56. Charlie's Angels DVD	10-14-16	Gamma	Negative Binomial	Gamma	Gamma
57. Charlie's Angels DVD	04-04-04	Gamma	Negative Binomial	Gamma	Gamma
58. Ice Age DVD	30-30-30	Negative Binomial	Negative Binomial	Lognormal	Negative Binomial
59. Ice Age DVD	10-14-16	Gamma	Lognormal	Weibull	Exclude from DAR(1) modeling
60. Ice Age DVD	04-04-04	Negative Binomial	Lognormal	Weibull	Exclude from DAR(1) modeling
61. Oprah without Commercials	30-30-30	Weibull	Lognormal	Weibull	Weibull
62. Oprah without Commercials	10-14-16	Weibull	Lognormal	Weibull	Weibull
63. Oprah without Commercials	04-04-04	Weibull	Lognormal	Weibull	Weibull

TABLE A.2.2 BEST DISTRIBUTION FIT CONCLUSIONS FOR P FRAMES OF LOW ACTIVITY

Video Trace	QL	Q-Q plot	KL test	KS test	Conclusion
1. Die Hard One	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
2. Die Hard One	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
3. Die Hard One	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
4. Citizen Kane	30-30-30	Gamma	Lognormal	Gamma	Gamma
5. Citizen Kane	10-14-16	Lognormal	Negative Binomial	Lognormal	Lognormal
6. Citizen Kane	04-04-04	Gamma	Lognormal	Lognormal	Lognormal
7. Silence of the Lambs	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
8. Silence of the Lambs	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
9. Silence of the Lambs	04-04-04	Gamma	Negative Binomial	Gamma	Gamma
10. Star Wars IV	30-30-30	Lognormal	Negative Binomial	Lognormal	Lognormal
11. Star Wars IV	10-14-16	Lognormal	Negative Binomial	Lognormal	Lognormal
12. Star Wars IV	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
13. Terminator One	30-30-30	Gamma	Lognormal	Gamma	Gamma
14. Terminator One	10-14-16	Gamma	Lognormal	Gamma	Gamma
15. Terminator One	04-04-04	Lognormal	Negative Binomial	Lognormal	Lognormal
16. Aladdin	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
17. Aladdin	10-14-16	Lognormal	Lognormal	Gamma	Lognormal
18. Aladdin	04-04-04	Lognormal	Negative Binomial	Lognormal	Lognormal
19. Cinderella	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
20. Cinderella	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
21. Cinderella	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
22. Tonight Show with Commercials	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
23. Tonight Show with Commercials	10-14-16	Gamma	Negative Binomial	Gamma	Gamma
24. Tonight Show with Commercials	04-04-04	Weibull	Lognormal	Weibull	Weibull
25. Tonight Show without Commercials	30-30-30	Gamma	Exponential	Geometric	Exclude from DAR(1) modeling
26. Tonight Show without	10-14-16	Gamma	Exponential	Lognormal	Exclude from DAR(1) modeling

Commercials					
27. Tonight Show without Commercials	04-04-04	Weibull	Exponential	Weibull	Weibull
28. Lecture-Reisslein	30-30-30	Weibull	Lognormal	Weibull	Weibull
29. Lecture-Reisslein	10-14-16	Weibull	Negative Binomial	Weibull	Weibull
30. Lecture-Reisslein	04-04-04	Weibull	Lognormal	Weibull	Weibull
31. Lecture HQ-Reisslein	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
32. Lecture HQ-Reisslein	10-14-16	Pearson V	Lognormal	Pearson V	Pearson V
33. Lecture HQ-Reisslein	04-04-04	Gamma	Negative Binomial	Gamma	Gamma
34. Lecture-Gupta	30-30-30	Lognormal	Lognormal	Negative Binomial	Lognormal
35. Lecture-Gupta	10-14-16	Weibull	Negative Binomial	Weibull	Weibull
36. Lecture-Gupta	04-04-04	Weibull	Lognormal	Weibull	Weibull
37. Baseball with Commercials	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
38. Baseball with Commercials	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
39. Baseball with Commercials	04-04-04	Weibull	Lognormal	Weibull	Weibull
40. Friends vol.4 DVD	30-30-30	Lognormal	Lognormal	Gamma	Lognormal
41. Friends vol.4 DVD	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
42. Friends vol.4 DVD	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
43. Tokyo Olympics DVD	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
44. Tokyo Olympics DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
45. Tokyo Olympics DVD	04-04-04	Weibull	Negative Binomial	Weibull	Weibull
46. O Brother DVD	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
47. O Brother DVD	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
48. O Brother DVD	04-04-04	Gamma	Negative Binomial	Gamma	Gamma
49. Die Another Day DVD	30-30-30	Pearson V	Lognormal	Lognormal	Lognormal
50. Die Another Day DVD	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
51. Die Another Day DVD	04-04-04	Lognormal	Negative Binomial	Lognormal	Lognormal
52. The Transporter DVD	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
53. The Transporter DVD	10-14-16	Lognormal	Negative	Lognormal	Lognormal

			Binomial		
54. The Transporter DVD	04-04-04	Lognormal	Lognormal	Lognormal	Lognormal
55. Charlie's Angels DVD	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
56. Charlie's Angels DVD	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
57. Charlie's Angels DVD	04-04-04	Negative Binomial	Lognormal	Negative Binomial	Negative Binomial
58. Ice Age DVD	30-30-30	Lognormal	Lognormal	Gamma	Lognormal
59. Ice Age DVD	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
60. Ice Age DVD	04-04-04	Lognormal	Lognormal	Lognormal	Lognormal
61. Oprah without Commercials	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
62. Oprah without Commercials	10-14-16	Weibull	Negative Binomial	Weibull	Weibull
63. Oprah without Commercials	04-04-04	Lognormal	Lognormal	Pearson V	Lognormal

TABLE A.2.3 BEST DISTRIBUTION FIT CONCLUSIONS FOR B FRAMES OF LOW ACTIVITY

Video Trace	QL	Q-Q plot	KL test	KS test	Conclusion
1. Die Hard One	30-30-30	Weibull	Negative Binomial	Weibull	Weibull
2. Die Hard One	10-14-16	Gamma	Lognormal	Gamma	Gamma
3. Die Hard One	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
4. Citizen Kane	30-30-30	Weibull	Lognormal	Weibull	Weibull
5. Citizen Kane	10-14-16	Gamma	Lognormal	Gamma	Gamma
6. Citizen Kane	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
7. Silence of the Lambs	30-30-30	Weibull	Negative Binomial	Weibull	Weibull
8. Silence of the Lambs	10-14-16	Weibull	Lognormal	Weibull	Weibull
9. Silence of the Lambs	04-04-04	Gamma	Lognormal	Gamma	Gamma
10. Star Wars IV	30-30-30	Gamma	Lognormal	Gamma	Gamma
11. Star Wars IV	10-14-16	Negative Binomial	Lognormal	Negative Binomial	Negative Binomial
12. Star Wars IV	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
13. Terminator One	30-30-30	Weibull	Lognormal	Weibull	Weibull

14. Terminator One	10-14-16	Weibull	Lognormal	Gamma	Exclude from DAR(1) modeling
15. Terminator One	04-04-04	Gamma	Lognormal	Lognormal	Lognormal
16. Aladdin	30-30-30	Gamma	Lognormal	Gamma	Gamma
17. Aladdin	10-14-16	Lognormal	Negative Binomial	Lognormal	Lognormal
18. Aladdin	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
19. Cinderella	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
20. Cinderella	10-14-16	Gamma	Lognormal	Gamma	Gamma
21. Cinderella	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
22. Tonight Show with Commercials	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
23. Tonight Show with Commercials	10-14-16	Gamma	Lognormal	Gamma	Gamma
24. Tonight Show with Commercials	04-04-04	Weibull	Negative Binomial	Weibull	Weibull
25. Tonight Show without Commercials	30-30-30	Exponential	Lognormal	Weibull	Exclude from DAR(1) modeling
26. Tonight Show without Commercials	10-14-16	Geometric	Lognormal	Gamma	Exclude from DAR(1) modeling
27. Tonight Show without Commercials	04-04-04	Gamma	Exponential	Weibull	Exclude from DAR(1) modeling
28. Lecture-Reisslein	30-30-30	Weibull	Lognormal	Weibull	Weibull
29. Lecture-Reisslein	10-14-16	Weibull	Negative Binomial	Weibull	Weibull
30. Lecture-Reisslein	04-04-04	Weibull	Negative Binomial	Weibull	Weibull
31. Lecture HQ-Reisslein	30-30-30	Weibull	Lognormal	Weibull	Weibull
32. Lecture HQ-Reisslein	10-14-16	Gamma	Negative Binomial	Gamma	Gamma
33. Lecture HQ-Reisslein	04-04-04	Gamma	Negative Binomial	Gamma	Gamma
34. Lecture-Gupta	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
35. Lecture-Gupta	10-14-16	Weibull	Lognormal	Weibull	Weibull
36. Lecture-Gupta	04-04-04	Weibull	Negative Binomial	Weibull	Weibull
37. Baseball with Commercials	30-30-30	Gamma	Lognormal	Gamma	Gamma
38. Baseball with Commercials	10-14-16	Gamma	Negative Binomial	Gamma	Gamma
39. Baseball with Commercials	04-04-04	Weibull	Lognormal	Weibull	Weibull

40. Friends vol.4 DVD	30-30-30	Weibull	Lognormal	Weibull	Weibull
41. Friends vol.4 DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
42. Friends vol.4 DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
43. Tokyo Olympics DVD	30-30-30	Weibull	Lognormal	Weibull	Weibull
44. Tokyo Olympics DVD	10-14-16	Weibull	Lognormal	Weibull	Weibull
45. Tokyo Olympics DVD	04-04-04	Weibull	Lognormal	Weibull	Weibull
46. O Brother DVD	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
47. O Brother DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
48. O Brother DVD	04-04-04	Geometric	Lognormal	Geometric	Geometric
49. Die Another Day DVD	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
50. Die Another Day DVD	10-14-16	Weibull	Lognormal	Weibull	Weibull
51. Die Another Day DVD	04-04-04	Weibull	Lognormal	Weibull	Weibull
52. The Transporter DVD	30-30-30	Weibull	Negative Binomial	Weibull	Weibull
53. The Transporter DVD	10-14-16	Weibull	Negative Binomial	Weibull	Weibull
54. The Transporter DVD	04-04-04	Weibull	Lognormal	Weibull	Weibull
55. Charlie's Angels DVD	30-30-30	Lognormal	Lognormal	Gamma	Lognormal
56. Charlie's Angels DVD	10-14-16	Weibull	Lognormal	Weibull	Weibull
57. Charlie's Angels DVD	04-04-04	Weibull	Lognormal	Weibull	Weibull
58. Ice Age DVD	30-30-30	Weibull	Lognormal	Weibull	Weibull
59. Ice Age DVD	10-14-16	Exponential	Lognormal	Exponential	Exponential
60. Ice Age DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
61. Oprah without Commercials	30-30-30	Weibull	Lognormal	Weibull	Weibull
62. Oprah without Commercials	10-14-16	Weibull	Lognormal	Weibull	Weibull
63. Oprah without Commercials	04-04-04	Lognormal	Lognormal	Lognormal	Lognormal

TABLE A.2.4 BEST DISTRIBUTION FIT CONCLUSIONS FOR I FRAMES OF HIGH ACTIVITY

Video Trace	QL	Q-Q plot	KL test	KS test	Conclusion
1. Die Hard One	30-30-30	Gamma	Lognormal	Gamma	Gamma
2. Die Hard One	10-14-16	Gamma	Lognormal	Gamma	Gamma
3. Die Hard One	04-04-04	Weibull	Lognormal	Weibull	Weibull
4. Citizen Kane	30-30-30	Pearson V	Negative Binomial	Pearson V	Pearson V
5. Citizen Kane	10-14-16	Pearson V	Negative Binomial	Pearson V	Pearson V
6. Citizen Kane	04-04-04	Gamma	Negative Binomial	Gamma	Gamma
7. Silence of the Lambs	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
8. Silence of the Lambs	10-14-16	Lognormal	Lognormal	Pearson V	Lognormal
9. Silence of the Lambs	04-04-04	Pearson V	Lognormal	Lognormal	Lognormal
10. Star Wars IV	30-30-30	Pearson V	Negative Binomial	Pearson V	Pearson V
11. Star Wars IV	10-14-16	Lognormal	Lognormal	Negative Binomial	Lognormal
12. Star Wars IV	04-04-04	Gamma	Lognormal	Lognormal	Lognormal
13. Terminator One	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
14. Terminator One	10-14-16	Weibull	Lognormal	Weibull	Weibull
15. Terminator One	04-04-04	Gamma	Negative Binomial	Gamma	Gamma
16. Aladdin	30-30-30	Weibull	Negative Binomial	Weibull	Weibull
17. Aladdin	10-14-16	Lognormal	Lognormal	Negative Binomial	Lognormal
18. Aladdin	04-04-04	Lognormal	Negative Binomial	Lognormal	Lognormal
19. Cinderella	30-30-30	Pearson V	Negative Binomial	Pearson V	Pearson V
20. Cinderella	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
21. Cinderella	04-04-04	Gamma	Lognormal	Gamma	Gamma
22. Tonight Show with Commercials	30-30-30	Lognormal	Lognormal	Pearson V	Lognormal
23. Tonight Show with Commercials	10-14-16	Gamma	Lognormal	Gamma	Gamma
24. Tonight Show with Commercials	04-04-04	Weibull	Lognormal	Weibull	Weibull
25. Tonight Show without Commercials	30-30-30	Lognormal	Lognormal	Pearson V	Lognormal

26. Tonight Show without Commercials	10-14-16	Gamma	Negative Binomial	Gamma	Gamma
27. Tonight Show without Commercials	04-04-04	Weibull	Lognormal	Weibull	Weibull
28. Lecture-Reisslein	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
29. Lecture-Reisslein	10-14-16	Pearson V	Lognormal	Lognormal	Lognormal
30. Lecture-Reisslein	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
31. Lecture HQ-Reisslein	30-30-30	Pearson V	Negative Binomial	Pearson V	Pearson V
32. Lecture HQ-Reisslein	10-14-16	Pearson V	Lognormal	Pearson V	Pearson V
33. Lecture HQ-Reisslein	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
34. Lecture-Gupta	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
35. Lecture-Gupta	10-14-16	Pearson V	Lognormal	Pearson V	Pearson V
36. Lecture-Gupta	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
37. Baseball with Commercials	30-30-30	Gamma	Lognormal	Gamma	Gamma
38. Baseball with Commercials	10-14-16	Gamma	Negative Binomial	Gamma	Gamma
39. Baseball with Commercials	04-04-04	Lognormal	Lognormal	Negative Binomial	Lognormal
40. Friends vol.4 DVD	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
41. Friends vol.4 DVD	10-14-16	Gamma	Negative Binomial	Gamma	Gamma
42. Friends vol.4 DVD	04-04-04	Negative Binomial	Negative Binomial	Gamma	Negative Binomial
43. Tokyo Olympics DVD	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
44. Tokyo Olympics DVD	10-14-16	Lognormal	Negative Binomial	Lognormal	Lognormal
45. Tokyo Olympics DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
46. O Brother DVD	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
47. O Brother DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
48. O Brother DVD	04-04-04	Weibull	Lognormal	Weibull	Weibull
49. Die Another Day DVD	30-30-30	Lognormal	Negative Binomial	Lognormal	Lognormal
50. Die Another Day DVD	10-14-16	Weibull	Negative Binomial	Weibull	Weibull
51. Die Another Day DVD	04-04-04	Weibull	Negative Binomial	Weibull	Weibull
52. The Transporter	30-30-30	Pearson V	Negative	Pearson V	Pearson V

DVD			Binomial		
53. The Transporter DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
54. The Transporter DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
55. Charlie's Angels DVD	30-30-30	Gamma	Lognormal	Gamma	Gamma
56. Charlie's Angels DVD	10-14-16	Weibull	Negative Binomial	Weibull	Weibull
57. Charlie's Angels DVD	04-04-04	Weibull	Lognormal	Weibull	Weibull
58. Ice Age DVD	30-30-30	Gamma	Lognormal	Gamma	Gamma
59. Ice Age DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
60. Ice Age DVD	04-04-04	Gamma	Lognormal	Lognormal	Lognormal
61. Oprah without Commercials	30-30-30	Lognormal	Lognormal	Pearson V	Lognormal
62. Oprah without Commercials	10-14-16	Pearson V	Lognormal	Lognormal	Lognormal
63. Oprah without Commercials	04-04-04	Negative Binomial	Weibull	Negative Binomial	Negative Binomial

TABLE A.2.5 BEST DISTRIBUTION FIT CONCLUSIONS FOR P FRAMES OF HIGH ACTIVITY

Video Trace	QL	Q-Q plot	KL test	KS test	Conclusion
1. Die Hard One	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
2. Die Hard One	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
3. Die Hard One	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
4. Citizen Kane	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
5. Citizen Kane	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
6. Citizen Kane	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
7. Silence of the Lambs	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
8. Silence of the Lambs	10-14-16	Pearson V	Lognormal	Pearson V	Pearson V
9. Silence of the Lambs	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
10. Star Wars IV	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
11. Star Wars IV	10-14-16	Lognormal	Negative Binomial	Lognormal	Lognormal
12. Star Wars IV	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V

13. Terminator One	30-30-30	Pearson V	Negative Binomial	Pearson V	Pearson V
14. Terminator One	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
15. Terminator One	04-04-04	Lognormal	Negative Binomial	Lognormal	Lognormal
16. Aladdin	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
17. Aladdin	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
18. Aladdin	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
19. Cinderella	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
20. Cinderella	10-14-16	Lognormal	Lognormal	Pearson V	Lognormal
21. Cinderella	04-04-04	Negative Binomial	Negative Binomial	Lognormal	Negative Binomial
22. Tonight Show with Commercials	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
23. Tonight Show with Commercials	10-14-16	Pearson V	Lognormal	Pearson V	Pearson V
24. Tonight Show with Commercials	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
25. Tonight Show without Commercials	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
26. Tonight Show without Commercials	10-14-16	Lognormal	Negative Binomial	Lognormal	Lognormal
27. Tonight Show without Commercials	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
28. Lecture-Reisslein	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
29. Lecture-Reisslein	10-14-16	Pearson V	Lognormal	Pearson V	Pearson V
30. Lecture-Reisslein	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
31. Lecture HQ-Reisslein	30-30-30	Pearson V	Lognormal	Lognormal	Lognormal
32. Lecture HQ-Reisslein	10-14-16	Lognormal	Negative Binomial	Lognormal	Lognormal
33. Lecture HQ-Reisslein	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
34. Lecture-Gupta	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
35. Lecture-Gupta	10-14-16	Pearson V	Lognormal	Pearson V	Pearson V
36. Lecture-Gupta	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
37. Baseball with Commercials	30-30-30	Lognormal	Negative Binomial	Lognormal	Lognormal
38. Baseball with Commercials	10-14-16	Lognormal	Negative Binomial	Lognormal	Lognormal
39. Baseball with Commercials	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V

40. Friends vol.4 DVD	30-30-30	Lognormal	Negative Binomial	Lognormal	Lognormal
41. Friends vol.4 DVD	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
42. Friends vol.4 DVD	04-04-04	Lognormal	Lognormal	Lognormal	Lognormal
43. Tokyo Olympics DVD	30-30-30	Gamma	Lognormal	Gamma	Gamma
44. Tokyo Olympics DVD	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
45. Tokyo Olympics DVD	04-04-04	Lognormal	Lognormal	Lognormal	Lognormal
46. O Brother DVD	30-30-30	Gamma	Negative Binomial	Lognormal	Exclude from DAR(1) modeling
47. O Brother DVD	10-14-16	Gamma	Negative Binomial	Gamma	Gamma
48. O Brother DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
49. Die Another Day DVD	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
50. Die Another Day DVD	10-14-16	Lognormal	Lognormal	Gamma	Lognormal
51. Die Another Day DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
52. The Transporter DVD	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
53. The Transporter DVD	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
54. The Transporter DVD	04-04-04	Lognormal	Lognormal	Lognormal	Lognormal
55. Charlie's Angels DVD	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
56. Charlie's Angels DVD	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
57. Charlie's Angels DVD	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
58. Ice Age DVD	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
59. Ice Age DVD	10-14-16	Lognormal	Lognormal	Gamma	Lognormal
60. Ice Age DVD	04-04-04	Lognormal	Negative Binomial	Lognormal	Lognormal
61. Oprah without Commercials	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
62. Oprah without Commercials	10-14-16	Pearson V	Negative Binomial	Pearson V	Pearson V
63. Oprah without Commercials	04-04-04	Pearson V	Lognormal	Lognormal	Lognormal

TABLE A.2.6 BEST DISTRIBUTION FIT CONCLUSIONS FOR B FRAMES OF HIGH ACTIVITY

Video Trace	QL	Q-Q plot	KL test	KS test	Conclusion
1. Die Hard One	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
2. Die Hard One	10-14-16	Gamma	Negative Binomial	Gamma	Gamma
3. Die Hard One	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
4. Citizen Kane	30-30-30	Gamma	Lognormal	Gamma	Gamma
5. Citizen Kane	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
6. Citizen Kane	04-04-04	Pearson V	Lognormal	Lognormal	Lognormal
7. Silence of the Lambs	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
8. Silence of the Lambs	10-14-16	Pearson V	Negative Binomial	Lognormal	Exclude from DAR(1) modeling
9. Silence of the Lambs	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
10. Star Wars IV	30-30-30	Gamma	Lognormal	Gamma	Gamma
11. Star Wars IV	10-14-16	Gamma	Lognormal	Gamma	Gamma
12. Star Wars IV	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
13. Terminator One	30-30-30	Lognormal	Lognormal	Gamma	Lognormal
14. Terminator One	10-14-16	Gamma	Lognormal	Gamma	Gamma
15. Terminator One	04-04-04	Gamma	Lognormal	Gamma	Gamma
16. Aladdin	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
17. Aladdin	10-14-16	Gamma	Lognormal	Lognormal	Lognormal
18. Aladdin	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
19. Cinderella	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
20. Cinderella	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
21. Cinderella	04-04-04	Lognormal	Negative Binomial	Lognormal	Lognormal
22. Tonight Show with Commercials	30-30-30	Lognormal	Lognormal	Lognormal	Lognormal
23. Tonight Show with Commercials	10-14-16	Pearson V	Negative Binomial	Pearson V	Pearson V
24. Tonight Show with Commercials	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
25. Tonight Show without Commercials	30-30-30	Lognormal	Lognormal	Gamma	Lognormal
26. Tonight Show without	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal

Commercials					
27. Tonight Show without Commercials	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
28. Lecture-Reisslein	30-30-30	Pearson V	Lognormal	Lognormal	Lognormal
29. Lecture-Reisslein	10-14-16	Pearson V	Lognormal	Pearson V	Pearson V
30. Lecture-Reisslein	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
31. Lecture HQ-Reisslein	30-30-30	Lognormal	Lognormal	Weibull	Lognormal
32. Lecture HQ-Reisslein	10-14-16	Gamma	Negative Binomial	Gamma	Gamma
33. Lecture HQ-Reisslein	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
34. Lecture-Gupta	30-30-30	Pearson V	Lognormal	Pearson V	Pearson V
35. Lecture-Gupta	10-14-16	Pearson V	Lognormal	Pearson V	Pearson V
36. Lecture-Gupta	04-04-04	Pearson V	Negative Binomial	Pearson V	Pearson V
37. Baseball with Commercials	30-30-30	Gamma	Lognormal	Gamma	Gamma
38. Baseball with Commercials	10-14-16	Lognormal	Lognormal	Lognormal	Lognormal
39. Baseball with Commercials	04-04-04	Pearson V	Lognormal	Pearson V	Pearson V
40. Friends vol.4 DVD	30-30-30	Weibull	Lognormal	Weibull	Weibull
41. Friends vol.4 DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
42. Friends vol.4 DVD	04-04-04	Weibull	Negative Binomial	Weibull	Weibull
43. Tokyo Olympics DVD	30-30-30	Weibull	Negative Binomial	Weibull	Weibull
44. Tokyo Olympics DVD	10-14-16	Weibull	Negative Binomial	Weibull	Weibull
45. Tokyo Olympics DVD	04-04-04	Weibull	Negative Binomial	Weibull	Weibull
46. O Brother DVD	30-30-30	Lognormal	Lognormal	Gamma	Lognormal
47. O Brother DVD	10-14-16	Gamma	Lognormal	Gamma	Gamma
48. O Brother DVD	04-04-04	Weibull	Lognormal	Weibull	Weibull
49. Die Another Day DVD	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
50. Die Another Day DVD	10-14-16	Lognormal	Lognormal	Gamma	Lognormal
51. Die Another Day DVD	04-04-04	Weibull	Negative Binomial	Weibull	Weibull
52. The Transporter DVD	30-30-30	Weibull	Lognormal	Weibull	Weibull
53. The Transporter DVD	10-14-16	Weibull	Negative Binomial	Weibull	Weibull

54. The Transporter DVD	04-04-04	Weibull	Lognormal	Weibull	Weibull
55. Charlie's Angels DVD	30-30-30	Gamma	Negative Binomial	Gamma	Gamma
56. Charlie's Angels DVD	10-14-16	Lognormal	Lognormal	Gamma	Lognormal
57. Charlie's Angels DVD	04-04-04	Gamma	Negative Binomial	Gamma	Gamma
58. Ice Age DVD	30-30-30	Weibull	Negative Binomial	Weibull	Weibull
59. Ice Age DVD	10-14-16	Weibull	Lognormal	Weibull	Weibull
60. Ice Age DVD	04-04-04	Gamma	Lognormal	Gamma	Gamma
61. Oprah without Commercials	30-30-30	Gamma	Lognormal	Gamma	Gamma
62. Oprah without Commercials	10-14-16	Pearson V	Negative Binomial	Pearson V	Pearson V
63. Oprah without Commercials	04-04-04	Lognormal	Lognormal	Lognormal	Lognormal

CASE STUDY: HYBRID MODELING FOR MULTIPLEXED TRAFFIC

TABLE A.2.7 INFORMATION ON HYBRID MODELING OF I FRAMES OF LOW ACTIVITY

Video Trace	QL	BEST FIT	Max Frame Size (Bytes)	States In DAR	Autocorrelation
1. Die Hard One	30-30-30	Lognormal	1871	39	0,8796
2. Die Hard One	10-14-16	Weibull	5435	28	0,8383
3. Die Hard One	04-04-04	Weibull	11328	57	0,7493
4. Citizen Kane	30-30-30	Gamma	1933	41	0,9253
5. Citizen Kane	10-14-16	Weibull	5235	27	0,9109
6. Citizen Kane	04-04-04	Weibull	10076	51	0,9206
7. Silence of the Lambs	30-30-30	Lognormal	1493	32	0,9170
8. Silence of the Lambs	10-14-16	Gamma	4083	86	0,8856
9. Silence of the Lambs	04-04-04	Weibull	8866	45	0,8533
10. Star Wars IV	30-30-30	Lognormal	2850	60	0,8428
11. Star Wars IV	10-14-16	Weibull	4584	96	0,8630
12. Star Wars IV	04-04-04	Weibull	9387	47	0,8328

13. Terminator One	30-30-30	Lognormal	1762	37	0,9293
14. Terminator One	10-14-16	Gamma	5642	29	0,8689
15. Terminator One	04-04-04	Weibull	11186	56	0,7975
16. Aladdin	30-30-30	Gamma	2553	54	0,8926
17. Aladdin	10-14-16	Weibull	7342	37	0,8436
18. Aladdin	04-04-04	Negative Binomial	15116	76	0,7995
19. Cinderella	30-30-30	Gamma	2039	43	0,8954
20. Cinderella	10-14-16	Weibull	5644	29	0,8482
21. Cinderella	04-04-04	Weibull	12736	64	0,8352
22. Tonight Show with Commercials	30-30-30	Weibull	4047	85	0,8683
23. Tonight Show with Commercials	10-14-16	Weibull	8208	42	0,8750
24. Tonight Show with Commercials	04-04-04	Weibull	15539	78	0,7821
25. Tonight Show without Commercials	30-30-30	Negative Binomial	1777	38	0,9870
26. Tonight Show without Commercials	10-14-16	Gamma	4861	25	0,9778
27. Tonight Show without Commercials	04-04-04	Lognormal	9584	48	0,9701
28. Lecture-Reisslein	30-30-30	Negative Binomial	2727	57	0,9544
29. Lecture-Reisslein	10-14-16				
30. Lecture-Reisslein	04-04-04				
31. Lecture HQ-Reisslein	30-30-30	Pearson V	6318	132	0,9810
32. Lecture HQ-Reisslein	10-14-16	Gamma	12656	64	0,9573
33. Lecture HQ-Reisslein	04-04-04	Weibull	26469	133	0,9302
34. Lecture-Gupta	30-30-30	Weibull	2846	60	0,9050
35. Lecture-Gupta	10-14-16	Weibull	7963	40	0,8680
36. Lecture-Gupta	04-04-04	Weibull	14844	75	0,9014
37. Baseball with Commercials	30-30-30	Weibull	1744	37	0,8844
38. Baseball with Commercials	10-14-16	Weibull	5770	29	0,8553
39. Baseball with Commercials	04-04-04	Weibull	14649	74	0,7609
40. Friends vol.4 DVD	30-30-30	Pearson V	1598	34	0,8844

41. Friends vol.4 DVD	10-14-16	Gamma	4118	86	0,8454
42. Friends vol.4 DVD	04-04-04	Gamma	10144	51	0,8704
43. Tokyo Olympics DVD	30-30-30	Lognormal	1458	31	0,9161
44. Tokyo Olympics DVD	10-14-16				
45. Tokyo Olympics DVD	04-04-04	Gamma	10849	55	0,8886
46. O Brother DVD	30-30-30	Gamma	1483	31	0,9417
47. O Brother DVD	10-14-16	Weibull	3418	72	0,9281
48. O Brother DVD	04-04-04	Gamma	9408	48	0,9236
49. Die Another Day DVD	30-30-30	Pearson V	1177	25	0,8771
50. Die Another Day DVD	10-14-16	Gamma	4039	85	0,8294
51. Die Another Day DVD	04-04-04	Gamma	8212	42	0,8113
52. The Transporter DVD	30-30-30	Gamma	1294	27	0,8803
53. The Transporter DVD	10-14-16	Weibull	3740	78	0,8383
54. The Transporter DVD	04-04-04	Weibull	8428	43	0,8046
55. Charlie's Angels DVD	30-30-30	Lognormal	1502	32	0,8750
56. Charlie's Angels DVD	10-14-16	Gamma	4322	91	0,8436
57. Charlie's Angels DVD	04-04-04	Gamma	8862	45	0,8013
58. Ice Age DVD	30-30-30	Lognormal	1166	25	0,9211
59. Ice Age DVD	10-14-16				
60. Ice Age DVD	04-04-04				
61. Oprah without Commercials	30-30-30	Weibull	2159	45	0,9090
62. Oprah without Commercials	10-14-16	Weibull	7283	37	0,9049
63. Oprah without Commercials	04-04-04	Weibull	13849	70	0,9098

TABLE A.2.8 INFORMATION ON HYBRID MODELING OF P FRAMES OF LOW ACTIVITY

Video Trace	QL	BEST FIT	Max Frame Size (Bytes)	States In DAR	Autocorrelation
1. Die Hard One	30-30-30	Lognormal	1753	37	0,4322
2. Die Hard One	10-14-16	Lognormal	3129	66	0,4079
3. Die Hard One	04-04-04	Pearson V	11030	56	0,5234
4. Citizen Kane	30-30-30	Gamma	1456	31	0,3362
5. Citizen Kane	10-14-16	Lognormal	3074	65	0,5239
6. Citizen Kane	04-04-04	Lognormal	10638	54	0,7078
7. Silence of the Lambs	30-30-30	Gamma	1351	29	0,3335
8. Silence of the Lambs	10-14-16	Lognormal	2160	45	0,3630
9. Silence of the Lambs	04-04-04	Gamma	6441	33	0,5773
10. Star Wars IV	30-30-30	Lognormal	1574	33	0,3749
11. Star Wars IV	10-14-16	Lognormal	2612	55	0,3280
12. Star Wars IV	04-04-04	Pearson V	8061	41	0,5074
13. Terminator One	30-30-30	Gamma	1867	39	0,5124
14. Terminator One	10-14-16	Gamma	3734	78	0,5002
15. Terminator One	04-04-04	Lognormal	9813	50	0,6284
16. Aladdin	30-30-30	Lognormal	2280	48	0,4689
17. Aladdin	10-14-16	Lognormal	4047	85	0,5439
18. Aladdin	04-04-04	Lognormal	14594	73	0,7107
19. Cinderella	30-30-30	Pearson V	1911	40	0,3800
20. Cinderella	10-14-16	Lognormal	4177	88	0,4199
21. Cinderella	04-04-04	Pearson V	11000	55	0,6228
22. Tonight Show with Commercials	30-30-30	Pearson V	2058	43	0,4379
23. Tonight Show with Commercials	10-14-16	Gamma	4803	25	0,5107
24. Tonight Show with Commercials	04-04-04	Weibull	16070	81	0,7228
25. Tonight Show without Commercials	30-30-30				
26. Tonight Show without Commercials	10-14-16				

27. Tonight Show without Commercials	04-04-04	Weibull	8177	41	0,9188
28. Lecture-Reisslein	30-30-30	Weibull	4099	86	0,7643
29. Lecture-Reisslein	10-14-16	Weibull	4081	86	0,9247
30. Lecture-Reisslein	04-04-04	Weibull	27671	139	0,9737
31. Lecture HQ-Reisslein	30-30-30	Lognormal	6035	126	0,4129
32. Lecture HQ-Reisslein	10-14-16	Pearson V	11751	59	0,6948
33. Lecture HQ-Reisslein	04-04-04	Gamma	37267	187	0,7261
34. Lecture-Gupta	30-30-30	Lognormal	1833	39	0,2290
35. Lecture-Gupta	10-14-16	Weibull	3996	84	0,6693
36. Lecture-Gupta	04-04-04	Weibull	11780	59	0,8527
37. Baseball with Commercials	30-30-30	Lognormal	1729	37	0,5842
38. Baseball with Commercials	10-14-16	Lognormal	3234	68	0,5542
39. Baseball with Commercials	04-04-04	Weibull	13117	66	0,7354
40. Friends vol.4 DVD	30-30-30	Lognormal	1417	30	0,3164
41. Friends vol.4 DVD	10-14-16	Lognormal	2581	54	0,2960
42. Friends vol.4 DVD	04-04-04	Pearson V	9468	48	0,3412
43. Tokyo Olympics DVD	30-30-30	Gamma	1398	30	0,6341
44. Tokyo Olympics DVD	10-14-16	Gamma	2780	58	0,6156
45. Tokyo Olympics DVD	04-04-04	Weibull	9636	49	0,7225
46. O Brother DVD	30-30-30	Lognormal	1231	26	0,3418
47. O Brother DVD	10-14-16	Lognormal	2379	50	0,3781
48. O Brother DVD	04-04-04	Gamma	8322	42	0,5279
49. Die Another Day DVD	30-30-30	Lognormal	1257	27	0,2801
50. Die Another Day DVD	10-14-16	Lognormal	2279	48	0,2223
51. Die Another Day DVD	04-04-04	Lognormal	8331	42	0,2971
52. The Transporter DVD	30-30-30	Gamma	1539	33	0,3964
53. The Transporter DVD	10-14-16	Lognormal	2200	46	0,2827
54. The Transporter DVD	04-04-04	Lognormal	7249	37	0,3727
55. Charlie's Angels DVD	30-30-30	Lognormal	1490	32	0,3791

56. Charlie's Angels DVD	10-14-16	Lognormal	2395	50	0,3354
57. Charlie's Angels DVD	04-04-04	Negative Binomial	7608	39	0,4450
58. Ice Age DVD	30-30-30	Lognormal	1373	29	0,3011
59. Ice Age DVD	10-14-16	Lognormal	2406	51	0,2540
60. Ice Age DVD	04-04-04	Lognormal	7770	39	0,2968
61. Oprah without Commercials	30-30-30	Pearson V	1623	34	0,3747
62. Oprah without Commercials	10-14-16	Weibull	3697	78	0,5566
63. Oprah without Commercials	04-04-04	Lognormal	13680	69	0,7077

TABLE A.2.9 INFORMATION ON HYBRID MODELING OF B FRAMES OF LOW ACTIVITY

Video Trace	QL	BEST FIT	Max Frame Size (Bytes)	States In DAR	Autocorrelation
1. Die Hard One	30-30-30	Weibull	1040	22	0,6822
2. Die Hard One	10-14-16	Gamma	1829	39	0,6798
3. Die Hard One	04-04-04	Pearson V	7872	40	0,6724
4. Citizen Kane	30-30-30	Weibull	783	17	0,5783
5. Citizen Kane	10-14-16	Gamma	2014	42	0,6265
6. Citizen Kane	04-04-04	Pearson V	6322	32	0,7155
7. Silence of the Lambs	30-30-30	Weibull	697	15	0,5717
8. Silence of the Lambs	10-14-16	Weibull	1074	23	0,6249
9. Silence of the Lambs	04-04-04	Gamma	6186	31	0,8281
10. Star Wars IV	30-30-30	Gamma	1954	41	0,6287
11. Star Wars IV	10-14-16	Negative Binomial	1304	28	0,6469
12. Star Wars IV	04-04-04	Pearson V	6916	35	0,6880
13. Terminator One	30-30-30	Weibull	2588	54	0,6808
14. Terminator One	10-14-16				
15. Terminator One	04-04-04	Lognormal	8714	44	0,5751
16. Aladdin	30-30-30	Gamma	2367	50	0,6554
17. Aladdin	10-14-16	Lognormal	3793	80	0,6188

18. Aladdin	04-04-04	Pearson V	14049	71	0,7264
19. Cinderella	30-30-30	Gamma	988	21	0,6412
20. Cinderella	10-14-16	Gamma	1710	36	0,6121
21. Cinderella	04-04-04	Pearson V	9630	49	0,6678
22. Tonight Show with Commercials	30-30-30	Gamma	1325	28	0,7779
23. Tonight Show with Commercials	10-14-16	Gamma	2443	51	0,8254
24. Tonight Show with Commercials	04-04-04	Weibull	13635	69	0,9115
25. Tonight Show without Commercials	30-30-30				
26. Tonight Show without Commercials	10-14-16				
27. Tonight Show without Commercials	04-04-04				
28. Lecture-Reisslein	30-30-30	Weibull	1379	29	0,7249
29. Lecture-Reisslein	10-14-16	Weibull	2420	51	0,7567
30. Lecture-Reisslein	04-04-04	Weibull	11543	58	0,9917
31. Lecture HQ-Reisslein	30-30-30	Weibull	9282	194	0,4640
32. Lecture HQ-Reisslein	10-14-16	Gamma	13705	69	0,4956
33. Lecture HQ-Reisslein	04-04-04	Gamma	40203	202	0,7459
34. Lecture-Gupta	30-30-30	Gamma	1814	38	0,5118
35. Lecture-Gupta	10-14-16	Weibull	2486	52	0,6558
36. Lecture-Gupta	04-04-04	Weibull	10017	51	0,9028
37. Baseball with Commercials	30-30-30	Gamma	1323	28	0,7388
38. Baseball with Commercials	10-14-16	Gamma	2623	55	0,7857
39. Baseball with Commercials	04-04-04	Weibull	10699	54	0,8880
40. Friends vol.4 DVD	30-30-30	Weibull	795	17	0,6291
41. Friends vol.4 DVD	10-14-16	Gamma	1087	23	0,6338
42. Friends vol.4 DVD	04-04-04	Gamma	5090	26	0,6803
43. Tokyo Olympics DVD	30-30-30	Weibull	755	16	0,7632
44. Tokyo Olympics DVD	10-14-16	Weibull	1284	27	0,7686
45. Tokyo Olympics DVD	04-04-04	Weibull	5620	29	0,7562

46. O Brother DVD	30-30-30	Gamma	488	11	0,6236
47. O Brother DVD	10-14-16	Gamma	881	19	0,6887
48. O Brother DVD	04-04-04	Geometric	4094	21	0,8263
49. Die Another Day DVD	30-30-30	Gamma	1185	25	0,6729
50. Die Another Day DVD	10-14-16	Weibull	1088	23	0,6784
51. Die Another Day DVD	04-04-04	Weibull	7556	38	0,7342
52. The Transporter DVD	30-30-30	Weibull	1141	24	0,6961
53. The Transporter DVD	10-14-16	Weibull	1788	38	0,7370
54. The Transporter DVD	04-04-04	Weibull	5958	30	0,7295
55. Charlie's Angels DVD	30-30-30	Lognormal	786	17	0,7117
56. Charlie's Angels DVD	10-14-16	Weibull	945	20	0,7458
57. Charlie's Angels DVD	04-04-04	Weibull	4745	24	0,7626
58. Ice Age DVD	30-30-30	Weibull	692	15	0,5771
59. Ice Age DVD	10-14-16	Exponential	1089	23	0,6028
60. Ice Age DVD	04-04-04	Gamma	4492	23	0,7604
61. Oprah without Commercials	30-30-30	Weibull	684	15	0,7620
62. Oprah without Commercials	10-14-16	Weibull	1460	31	0,9403
63. Oprah without Commercials	04-04-04	Lognormal	9735	49	0,9461

TABLE A.2.10 INFORMATION ON HYBRID MODELING OF I FRAMES OF HIGH ACTIVITY

Video Trace	QL	BEST FIT	Max Frame Size (Bytes)	States In DAR	Autocorrelation
1. Die Hard One	30-30-30	Gamma	2677	56	0,7777
2. Die Hard One	10-14-16	Gamma	6897	35	0,7888
3. Die Hard One	04-04-04	Weibull	12496	63	0,7375
4. Citizen Kane	30-30-30	Pearson V	2731	57	0,9052
5. Citizen Kane	10-14-16	Pearson V	8406	43	0,8829
6. Citizen Kane	04-04-04	Gamma	14495	73	0,8672

7. Silence of the Lambs	30-30-30	Pearson V	2858	60	0,9256
8. Silence of the Lambs	10-14-16	Lognormal	8450	43	0,9125
9. Silence of the Lambs	04-04-04	Lognormal	14938	75	0,8872
10. Star Wars IV	30-30-30	Pearson V	4279	90	0,9172
11. Star Wars IV	10-14-16	Lognormal	9992	50	0,8920
12. Star Wars IV	04-04-04	Lognormal	16816	85	0,8482
13. Terminator One	30-30-30	Lognormal	2399	50	0,8281
14. Terminator One	10-14-16	Weibull	6762	34	0,8244
15. Terminator One	04-04-04	Gamma	13004	66	0,7893
16. Aladdin	30-30-30	Weibull	3286	69	0,7745
17. Aladdin	10-14-16	Lognormal	9345	47	0,7351
18. Aladdin	04-04-04	Lognormal	17364	87	0,7166
19. Cinderella	30-30-30	Pearson V	4598	96	0,7673
20. Cinderella	10-14-16	Lognormal	11283	57	0,8059
21. Cinderella	04-04-04	Gamma	19378	97	0,8102
22. Tonight Show with Commercials	30-30-30	Lognormal	4143	87	0,8133
23. Tonight Show with Commercials	10-14-16	Gamma	10281	52	0,7636
24. Tonight Show with Commercials	04-04-04	Weibull	18133	91	0,7521
25. Tonight Show without Commercials	30-30-30	Lognormal	3261	68	0,9281
26. Tonight Show without Commercials	10-14-16	Gamma	8782	44	0,9055
27. Tonight Show without Commercials	04-04-04	Weibull	16055	81	0,9109
28. Lecture-Reisslein	30-30-30	Pearson V	3011	63	0,9718
29. Lecture-Reisslein	10-14-16	Lognormal	8962	45	0,9720
30. Lecture-Reisslein	04-04-04	Pearson V	16705	84	0,9670
31. Lecture HQ-Reisslein	30-30-30	Pearson V	6778	142	0,9834
32. Lecture HQ-Reisslein	10-14-16	Pearson V	18575	93	0,9847
33. Lecture HQ-Reisslein	04-04-04	Pearson V	36853	185	0,9844
34. Lecture-Gupta	30-30-30	Pearson V	3475	73	0,9614
35. Lecture-Gupta	10-14-16	Pearson V	9242	47	0,9655

36. Lecture-Gupta	04-04-04	Pearson V	16668	84	0,9597
37. Baseball with Commercials	30-30-30	Gamma	2397	50	0,7925
38. Baseball with Commercials	10-14-16	Gamma	7749	39	0,7781
39. Baseball with Commercials	04-04-04	Lognormal	15017	76	0,7198
40. Friends vol.4 DVD	30-30-30	Gamma	1594	34	0,7468
41. Friends vol.4 DVD	10-14-16	Gamma	4898	25	0,7917
42. Friends vol.4 DVD	04-04-04	Negative Binomial	10185	51	0,7891
43. Tokyo Olympics DVD	30-30-30	Pearson V	1801	38	0,9286
44. Tokyo Olympics DVD	10-14-16	Lognormal	6549	33	0,9181
45. Tokyo Olympics DVD	04-04-04	Gamma	11555	58	0,8945
46. O Brother DVD	30-30-30	Lognormal	1539	33	0,9102
47. O Brother DVD	10-14-16	Gamma	5210	27	0,9066
48. O Brother DVD	04-04-04	Weibull	10207	52	0,8920
49. Die Another Day DVD	30-30-30	Lognormal	1321	28	0,7996
50. Die Another Day DVD	10-14-16	Weibull	3997	84	0,7704
51. Die Another Day DVD	04-04-04	Weibull	8276	42	0,7322
52. The Transporter DVD	30-30-30	Pearson V	1619	34	0,7315
53. The Transporter DVD	10-14-16	Gamma	4904	25	0,7699
54. The Transporter DVD	04-04-04	Gamma	10768	54	0,7292
55. Charlie's Angels DVD	30-30-30	Gamma	1670	35	0,8477
56. Charlie's Angels DVD	10-14-16	Weibull	5433	28	0,8084
57. Charlie's Angels DVD	04-04-04	Weibull	10945	55	0,7793
58. Ice Age DVD	30-30-30	Gamma	1170	25	0,8271
59. Ice Age DVD	10-14-16	Gamma	4410	92	0,8382
60. Ice Age DVD	04-04-04	Lognormal	10524	53	0,8318
61. Oprah without Commercials	30-30-30	Lognormal	2370	50	0,8622
62. Oprah without Commercials	10-14-16	Lognormal	7610	39	0,8376
63. Oprah without Commercials	04-04-04	Weibull	14208	72	0,8841

TABLE A.2.11 INFORMATION ON HYBRID MODELING OF P FRAMES OF HIGH ACTIVITY

Video Trace	QL	BEST FIT	Max Frame Size (Bytes)	States In DAR	Autocorrelation
1. Die Hard One	30-30-30	Lognormal	1971	42	0,6070
2. Die Hard One	10-14-16	Lognormal	3930	82	0,5509
3. Die Hard One	04-04-04	Pearson V	12952	65	0,6220
4. Citizen Kane	30-30-30	Lognormal	2331	49	0,6778
5. Citizen Kane	10-14-16	Lognormal	5744	29	0,7246
6. Citizen Kane	04-04-04	Pearson V	16633	84	0,8195
7. Silence of the Lambs	30-30-30	Pearson V	2189	46	0,7500
8. Silence of the Lambs	10-14-16	Pearson V	5293	27	0,7924
9. Silence of the Lambs	04-04-04	Pearson V	16406	83	0,8663
10. Star Wars IV	30-30-30	Lognormal	2381	50	0,5656
11. Star Wars IV	10-14-16	Lognormal	5774	29	0,5825
12. Star Wars IV	04-04-04	Pearson V	17518	88	0,6935
13. Terminator One	30-30-30	Pearson V	2441	51	0,5387
14. Terminator One	10-14-16	Lognormal	5278	27	0,5743
15. Terminator One	04-04-04	Lognormal	15279	77	0,6747
16. Aladdin	30-30-30	Lognormal	3291	69	0,5534
17. Aladdin	10-14-16	Lognormal	7538	38	0,6285
18. Aladdin	04-04-04	Pearson V	22560	113	0,7275
19. Cinderella	30-30-30	Pearson V	3980	83	0,6138
20. Cinderella	10-14-16	Lognormal	9553	48	0,6834
21. Cinderella	04-04-04	Negative Binomial	26290	132	0,7920
22. Tonight Show with Commercials	30-30-30	Lognormal	4047	85	0,5820
23. Tonight Show with Commercials	10-14-16	Pearson V	8728	44	0,7450
24. Tonight Show with Commercials	04-04-04	Pearson V	22628	114	0,7639
25. Tonight Show without Commercials	30-30-30	Lognormal	3338	70	0,6635
26. Tonight Show without	10-14-16	Lognormal	7356	37	0,7313

Commercials					
27. Tonight Show without Commercials	04-04-04	Pearson V	19820	100	0,8035
28. Lecture-Reisslein	30-30-30	Pearson V	2219	47	0,7168
29. Lecture-Reisslein	10-14-16	Pearson V	10258	52	0,8528
30. Lecture-Reisslein	04-04-04	Pearson V	18135	91	0,9269
31. Lecture HQ-Reisslein	30-30-30	Lognormal	7642	160	0,4617
32. Lecture HQ-Reisslein	10-14-16	Lognormal	14442	73	0,6918
33. Lecture HQ-Reisslein	04-04-04	Pearson V	31532	158	0,8365
34. Lecture-Gupta	30-30-30	Pearson V	2350	49	0,5216
35. Lecture-Gupta	10-14-16	Pearson V	5557	28	0,7736
36. Lecture-Gupta	04-04-04	Pearson V	16968	85	0,8881
37. Baseball with Commercials	30-30-30	Lognormal	2338	49	0,6388
38. Baseball with Commercials	10-14-16	Lognormal	5704	29	0,6263
39. Baseball with Commercials	04-04-04	Pearson V	18012	91	0,7162
40. Friends vol.4 DVD	30-30-30	Lognormal	1544	33	0,4619
41. Friends vol.4 DVD	10-14-16	Lognormal	3337	70	0,3675
42. Friends vol.4 DVD	04-04-04	Lognormal	11048	56	0,4198
43. Tokyo Olympics DVD	30-30-30	Gamma	1592	34	0,6602
44. Tokyo Olympics DVD	10-14-16	Lognormal	4135	87	0,6623
45. Tokyo Olympics DVD	04-04-04	Lognormal	14114	71	0,8296
46. O Brother DVD	30-30-30				
47. O Brother DVD	10-14-16	Gamma	3471	73	0,5855
48. O Brother DVD	04-04-04	Gamma	11367	57	0,7129
49. Die Another Day DVD	30-30-30	Gamma	1853	39	0,5604
50. Die Another Day DVD	10-14-16	Lognormal	4246	89	0,5072
51. Die Another Day DVD	04-04-04	Gamma	11792	59	0,6064
52. The Transporter DVD	30-30-30	Lognormal	1401	30	0,4912
53. The Transporter DVD	10-14-16	Lognormal	3384	71	0,4279
54. The Transporter DVD	04-04-04	Lognormal	11559	58	0,5586

55. Charlie's Angels DVD	30-30-30	Pearson V	1642	35	0,5329
56. Charlie's Angels DVD	10-14-16	Lognormal	3417	72	0,5372
57. Charlie's Angels DVD	04-04-04	Pearson V	11400	57	0,6659
58. Ice Age DVD	30-30-30	Gamma	1374	29	0,4414
59. Ice Age DVD	10-14-16	Lognormal	2951	62	0,3612
60. Ice Age DVD	04-04-04	Lognormal	10686	54	0,4534
61. Oprah without Commercials	30-30-30	Lognormal	2127	45	0,6131
62. Oprah without Commercials	10-14-16	Pearson V	5375	27	0,6496
63. Oprah without Commercials	04-04-04	Lognormal	16771	84	0,7876

TABLE A.2.12 INFORMATION ONHYBRID MODELING OF B FRAMES OF HIGH ACTIVITY

Video Trace	QL	BEST FIT	Max Frame Size (Bytes)	States In DAR	Autocorrelation
1. Die Hard One	30-30-30	Gamma	1649	35	0,6342
2. Die Hard One	10-14-16	Gamma	2795	59	0,5302
3. Die Hard One	04-04-04	Pearson V	10424	53	0,5462
4. Citizen Kane	30-30-30	Gamma	1260	27	0,7392
5. Citizen Kane	10-14-16	Lognormal	2283	48	0,6672
6. Citizen Kane	04-04-04	Lognormal	9910	50	0,6533
7. Silence of the Lambs	30-30-30	Gamma	1654	35	0,7513
8. Silence of the Lambs	10-14-16				
9. Silence of the Lambs	04-04-04	Pearson V	14630	74	0,8175
10. Star Wars IV	30-30-30	Gamma	1891	40	0,6851
11. Star Wars IV	10-14-16	Gamma	3767	79	0,6170
12. Star Wars IV	04-04-04	Pearson V	14214	72	0,6760
13. Terminator One	30-30-30	Lognormal	3455	72	0,5123
14. Terminator One	10-14-16	Gamma	7367	37	0,5020
15. Terminator One	04-04-04	Gamma	24402	123	0,4580
16. Aladdin	30-30-30	Lognormal	2929	62	0,6057

17. Aladdin	10-14-16	Lognormal	6103	31	0,5552
18. Aladdin	04-04-04	Pearson V	21746	109	0,6455
19. Cinderella	30-30-30	Lognormal	3429	72	0,7270
20. Cinderella	10-14-16	Lognormal	7401	38	0,6744
21. Cinderella	04-04-04	Lognormal	24873	125	0,7738
22. Tonight Show with Commercials	30-30-30	Lognormal	2336	49	0,8598
23. Tonight Show with Commercials	10-14-16	Pearson V	5237	27	0,8943
24. Tonight Show with Commercials	04-04-04	Pearson V	20305	102	0,9217
25. Tonight Show without Commercials	30-30-30	Lognormal	1719	36	0,8725
26. Tonight Show without Commercials	10-14-16	Lognormal	3906	82	0,9446
27. Tonight Show without Commercials	04-04-04	Pearson V	16683	84	0,9574
28. Lecture-Reisslein	30-30-30	Lognormal	1670	35	0,7831
29. Lecture-Reisslein	10-14-16	Pearson V	3580	75	0,8745
30. Lecture-Reisslein	04-04-04	Pearson V	15419	78	0,9525
31. Lecture HQ-Reisslein	30-30-30	Lognormal	11386	238	0,4678
32. Lecture HQ-Reisslein	10-14-16	Gamma	16696	84	0,5887
33. Lecture HQ-Reisslein	04-04-04	Pearson V	32954	165	0,9000
34. Lecture-Gupta	30-30-30	Pearson V	1608	34	0,7629
35. Lecture-Gupta	10-14-16	Pearson V	3444	72	0,7917
36. Lecture-Gupta	04-04-04	Pearson V	13391	67	0,9400
37. Baseball with Commercials	30-30-30	Gamma	1779	38	0,8115
38. Baseball with Commercials	10-14-16	Lognormal	2988	63	0,8265
39. Baseball with Commercials	04-04-04	Pearson V	11621	59	0,8806
40. Friends vol.4 DVD	30-30-30	Weibull	1342	28	0,7603
41. Friends vol.4 DVD	10-14-16	Gamma	2630	55	0,7353
42. Friends vol.4 DVD	04-04-04	Weibull	10698	54	0,6787
43. Tokyo Olympics DVD	30-30-30	Weibull	1083	23	0,7720
44. Tokyo Olympics DVD	10-14-16	Weibull	2320	49	0,7199

45. Tokyo Olympics DVD	04-04-04	Weibull	10394	52	0,6743
46. O Brother DVD	30-30-30	Lognormal	1266	27	0,8561
47. O Brother DVD	10-14-16	Gamma	2050	43	0,8451
48. O Brother DVD	04-04-04	Weibull	7798	39	0,7947
49. Die Another Day DVD	30-30-30	Gamma	1357	29	0,8048
50. Die Another Day DVD	10-14-16	Lognormal	2240	47	0,7821
51. Die Another Day DVD	04-04-04	Weibull	8364	42	0,7186
52. The Transporter DVD	30-30-30	Weibull	1790	38	0,7509
53. The Transporter DVD	10-14-16	Weibull	2473	52	0,7300
54. The Transporter DVD	04-04-04	Weibull	9586	48	0,6690
55. Charlie's Angels DVD	30-30-30	Gamma	1341	28	0,8083
56. Charlie's Angels DVD	10-14-16	Lognormal	2799	59	0,8043
57. Charlie's Angels DVD	04-04-04	Gamma	12117	61	0,7559
58. Ice Age DVD	30-30-30	Weibull	1623	34	0,7585
59. Ice Age DVD	10-14-16	Weibull	2342	49	0,7901
60. Ice Age DVD	04-04-04	Gamma	8251	42	0,7534
61. Oprah without Commercials	30-30-30	Gamma	1193	25	0,8676
62. Oprah without Commercials	10-14-16	Pearson V	2696	57	0,9190
63. Oprah without Commercials	04-04-04	Lognormal	13269	67	0,9623

Packet size = 48 Bytes/packet for the 30-30-30 movie traces and the traces highlighted red, 200 Bytes/packet for the rest

TABLE A.2.13 AUTOCORRELATION COEFFICIENT OF MODELED SOURCES FOR I FRAMES OF LOW ACTIVITY

Video Trace	QL	5 sources		10 sources		15 sources	
		Actual ρ	Modeled ρ	Actual ρ	Modeled ρ	Actual ρ	Modeled ρ
Die Hard One	30-30-30	0,8894	0,8805	0,8759	0,8770	0,8739	0,8711
Die Hard One	10-14-16	0,8243	0,8351	0,8404	0,8311	0,8186	0,8370
Die Hard One	04-04-04	0,7636	0,7636	0,7361	0,7523	0,7486	0,7425
Citizen Kane	30-30-30	0,9258	0,9284	0,9018	0,9297	0,9407	0,9302
Citizen Kane	10-14-16	0,9221	0,9127	0,8916	0,9100	0,8992	0,9197
Citizen Kane	04-04-04	0,8719	0,9213	0,8876	0,9269	0,9517	0,9146
Silence of the Lambs	30-30-30	0,9237	0,9159	0,9205	0,9140	0,9027	0,9187
Silence of the Lambs	10-14-16	0,8824	0,8850	0,8593	0,8936	0,8860	0,8917
Silence of the Lambs	04-04-04	0,8589	0,8490	0,8232	0,8489	0,8762	0,8581
Star Wars IV	30-30-30	0,8234	0,8307	0,8271	0,8396	0,8544	0,8433
Star Wars IV	10-14-16	0,8583	0,8623	0,8780	0,8540	0,8650	0,8607
Star Wars IV	04-04-04	0,8209	0,8366	0,8153	0,8265	0,8349	0,8292
Terminator One	30-30-30	0,9116	0,9238	0,9200	0,9261	0,9169	0,9328
Terminator One	10-14-16	0,8556	0,8753	0,9074	0,8614	0,8419	0,8784
Terminator One	04-04-04	0,8008	0,8040	0,8487	0,7916	0,7653	0,7991
Aladdin	30-30-30	0,8762	0,9019	0,9095	0,8776	0,8624	0,8999
Aladdin	10-14-16	0,8253	0,8502	0,8254	0,8406	0,8383	0,8450
Aladdin	04-04-04	0,7763	0,7894	0,8338	0,7715	0,7938	0,7943
Cinderella	30-30-30	0,8942	0,8983	0,8809	0,8792	0,8914	0,9016
Cinderella	10-14-16	0,8235	0,8503	0,8449	0,8607	0,8415	0,8483
Cinderella	04-04-04	0,8344	0,8238	0,8486	0,8364	0,8325	0,8324
Tonight Show with Commercials	30-30-30	0,9079	0,8702	0,8830	0,8668	0,8724	0,8831
Tonight Show with Commercials	10-14-16	0,8913	0,8779	0,8848	0,8613	0,8487	0,8744
Tonight Show with Commercials	04-04-04	0,7339	0,7777	0,7736	0,7512	0,8075	0,7835
Tonight Show without Commercials	30-30-30	0,9845	0,9829	0,9799	0,9817	0,9863	0,9853
Tonight Show without Commercials	10-14-16	0,9197	0,9625	0,9832	0,9759	0,9786	0,9760
Tonight Show without Commercials	04-04-04	0,9836	0,9722	0,9751	0,9718	0,9111	0,9765
Lecture-Reisslein	30-30-30	0,9619	0,9510	0,8935	0,9533	0,9481	0,9565
Lecture-Reisslein	10-14-16						
Lecture-Reisslein	04-04-04						
Lecture HQ-Reisslein	30-30-30	0,9772	0,9843	0,9812	0,9692	0,9754	0,9798
Lecture HQ-Reisslein	10-14-16	0,9714	0,9461	0,9567	0,9485	0,9588	0,9620
Lecture HQ-Reisslein	04-04-04	0,9474	0,9310	0,9167	0,9308	0,9318	0,9206
Lecture-Gupta	30-30-30	0,8643	0,9013	0,8949	0,9069	0,9453	0,8975
Lecture-Gupta	10-14-16	0,9261	0,8883	0,8529	0,8641	0,8891	0,8764

Lecture-Gupta	04-04-04	0,9178	0,9102	0,8906	0,9066	0,8413	0,9059
Baseball with Commercials	30-30-30	0,8721	0,8776	0,8721	0,8900	0,8792	0,8733
Baseball with Commercials	10-14-16	0,8614	0,8491	0,8700	0,8507	0,8632	0,8580
Baseball with Commercials	04-04-04	0,7599	0,7525	0,7609	0,7740	0,7864	0,7546
Friends vol.4 DVD	30-30-30	0,8533	0,8914	0,9090	0,8913	0,8669	0,8863
Friends vol.4 DVD	10-14-16	0,8447	0,8342	0,8269	0,8490	0,8459	0,8432
Friends vol.4 DVD	04-04-04	0,8518	0,8669	0,8752	0,8705	0,8817	0,8700
Tokyo Olympics DVD	30-30-30	0,9092	0,9169	0,9128	0,9207	0,9051	0,9080
Tokyo Olympics DVD	10-14-16						
Tokyo Olympics DVD	04-04-04	0,8860	0,8752	0,8664	0,8924	0,8806	0,8911
O Brother DVD	30-30-30	0,9388	0,9494	0,9165	0,9457	0,9367	0,9406
O Brother DVD	10-14-16	0,9190	0,9309	0,9010	0,9173	0,9294	0,9223
O Brother DVD	04-04-04	0,9269	0,9242	0,9189	0,9059	0,9212	0,9271
Die Another Day DVD	30-30-30	0,8844	0,8774	0,8634	0,8673	0,8626	0,8809
Die Another Day DVD	10-14-16	0,8594	0,8350	0,8436	0,8307	0,8338	0,8337
Die Another Day DVD	04-04-04	0,8686	0,8201	0,8308	0,8179	0,7837	0,8091
The Transporter DVD	30-30-30	0,8497	0,8765	0,8584	0,8726	0,8881	0,8720
The Transporter DVD	10-14-16	0,8378	0,8333	0,8297	0,8351	0,8195	0,8381
The Transporter DVD	04-04-04	0,8296	0,8021	0,7949	0,8061	0,7832	0,8047
Charlie's Angels DVD	30-30-30	0,8661	0,8858	0,8718	0,8642	0,8452	0,8661
Charlie's Angels DVD	10-14-16	0,8368	0,8328	0,8167	0,8480	0,8677	0,8361
Charlie's Angels DVD	04-04-04	0,7869	0,8127	0,7914	0,8077	0,7943	0,7910
Ice Age DVD	30-30-30	0,9135	0,9083	0,9181	0,9257	0,8874	0,9200
Ice Age DVD	10-14-16						
Ice Age DVD	04-04-04						
Oprah without Commercials	30-30-30	0,9145	0,9129	0,8957	0,9052	0,8856	0,9063
Oprah without Commercials	10-14-16	0,8700	0,9085	0,8939	0,9056	0,8826	0,9034
Oprah without Commercials	04-04-04	0,8856	0,9059	0,8990	0,9142	0,9126	0,9064

TABLE A.2.14 AUTOCORRELATION COEFFICIENT OF MODELED SOURCES FOR P FRAMES OF LOW ACTIVITY

Video Trace	QL	5 sources		10 sources		15 sources	
		Actual ρ	Modeled ρ	Actual ρ	Modeled ρ	Actual ρ	Modeled ρ
Die Hard One	30-30-30	0,4218	0,4227	0,3760	0,4417	0,4159	0,4265
Die Hard One	10-14-16	0,4162	0,3996	0,4106	0,4114	0,4138	0,4147
Die Hard One	04-04-04	0,5189	0,5344	0,5366	0,5268	0,5088	0,5076
Citizen Kane	30-30-30	0,4614	0,3321	0,4355	0,3410	0,3983	0,3315
Citizen Kane	10-14-16	0,4889	0,5138	0,5943	0,5183	0,5186	0,5225
Citizen Kane	04-04-04	0,7028	0,7064	0,6600	0,7132	0,6781	0,7158
Silence of the Lambs	30-30-30	0,2810	0,3369	0,2334	0,3445	0,2963	0,3396
Silence of the Lambs	10-14-16	0,3377	0,3552	0,3552	0,3603	0,3381	0,3630
Silence of the Lambs	04-04-04	0,5632	0,5730	0,5472	0,5818	0,5709	0,5717
Star Wars IV	30-30-30	0,3971	0,3876	0,2934	0,3557	0,4039	0,3790
Star Wars IV	10-14-16	0,3223	0,3253	0,3172	0,3485	0,3295	0,3210
Star Wars IV	04-04-04	0,4978	0,5088	0,5340	0,5073	0,5164	0,4962
Terminator One	30-30-30	0,4901	0,5208	0,5070	0,5049	0,5420	0,5121
Terminator One	10-14-16	0,5103	0,4990	0,4854	0,5055	0,4780	0,5129
Terminator One	04-04-04	0,6428	0,6297	0,6160	0,6052	0,6400	0,6229
Aladdin	30-30-30	0,4747	0,4740	0,4758	0,4726	0,4473	0,4585
Aladdin	10-14-16	0,5395	0,5434	0,5828	0,5398	0,5646	0,5428
Aladdin	04-04-04	0,6901	0,7119	0,6984	0,7033	0,7792	0,7066
Cinderella	30-30-30	0,3880	0,3818	0,3782	0,3944	0,4186	0,3854
Cinderella	10-14-16	0,4220	0,4268	0,4308	0,4276	0,4270	0,4238
Cinderella	04-04-04	0,6279	0,6142	0,5932	0,6304	0,6227	0,6239
Tonight Show with Commercials	30-30-30	0,4502	0,4536	0,4482	0,4265	0,4314	0,4476
Tonight Show with Commercials	10-14-16	0,5243	0,5131	0,4598	0,5195	0,5012	0,5137
Tonight Show with Commercials	04-04-04	0,7545	0,7273	0,7250	0,7213	0,7425	0,7157
Tonight Show without Commercials	30-30-30						
Tonight Show without Commercials	10-14-16						
Tonight Show without Commercials	04-04-04	0,9117	0,9157	0,9160	0,9092	0,9150	0,9181
Lecture-Reisslein	30-30-30	0,8059	0,7953	0,7472	0,7739	0,6416	0,7572
Lecture-Reisslein	10-14-16	0,8913	0,9306	0,9471	0,9221	0,9234	0,9205
Lecture-Reisslein	04-04-04	0,9805	0,9736	0,9927	0,9718	0,9559	0,9671
Lecture HQ-Reisslein	30-30-30	0,4553	0,4165	0,5153	0,4060	0,3432	0,4010
Lecture HQ-Reisslein	10-14-16	0,6775	0,6708	0,6530	0,7072	0,6554	0,6933
Lecture HQ-Reisslein	04-04-04	0,7381	0,7290	0,7255	0,7297	0,7333	0,7290
Lecture-Gupta	30-30-30	0,4027	0,2228	0,2702	0,2221	0,2701	0,2210
Lecture-Gupta	10-14-16	0,6418	0,6718	0,6771	0,6725	0,6477	0,6623
Lecture-Gupta	04-04-04	0,8852	0,8567	0,7043	0,8502	0,7510	0,8536
Baseball with	30-30-30	0,5807	0,5878	0,5495	0,5891	0,5127	0,5726

Commercials							
Baseball with Commercials	10-14-16	0,5615	0,5536	0,5356	0,5551	0,5574	0,5605
Baseball with Commercials	04-04-04	0,7432	0,7329	0,7246	0,7449	0,7457	0,7443
Friends vol.4 DVD	30-30-30	0,2763	0,3206	0,4446	0,3128	0,3417	0,3117
Friends vol.4 DVD	10-14-16	0,2959	0,3005	0,3184	0,2952	0,2958	0,2970
Friends vol.4 DVD	04-04-04	0,3623	0,3442	0,3168	0,3455	0,3557	0,3488
Tokyo Olympics DVD	30-30-30	0,6363	0,6340	0,6475	0,6335	0,6890	0,6309
Tokyo Olympics DVD	10-14-16	0,5955	0,6082	0,6035	0,6147	0,5910	0,6100
Tokyo Olympics DVD	04-04-04	0,7147	0,7054	0,6913	0,7154	0,7082	0,7261
O Brother DVD	30-30-30	0,2950	0,3441	0,4142	0,3376	0,3252	0,3405
O Brother DVD	10-14-16	0,3670	0,3615	0,3540	0,3808	0,3643	0,3760
O Brother DVD	04-04-04	0,5617	0,5371	0,5227	0,5362	0,4818	0,5235
Die Another Day DVD	30-30-30	0,2748	0,2895	0,2840	0,2822	0,3299	0,2880
Die Another Day DVD	10-14-16	0,2030	0,2224	0,2073	0,2256	0,2197	0,2243
Die Another Day DVD	04-04-04	0,2998	0,3013	0,3033	0,2974	0,2938	0,3113
The Transporter DVD	30-30-30	0,4099	0,4038	0,4178	0,3851	0,4242	0,3999
The Transporter DVD	10-14-16	0,2828	0,2962	0,2489	0,2852	0,2761	0,2871
The Transporter DVD	04-04-04	0,3603	0,3629	0,3496	0,3781	0,3625	0,3774
Charlie's Angels DVD	30-30-30	0,3833	0,3917	0,3918	0,3827	0,4447	0,3753
Charlie's Angels DVD	10-14-16	0,3481	0,3269	0,3414	0,3314	0,3456	0,3419
Charlie's Angels DVD	04-04-04	0,4308	0,4467	0,4761	0,4515	0,4501	0,4333
Ice Age DVD	30-30-30	0,3204	0,3038	0,3874	0,3209	0,3331	0,2978
Ice Age DVD	10-14-16	0,2565	0,2450	0,2830	0,2577	0,2599	0,2660
Ice Age DVD	04-04-04	0,2898	0,3101	0,2672	0,3022	0,2698	0,2932
Oprah without Commercials	30-30-30	0,3301	0,3649	0,2408	0,3756	0,4017	0,3677
Oprah without Commercials	10-14-16	0,6448	0,5502	0,6125	0,5787	0,5782	0,5511
Oprah without Commercials	04-04-04	0,7104	0,6983	0,7211	0,7240	0,7468	0,7186

TABLE A.2.15 AUTOCORRELATION COEFFICIENT OF MODELED SOURCES FOR B FRAMES OF LOW ACTIVITY

Video Trace	QL	5 sources		10 sources		15 sources	
		Actual ρ	Modeled ρ	Actual ρ	Modeled ρ	Actual ρ	Modeled ρ
Die Hard One	30-30-30	0,5902	0,6639	0,7034	0,6805	0,7132	0,6778
Die Hard One	10-14-16	0,6814	0,6776	0,6435	0,6804	0,6145	0,6800
Die Hard One	04-04-04	0,6550	0,6854	0,6570	0,6731	0,6552	0,6701
Citizen Kane	30-30-30	0,6289	0,5863	0,4495	0,5751	0,6891	0,5867
Citizen Kane	10-14-16	0,6475	0,6227	0,6386	0,6246	0,6554	0,6286
Citizen Kane	04-04-04	0,7326	0,7200	0,7132	0,7136	0,6725	0,7124
Silence of the Lambs	30-30-30	0,5022	0,5723	0,5497	0,5758	0,5633	0,5737
Silence of the Lambs	10-14-16	0,6532	0,6282	0,6579	0,6264	0,7310	0,6205
Silence of the Lambs	04-04-04	0,7897	0,8247	0,7940	0,8280	0,7766	0,8291

Star Wars IV	30-30-30	0,6372	0,6175	0,6648	0,6278	0,6623	0,6361
Star Wars IV	10-14-16	0,6377	0,6466	0,6518	0,6501	0,6656	0,6452
Star Wars IV	04-04-04	0,6876	0,6830	0,6557	0,6879	0,6466	0,6876
Terminator One	30-30-30	0,6883	0,6743	0,6145	0,6747	0,6913	0,6747
Terminator One	10-14-16						
Terminator One	04-04-04	0,5581	0,5723	0,5565	0,5732	0,5556	0,5783
Aladdin	30-30-30	0,6305	0,6609	0,6431	0,6670	0,6041	0,6598
Aladdin	10-14-16	0,5952	0,6255	0,6089	0,6228	0,6344	0,6164
Aladdin	04-04-04	0,7227	0,7256	0,8014	0,7225	0,7132	0,7299
Cinderella	30-30-30	0,6917	0,6398	0,5236	0,6448	0,6870	0,6444
Cinderella	10-14-16	0,6204	0,6075	0,5724	0,6204	0,6061	0,6115
Cinderella	04-04-04	0,6382	0,6661	0,6752	0,6644	0,6964	0,6678
Tonight Show with Commercials	30-30-30	0,7652	0,7784	0,7933	0,7817	0,7547	0,7787
Tonight Show with Commercials	10-14-16	0,8316	0,8273	0,8236	0,8260	0,8211	0,8261
Tonight Show with Commercials	04-04-04	0,9088	0,9089	0,9042	0,9079	0,9174	0,9107
Tonight Show without Commercials	30-30-30						
Tonight Show without Commercials	10-14-16						
Tonight Show without Commercials	04-04-04						
Lecture-Reisslein	30-30-30	0,7714	0,7287	0,6670	0,7159	0,7488	0,7156
Lecture-Reisslein	10-14-16	0,7643	0,7503	0,6643	0,7543	0,6982	0,7554
Lecture-Reisslein	04-04-04	0,9892	0,9917	0,9667	0,9923	0,9796	0,9916
Lecture HQ-Reisslein	30-30-30	0,5897	0,4642	0,2021	0,4660	0,4427	0,4600
Lecture HQ-Reisslein	10-14-16	0,6094	0,4908	0,3793	0,4867	0,3294	0,5017
Lecture HQ-Reisslein	04-04-04	0,7367	0,7357	0,7294	0,7477	0,7054	0,7410
Lecture-Gupta	30-30-30	0,3046	0,5058	0,5423	0,5169	0,4449	0,5106
Lecture-Gupta	10-14-16	0,5920	0,6568	0,5742	0,6549	0,6837	0,6595
Lecture-Gupta	04-04-04	0,8819	0,9014	0,8385	0,9020	0,8799	0,9055
Baseball with Commercials	30-30-30	0,7306	0,7338	0,7432	0,7353	0,7430	0,7364
Baseball with Commercials	10-14-16	0,7505	0,7825	0,8211	0,7796	0,7844	0,7884
Baseball with Commercials	04-04-04	0,8731	0,8785	0,8714	0,8881	0,8727	0,8911
Friends vol.4 DVD	30-30-30	0,5818	0,6249	0,6564	0,6297	0,5544	0,6269
Friends vol.4 DVD	10-14-16	0,5899	0,6464	0,6260	0,6304	0,6020	0,6334
Friends vol.4 DVD	04-04-04	0,6652	0,6770	0,6613	0,6899	0,6714	0,6889
Tokyo Olympics DVD	30-30-30	0,7073	0,7670	0,7791	0,7571	0,7613	0,7633
Tokyo Olympics DVD	10-14-16	0,7763	0,7695	0,7437	0,7654	0,7468	0,7699
Tokyo Olympics DVD	04-04-04	0,7113	0,7521	0,7367	0,7613	0,7186	0,7483
O Brother DVD	30-30-30	0,6251	0,6282	0,4759	0,6301	0,4977	0,6205
O Brother DVD	10-14-16	0,6611	0,6859	0,6177	0,6855	0,6796	0,6858
O Brother DVD	04-04-04	0,7936	0,8249	0,8080	0,8275	0,8027	0,8289
Die Another Day DVD	30-30-30	0,6377	0,6730	0,6990	0,6716	0,6111	0,6731

Die Another Day DVD	10-14-16	0,6777	0,6737	0,6751	0,6802	0,6800	0,6743
Die Another Day DVD	04-04-04	0,7018	0,7278	0,7044	0,7338	0,7056	0,7389
The Transporter DVD	30-30-30	0,7524	0,6974	0,6864	0,6889	0,6003	0,6940
The Transporter DVD	10-14-16	0,6555	0,7307	0,7549	0,7332	0,7758	0,7393
The Transporter DVD	04-04-04	0,6898	0,7359	0,7019	0,7267	0,6919	0,7188
Charlie's Angels DVD	30-30-30	0,6305	0,7105	0,6990	0,7062	0,6726	0,7151
Charlie's Angels DVD	10-14-16	0,6276	0,7400	0,7679	0,7421	0,6587	0,7467
Charlie's Angels DVD	04-04-04	0,7293	0,7670	0,7359	0,7650	0,7286	0,7558
Ice Age DVD	30-30-30	0,6750	0,5805	0,5374	0,5672	0,5840	0,5758
Ice Age DVD	10-14-16	0,6369	0,6017	0,6763	0,6020	0,6146	0,6050
Ice Age DVD	04-04-04	0,7147	0,7583	0,7239	0,7616	0,7338	0,7656
Oprah without Commercials	30-30-30	0,7472	0,7570	0,6003	0,7582	0,8179	0,7611
Oprah without Commercials	10-14-16	0,8734	0,9392	0,9152	0,9400	0,8915	0,9389
Oprah without Commercials	04-04-04	0,9507	0,9455	0,9407	0,9462	0,9528	0,9430

TABLE A.2.16 AUTOCORRELATION COEFFICIENT OF MODELED SOURCES FOR I FRAMES OF HIGH ACTIVITY

Video Trace	QL	5 sources		10 sources		15 sources	
		Actual ρ	Modeled ρ	Actual ρ	Modeled ρ	Actual ρ	Modeled ρ
Die Hard One	30-30-30	0,7684	0,7862	0,7690	0,7783	0,7676	0,7838
Die Hard One	10-14-16	0,7803	0,7644	0,7749	0,7804	0,7694	0,7729
Die Hard One	04-04-04	0,7429	0,7320	0,7139	0,7517	0,6951	0,7309
Citizen Kane	30-30-30	0,8969	0,8884	0,8870	0,9133	0,9068	0,8823
Citizen Kane	10-14-16	0,9116	0,8759	0,8901	0,8863	0,8918	0,8900
Citizen Kane	04-04-04	0,8574	0,8531	0,8522	0,8380	0,8596	0,8734
Silence of the Lambs	30-30-30	0,9368	0,9397	0,9158	0,9172	0,9226	0,9215
Silence of the Lambs	10-14-16	0,9050	0,9218	0,9057	0,8985	0,9038	0,9154
Silence of the Lambs	04-04-04	0,8887	0,9056	0,8799	0,8867	0,8660	0,8874
Star Wars IV	30-30-30	0,9267	0,9154	0,9202	0,9225	0,9309	0,9108
Star Wars IV	10-14-16	0,8818	0,8885	0,8949	0,8769	0,8684	0,8798
Star Wars IV	04-04-04	0,8595	0,8351	0,8522	0,8480	0,8361	0,8462
Terminator One	30-30-30	0,7888	0,8383	0,8570	0,8317	0,8224	0,8457
Terminator One	10-14-16	0,8041	0,8283	0,8135	0,8277	0,8410	0,8141
Terminator One	04-04-04	0,8022	0,7962	0,7949	0,7916	0,7849	0,7987
Aladdin	30-30-30	0,7663	0,7582	0,7720	0,7547	0,7895	0,7695
Aladdin	10-14-16	0,7255	0,7172	0,7014	0,7211	0,7363	0,7612
Aladdin	04-04-04	0,6982	0,7192	0,7411	0,7331	0,7415	0,7106
Cinderella	30-30-30	0,7565	0,7797	0,8174	0,7693	0,7891	0,7684
Cinderella	10-14-16	0,8146	0,7838	0,8108	0,7949	0,8462	0,8090
Cinderella	04-04-04	0,7937	0,8044	0,8007	0,7934	0,8059	0,7974

Tonight Show with Commercials	30-30-30	0,7992	0,8035	0,8452	0,8058	0,7959	0,8044
Tonight Show with Commercials	10-14-16	0,7484	0,7543	0,7674	0,7578	0,8188	0,7694
Tonight Show with Commercials	04-04-04	0,7799	0,7555	0,7591	0,7466	0,8269	0,7329
Tonight Show without Commercials	30-30-30	0,9062	0,9299	0,9355	0,9308	0,8965	0,9239
Tonight Show without Commercials	10-14-16	0,8873	0,9084	0,8716	0,8968	0,8709	0,9049
Tonight Show without Commercials	04-04-04	0,8603	0,9128	0,9440	0,9031	0,8884	0,9044
Lecture-Reisslein	30-30-30	0,9693	0,9682	0,9631	0,9730	0,9668	0,9688
Lecture-Reisslein	10-14-16	0,9789	0,9674	0,9760	0,9694	0,9743	0,9733
Lecture-Reisslein	04-04-04	0,9669	0,9608	0,9685	0,9630	0,9759	0,9627
Lecture HQ-Reisslein	30-30-30	0,9857	0,9827	0,9785	0,9838	0,9798	0,9854
Lecture HQ-Reisslein	10-14-16	0,9848	0,9840	0,9814	0,9768	0,9903	0,9809
Lecture HQ-Reisslein	04-04-04	0,9845	0,9839	0,9796	0,9803	0,9806	0,9821
Lecture-Gupta	30-30-30	0,9604	0,9557	0,9419	0,9623	0,9546	0,9597
Lecture-Gupta	10-14-16	0,9717	0,9615	0,9729	0,9657	0,9736	0,9634
Lecture-Gupta	04-04-04	0,9843	0,9578	0,9542	0,9577	0,9691	0,9626
Baseball with Commercials	30-30-30	0,7744	0,7944	0,7634	0,7851	0,7688	0,7882
Baseball with Commercials	10-14-16	0,7769	0,7924	0,7592	0,7752	0,7502	0,7675
Baseball with Commercials	04-04-04	0,7159	0,7193	0,6870	0,7144	0,7064	0,7184
Friends vol.4 DVD	30-30-30	0,7378	0,7323	0,7440	0,7601	0,7647	0,7567
Friends vol.4 DVD	10-14-16	0,7656	0,7928	0,7870	0,7810	0,7786	0,7737
Friends vol.4 DVD	04-04-04	0,7804	0,7944	0,7712	0,7916	0,7705	0,7943
Tokyo Olympics DVD	30-30-30	0,9394	0,9379	0,9382	0,9334	0,9047	0,9192
Tokyo Olympics DVD	10-14-16	0,8940	0,9232	0,8892	0,9219	0,9089	0,9223
Tokyo Olympics DVD	04-04-04	0,9137	0,8956	0,8856	0,9114	0,8932	0,8944
O Brother DVD	30-30-30	0,8787	0,9117	0,8844	0,9023	0,8728	0,8998
O Brother DVD	10-14-16	0,9163	0,9100	0,8737	0,9039	0,8875	0,9097
O Brother DVD	04-04-04	0,9046	0,8950	0,8874	0,8996	0,8747	0,8942
Die Another Day DVD	30-30-30	0,8206	0,7837	0,8356	0,7809	0,7910	0,7940
Die Another Day DVD	10-14-16	0,7635	0,7374	0,7785	0,7776	0,7405	0,7667
Die Another Day DVD	04-04-04	0,7258	0,7246	0,7274	0,7196	0,7174	0,7279
The Transporter DVD	30-30-30	0,6979	0,7144	0,7237	0,7188	0,7134	0,7202
The Transporter DVD	10-14-16	0,7391	0,7710	0,7999	0,7687	0,7686	0,7860
The Transporter DVD	04-04-04	0,7145	0,7457	0,7148	0,7140	0,7435	0,7153
Charlie's Angels DVD	30-30-30	0,8550	0,8434	0,8247	0,8542	0,8304	0,8521
Charlie's Angels DVD	10-14-16	0,8185	0,8031	0,8140	0,7915	0,8119	0,8230
Charlie's Angels DVD	04-04-04	0,7987	0,7840	0,7913	0,7825	0,7643	0,7817
Ice Age DVD	30-30-30	0,7985	0,8123	0,8091	0,8329	0,8202	0,8134
Ice Age DVD	10-14-16	0,8203	0,8387	0,8357	0,8051	0,8219	0,8297
Ice Age DVD	04-04-04	0,8313	0,8244	0,7920	0,8279	0,8155	0,8358
Oprah without Commercials	30-30-30	0,8555	0,8489	0,8590	0,8599	0,8587	0,8590

Oprah without Commercials	10-14-16	0,8449	0,8464	0,8262	0,8446	0,8624	0,8238
Oprah without Commercials	04-04-04	0,8804	0,8835	0,8915	0,8816	0,8627	0,8761

TABLE A.2.17 AUTOCORRELATION COEFFICIENT OF MODELED SOURCES FOR P FRAMES OF HIGH ACTIVITY

Video Trace	QL	5 sources		10 sources		15 sources	
		Actual ρ	Modeled ρ	Actual ρ	Modeled ρ	Actual ρ	Modeled ρ
Die Hard One	30-30-30	0,5999	0,6071	0,6019	0,6051	0,5792	0,6168
Die Hard One	10-14-16	0,5613	0,5604	0,5840	0,5414	0,5811	0,5563
Die Hard One	04-04-04	0,6223	0,6288	0,6441	0,6152	0,6557	0,6314
Citizen Kane	30-30-30	0,6652	0,6764	0,6809	0,6701	0,6726	0,6754
Citizen Kane	10-14-16	0,6861	0,7146	0,7420	0,7209	0,7248	0,7345
Citizen Kane	04-04-04	0,8275	0,8105	0,8190	0,8185	0,7984	0,8157
Silence of the Lambs	30-30-30	0,7363	0,7522	0,7355	0,7523	0,7529	0,7496
Silence of the Lambs	10-14-16	0,7739	0,8122	0,7738	0,7898	0,7832	0,7776
Silence of the Lambs	04-04-04	0,8645	0,8645	0,9074	0,8618	0,8619	0,8633
Star Wars IV	30-30-30	0,5779	0,5796	0,5461	0,5689	0,5853	0,5814
Star Wars IV	10-14-16	0,6962	0,5887	0,5790	0,5911	0,5069	0,5795
Star Wars IV	04-04-04	0,6722	0,6968	0,6907	0,7012	0,7041	0,6863
Terminator One	30-30-30	0,5354	0,5386	0,5565	0,5466	0,5512	0,5346
Terminator One	10-14-16	0,5944	0,5735	0,5437	0,5749	0,6014	0,5783
Terminator One	04-04-04	0,7107	0,6624	0,6757	0,6840	0,6797	0,6784
Aladdin	30-30-30	0,5508	0,5479	0,5105	0,5573	0,5453	0,5390
Aladdin	10-14-16	0,6326	0,6305	0,6082	0,6345	0,6367	0,6382
Aladdin	04-04-04	0,7635	0,7141	0,7264	0,7248	0,7100	0,7276
Cinderella	30-30-30	0,5982	0,6120	0,5915	0,5987	0,6151	0,6133
Cinderella	10-14-16	0,6688	0,6833	0,6652	0,6791	0,6655	0,6884
Cinderella	04-04-04	0,7794	0,7824	0,7699	0,7982	0,7861	0,7916
Tonight Show with Commercials	30-30-30	0,5699	0,5898	0,5469	0,5926	0,5928	0,5977
Tonight Show with Commercials	10-14-16	0,7467	0,7556	0,7080	0,7389	0,7616	0,7442
Tonight Show with Commercials	04-04-04	0,7354	0,7644	0,7726	0,7573	0,7858	0,7671
Tonight Show without Commercials	30-30-30	0,6364	0,6712	0,6542	0,6699	0,6511	0,6640
Tonight Show without Commercials	10-14-16	0,7569	0,7251	0,7091	0,7389	0,7094	0,7245
Tonight Show without Commercials	04-04-04	0,7984	0,8004	0,7997	0,8028	0,7855	0,8069
Lecture-Reisslein	30-30-30	0,6570	0,7234	0,7693	0,7204	0,7048	0,7141
Lecture-Reisslein	10-14-16	0,8488	0,8761	0,8220	0,8560	0,8373	0,8511
Lecture-Reisslein	04-04-04	0,9004	0,9244	0,9431	0,9275	0,9024	0,9290

Lecture HQ-Reisslein	30-30-30	0,5576	0,4451	0,4209	0,4603	0,5796	0,4455
Lecture HQ-Reisslein	10-14-16	0,7040	0,6889	0,7035	0,6929	0,6638	0,6989
Lecture HQ-Reisslein	04-04-04	0,8221	0,8430	0,8017	0,8318	0,8124	0,8186
Lecture-Gupta	30-30-30	0,5846	0,5135	0,3855	0,5142	0,6228	0,5194
Lecture-Gupta	10-14-16	0,7204	0,7764	0,7544	0,7783	0,8047	0,7680
Lecture-Gupta	04-04-04	0,9159	0,8819	0,9009	0,8815	0,8332	0,8828
Baseball with Commercials	30-30-30	0,6319	0,6400	0,6522	0,6414	0,6297	0,6323
Baseball with Commercials	10-14-16	0,6009	0,6100	0,6040	0,6261	0,6014	0,6237
Baseball with Commercials	04-04-04	0,6918	0,7229	0,6964	0,7237	0,7258	0,7181
Friends vol.4 DVD	30-30-30	0,4801	0,4552	0,4973	0,4696	0,4743	0,4730
Friends vol.4 DVD	10-14-16	0,3428	0,3712	0,3829	0,3652	0,3655	0,3595
Friends vol.4 DVD	04-04-04	0,4232	0,4037	0,4194	0,4274	0,4323	0,4018
Tokyo Olympics DVD	30-30-30	0,6565	0,6461	0,6774	0,6623	0,6366	0,6603
Tokyo Olympics DVD	10-14-16	0,6953	0,6723	0,6589	0,6607	0,6560	0,6604
Tokyo Olympics DVD	04-04-04	0,8311	0,8233	0,8122	0,8200	0,8046	0,8359
O Brother DVD	30-30-30						
O Brother DVD	10-14-16	0,5435	0,5944	0,5917	0,5861	0,5387	0,5816
O Brother DVD	04-04-04	0,7125	0,7084	0,6935	0,7113	0,7113	0,7029
Die Another Day DVD	30-30-30	0,5262	0,5561	0,5802	0,5586	0,5437	0,5582
Die Another Day DVD	10-14-16	0,4995	0,5083	0,5299	0,5026	0,5108	0,5056
Die Another Day DVD	04-04-04	0,6115	0,6035	0,6150	0,6229	0,5702	0,5898
The Transporter DVD	30-30-30	0,4882	0,4972	0,4643	0,4802	0,4846	0,4875
The Transporter DVD	10-14-16	0,4311	0,4112	0,4075	0,4207	0,4196	0,4262
The Transporter DVD	04-04-04	0,5895	0,5548	0,5491	0,5751	0,5673	0,5395
Charlie's Angels DVD	30-30-30	0,5406	0,5356	0,5502	0,5210	0,4938	0,5430
Charlie's Angels DVD	10-14-16	0,5394	0,5421	0,5152	0,5374	0,5368	0,5501
Charlie's Angels DVD	04-04-04	0,6744	0,6506	0,6518	0,6682	0,6660	0,6614
Ice Age DVD	30-30-30	0,4158	0,4523	0,4295	0,4325	0,4266	0,4433
Ice Age DVD	10-14-16	0,3327	0,3573	0,3576	0,3325	0,4044	0,3543
Ice Age DVD	04-04-04	0,4711	0,4281	0,4657	0,4666	0,4512	0,4426
Oprah without Commercials	30-30-30	0,5883	0,6305	0,6408	0,6154	0,6407	0,6115
Oprah without Commercials	10-14-16	0,6540	0,6574	0,6593	0,6490	0,6982	0,6394
Oprah without Commercials	04-04-04	0,8271	0,7762	0,8151	0,7819	0,7547	0,7878

TABLE A.2.18 AUTOCORRELATION COEFFICIENT OF MODELED SOURCES FOR B FRAMES OF HIGH ACTIVITY

Video Trace	QL	5 sources		10 sources		15 sources	
		Actual ρ	Modeled ρ	Actual ρ	Modeled ρ	Actual ρ	Modeled ρ
Die Hard One	30-30-30	0,6381	0,6354	0,6142	0,6340	0,6321	0,6309
Die Hard One	10-14-16	0,5059	0,5205	0,5078	0,5333	0,5168	0,5331
Die Hard One	04-04-04	0,5197	0,5434	0,5286	0,5458	0,5558	0,5447
Citizen Kane	30-30-30	0,7492	0,7370	0,7380	0,7303	0,7659	0,7413
Citizen Kane	10-14-16	0,6608	0,6689	0,6446	0,6711	0,6534	0,6650
Citizen Kane	04-04-04	0,6592	0,6468	0,7129	0,6509	0,6567	0,6559
Silence of the Lambs	30-30-30	0,7426	0,7517	0,7620	0,7489	0,7332	0,7542
Silence of the Lambs	10-14-16						
Silence of the Lambs	04-04-04	0,9002	0,8199	0,8040	0,8198	0,8572	0,8214
Star Wars IV	30-30-30	0,6829	0,6909	0,6964	0,6861	0,6673	0,6832
Star Wars IV	10-14-16	0,5789	0,6228	0,6167	0,6101	0,5869	0,6115
Star Wars IV	04-04-04	0,6712	0,6703	0,6747	0,6735	0,6625	0,6753
Terminator One	30-30-30	0,5055	0,5096	0,5167	0,5166	0,5193	0,5105
Terminator One	10-14-16	0,4802	0,5107	0,5066	0,5023	0,4561	0,5075
Terminator One	04-04-04	0,4694	0,4633	0,4241	0,4586	0,4386	0,4594
Aladdin	30-30-30	0,5944	0,6001	0,6324	0,6077	0,6041	0,6056
Aladdin	10-14-16	0,5472	0,5609	0,5441	0,5568	0,5539	0,5547
Aladdin	04-04-04	0,6976	0,6425	0,6325	0,6397	0,6264	0,6431
Cinderella	30-30-30	0,7775	0,7339	0,7674	0,7225	0,7497	0,7333
Cinderella	10-14-16	0,6627	0,6690	0,6848	0,6843	0,7036	0,6757
Cinderella	04-04-04	0,8116	0,7711	0,8579	0,7664	0,7793	0,7790
Tonight Show with Commercials	30-30-30	0,8664	0,8582	0,8575	0,8576	0,8690	0,8614
Tonight Show with Commercials	10-14-16	0,8659	0,8994	0,8698	0,8904	0,8864	0,8952
Tonight Show with Commercials	04-04-04	0,9382	0,9224	0,9143	0,9218	0,9263	0,9213
Tonight Show without Commercials	30-30-30	0,8422	0,8709	0,8740	0,8721	0,8569	0,8722
Tonight Show without Commercials	10-14-16	0,9336	0,9510	0,9340	0,9454	0,9406	0,9436
Tonight Show without Commercials	04-04-04	0,9603	0,9567	0,9559	0,9586	0,9709	0,9576
Lecture-Reisslein	30-30-30	0,7926	0,7809	0,7799	0,7825	0,7868	0,7849
Lecture-Reisslein	10-14-16	0,8630	0,8722	0,8727	0,8743	0,9044	0,8745
Lecture-Reisslein	04-04-04	0,9317	0,9507	0,9319	0,9541	0,9466	0,9522
Lecture HQ-Reisslein	30-30-30	0,3590	0,4675	0,3113	0,4128	0,6139	0,4457
Lecture HQ-Reisslein	10-14-16	0,5240	0,5665	0,5936	0,5795	0,6493	0,5895
Lecture HQ-Reisslein	04-04-04	0,8870	0,9019	0,8769	0,9027	0,9475	0,8964
Lecture-Gupta	30-30-30	0,7265	0,7712	0,7370	0,7524	0,6738	0,7597
Lecture-Gupta	10-14-16	0,7973	0,7922	0,8246	0,7870	0,7859	0,7943
Lecture-Gupta	04-04-04	0,9341	0,9387	0,9582	0,9416	0,9094	0,9446
Baseball with	30-30-30	0,7993	0,8158	0,8091	0,8114	0,8189	0,8097

Commercials							
Baseball with Commercials	10-14-16	0,8362	0,8266	0,8102	0,8277	0,8281	0,8300
Baseball with Commercials	04-04-04	0,8697	0,8855	0,8762	0,8842	0,8722	0,8789
Friends vol.4 DVD	30-30-30	0,7582	0,7516	0,7544	0,7550	0,7579	0,7577
Friends vol.4 DVD	10-14-16	0,7378	0,7473	0,7326	0,7353	0,7513	0,7339
Friends vol.4 DVD	04-04-04	0,6773	0,6963	0,6808	0,6812	0,6690	0,6777
Tokyo Olympics DVD	30-30-30	0,7616	0,7704	0,7552	0,7791	0,7138	0,7643
Tokyo Olympics DVD	10-14-16	0,7314	0,7182	0,7271	0,7155	0,6996	0,7180
Tokyo Olympics DVD	04-04-04	0,6810	0,6760	0,6433	0,6701	0,6882	0,6753
O Brother DVD	30-30-30	0,8666	0,8566	0,8231	0,8519	0,8390	0,8568
O Brother DVD	10-14-16	0,8441	0,8435	0,8348	0,8417	0,8106	0,8420
O Brother DVD	04-04-04	0,7706	0,7915	0,7907	0,7953	0,7809	0,7949
Die Another Day DVD	30-30-30	0,8131	0,8109	0,7975	0,8033	0,8257	0,8081
Die Another Day DVD	10-14-16	0,7770	0,7856	0,7684	0,7723	0,7657	0,7867
Die Another Day DVD	04-04-04	0,7307	0,7233	0,7498	0,7223	0,7191	0,7169
The Transporter DVD	30-30-30	0,7593	0,7532	0,7075	0,7509	0,7430	0,7538
The Transporter DVD	10-14-16	0,7281	0,7388	0,7291	0,7286	0,7501	0,7196
The Transporter DVD	04-04-04	0,6838	0,6619	0,6782	0,6753	0,6686	0,6713
Charlie's Angels DVD	30-30-30	0,7886	0,8064	0,7928	0,8161	0,7962	0,8102
Charlie's Angels DVD	10-14-16	0,7976	0,8090	0,8020	0,7942	0,7960	0,8039
Charlie's Angels DVD	04-04-04	0,8041	0,7591	0,7578	0,7565	0,7379	0,7668
Ice Age DVD	30-30-30	0,7656	0,7656	0,7625	0,7649	0,7196	0,7525
Ice Age DVD	10-14-16	0,7821	0,7893	0,7820	0,7864	0,7471	0,7877
Ice Age DVD	04-04-04	0,7471	0,7544	0,7250	0,7468	0,7340	0,7507
Oprah without Commercials	30-30-30	0,8572	0,8626	0,8776	0,8653	0,8449	0,8703
Oprah without Commercials	10-14-16	0,8972	0,9169	0,9007	0,9178	0,8909	0,9221
Oprah without Commercials	04-04-04	0,9577	0,9616	0,9664	0,9635	0,9638	0,9623

TABLE A.2.19 PACKET SIZE USED IN FINAL HYBRID MODELING (SECTION 3.10)

Movie Trace	Packet Size
Die Hard One, 30-30-30	48 Bytes/Packet
Die Hard One, 10-14-16	48 Bytes/Packet
Die Hard One, 04-04-04	200 Bytes/Packet
Citizen Kane, 30-30-30	48 Bytes/Packet
Citizen Kane, 10-14-16	48 Bytes/Packet
Citizen Kane, 04-04-04	200 Bytes/Packet
Silence of the Lambs, 30-30-30	48 Bytes/Packet
Silence of the Lambs, 04-04-04	200 Bytes/Packet
Star Wars IV, 30-30-30	48 Bytes/Packet
Star Wars IV, 10-14-16	48 Bytes/Packet
Star Wars IV, 04-04-04	200 Bytes/Packet
Terminator One, 30-30-30	48 Bytes/Packet
Terminator One, 04-04-04	200 Bytes/Packet
Aladdin, 30-30-30	48 Bytes/Packet
Aladdin, 10-14-16	48 Bytes/Packet
Aladdin, 04-04-04	200 Bytes/Packet
Cinderella, 30-30-30	48 Bytes/Packet
Cinderella, 10-14-16	48 Bytes/Packet
Cinderella, 04-04-04	200 Bytes/Packet
Tonight Show with Commercials, 30-30-30	48 Bytes/Packet
Tonight Show with Commercials, 10-14-16	48 Bytes/Packet
Tonight Show with Commercials, 04-04-04	200 Bytes/Packet
Lecture - Reisslein, 30-30-30	48 Bytes/Packet
Lecture HQ - Reisslein, 30-30-30	48 Bytes/Packet
Lecture HQ - Reisslein, 10-14-16	200 Bytes/Packet
Lecture HQ - Reisslein, 04-04-04	200 Bytes/Packet
Lecture - Gupta, 30-30-30	48 Bytes/Packet
Lecture - Gupta, 10-14-16	48 Bytes/Packet
Lecture - Gupta, 04-04-04	200 Bytes/Packet
Baseball with Commercials, 30-30-30	48 Bytes/Packet
Baseball with Commercials, 10-14-16	48 Bytes/Packet
Baseball with Commercials, 04-04-04	200 Bytes/Packet
Friends vol.4 DVD, 30-30-30	48 Bytes/Packet
Friends vol.4 DVD, 10-14-16	48 Bytes/Packet
Friends vol.4 DVD, 04-04-04	200 Bytes/Packet
Tokyo Olympics DVD, 30-30-30	48 Bytes/Packet
Tokyo Olympics DVD, 04-04-04	200 Bytes/Packet
O Brother DVD, 10-14-16	48 Bytes/Packet
O Brother DVD, 04-04-04	200 Bytes/Packet
Die Another Day DVD, 30-30-30	48 Bytes/Packet
Die Another Day DVD, 10-14-16	48 Bytes/Packet

Die Another Day DVD, 04-04-04	200 Bytes/Packet
The Transporter DVD, 30-30-30	48 Bytes/Packet
The Transporter DVD, 10-14-16	48 Bytes/Packet
The Transporter DVD, 04-04-04	200 Bytes/Packet
Charlie's Angels DVD, 30-30-30	48 Bytes/Packet
Charlie's Angels DVD, 10-14-16	48 Bytes/Packet
Charlie's Angels DVD, 04-04-04	200 Bytes/Packet
Ice Age DVD, 30-30-30	48 Bytes/Packet
Oprah without Commercials, 30-30-30	48 Bytes/Packet
Oprah without Commercials, 10-14-16	48 Bytes/Packet
Oprah without Commercials, 04-04-04	200 Bytes/Packet

PART 3: A VARIATION OF THE HYBRID MODEL

CASE STUDY: FINDING THE BEST FIT FOR SINGLE-SOURCE TRAFFIC

TABLE A.3.1 BEST DISTRIBUTION FIT CONCLUSIONS FOR P/B FRAMES OF LOW ACTIVITY

Video Trace	QL	Q-Q plot	KL test	Conclusion
1. Die Hard One	30-30-30	Geometric	Lognormal	Geometric
2. Die Hard One	10-14-16	Lognormal	Lognormal	Lognormal
3. Die Hard One	04-04-04	Lognormal	Negative Binomial	Lognormal
4. Citizen Kane	30-30-30	Gamma	Lognormal	Gamma
5. Citizen Kane	10-14-16	Weibull	Exponential	Weibull
6. Citizen Kane	04-04-04	Weibull	Geometric	Weibull
7. Silence of the Lambs	30-30-30	Lognormal	Lognormal	Lognormal
8. Silence of the Lambs	10-14-16	Weibull	Exponential	Weibull
9. Silence of the Lambs	04-04-04	Lognormal	Negative Binomial	Lognormal
10. Star Wars IV	30-30-30	Lognormal	Lognormal	Lognormal
11. Star Wars IV	10-14-16	Lognormal	Lognormal	Lognormal
12. Star Wars IV	04-04-04	Gamma	Exponential	Gamma
13. Terminator One	30-30-30	Lognormal	Exponential	Lognormal
14. Terminator One	10-14-16	Lognormal	Lognormal	Lognormal

15. Terminator One	04-04-04	Lognormal	Exponential	Lognormal
16. Aladdin	30-30-30	Geometric	Lognormal	Geometric
17. Aladdin	10-14-16	Weibull	Lognormal	Weibull
18. Aladdin	04-04-04	Weibull	Lognormal	Weibull
19. Cinderella	30-30-30	Exponential	Negative Binomial	Exponential
20. Cinderella	10-14-16	Exponential	Lognormal	Exponential
21. Cinderella	04-04-04	Exponential	Lognormal	Exponential
22. Tonight Show with Commercials	30-30-30	Lognormal	Negative Binomial	Lognormal
23. Tonight Show with Commercials	10-14-16	----------	Exponential	Exponential
24. Tonight Show with Commercials	04-04-04	Lognormal	Negative Binomial	Lognormal
25. Tonight Show without Commercials	30-30-30	Lognormal	Geometric	Lognormal
26. Tonight Show without Commercials	10-14-16	Lognormal	Negative Binomial	Lognormal
27. Tonight Show without Commercials	04-04-04	----------	Exponential	Exponential
28. Lecture-Reisslein	30-30-30	Geometric	Negative Binomial	Geometric
29. Lecture-Reisslein	10-14-16	Gamma	Negative Binomial	Gamma
30. Lecture-Reisslein	04-04-04	Gamma	Lognormal	Gamma
31. Lecture HQ-Reisslein	30-30-30	Gamma	Weibull	Gamma
32. Lecture HQ-Reisslein	10-14-16	Negative Binomial	Negative Binomial	Negative Binomial
33. Lecture HQ-Reisslein	04-04-04	Geometric	Lognormal	Geometric
34. Lecture-Gupta	30-30-30	Weibull	Negative Binomial	Weibull
35. Lecture-Gupta	10-14-16	Gamma	Negative Binomial	Gamma
36. Lecture-Gupta	04-04-04	Weibull	Negative Binomial	Weibull
37. Baseball with Commercials	30-30-30	----------	Lognormal	Lognormal
38. Baseball with Commercials	10-14-16	Lognormal	Exponential	Lognormal
39. Baseball with Commercials	04-04-04	Weibull	Exponential	Weibull
40. Friends vol.4 DVD	30-30-30	Lognormal	Negative Binomial	Lognormal
41. Friends vol.4 DVD	10-14-16	Weibull	Negative Binomial	Weibull
42. Friends vol.4 DVD	04-04-04	Lognormal	Exponential	Lognormal

43. Tokyo Olympics DVD	30-30-30	----------	Weibull	Weibull
44. Tokyo Olympics DVD	10-14-16	Weibull	Lognormal	Weibull
45. Tokyo Olympics DVD	04-04-04	Lognormal	Exponential	Lognormal
46. O Brother DVD	30-30-30	Weibull	Negative Binomial	Weibull
47. O Brother DVD	10-14-16	Weibull	Exponential	Weibull
48. O Brother DVD	04-04-04	Lognormal	Lognormal	Lognormal
49. Die Another Day DVD	30-30-30	----------	Lognormal	Lognormal
50. Die Another Day DVD	10-14-16	Lognormal	Lognormal	Lognormal
51. Die Another Day DVD	04-04-04	Lognormal	Lognormal	Lognormal
52. The Transporter DVD	30-30-30	----------	Lognormal	Lognormal
53. The Transporter DVD	10-14-16	----------	Lognormal	Lognormal
54. The Transporter DVD	04-04-04	Lognormal	Lognormal	Lognormal
55. Charlie's Angels DVD	30-30-30	Lognormal	Lognormal	Lognormal
56. Charlie's Angels DVD	10-14-16	Lognormal	Lognormal	Lognormal
57. Charlie's Angels DVD	04-04-04	Lognormal	Lognormal	Lognormal
58. Ice Age DVD	30-30-30	Lognormal	Exponential	Lognormal
59. Ice Age DVD	10-14-16	Lognormal	Lognormal	Lognormal
60. Ice Age DVD	04-04-04	Geometric	Lognormal	Geometric
61. Oprah without Commercials	30-30-30	Lognormal	Negative Binomial	Lognormal
62. Oprah without Commercials	10-14-16	Weibull	Geometric	Weibull
63. Oprah without Commercials	04-04-04	Lognormal	Geometric	Lognormal

TABLE A.3.2 BEST DISTRIBUTION FIT CONCLUSIONS FOR P/B FRAMES OF HIGH ACTIVITY

Video Trace	QL	Q-Q plot	KL test	Conclusion
1. Die Hard One	30-30-30	Lognormal	Lognormal	Lognormal
2. Die Hard One	10-14-16	Lognormal	Lognormal	Lognormal
3. Die Hard One	04-04-04	Weibull	Geometric	Weibull
4. Citizen Kane	30-30-30	Lognormal	Exponential	Lognormal
5. Citizen Kane	10-14-16	Lognormal	Geometric	Lognormal
6. Citizen Kane	04-04-04	Lognormal	Geometric	Lognormal
7. Silence of the Lambs	30-30-30	Gamma	Lognormal	Gamma
8. Silence of the Lambs	10-14-16	Lognormal	Negative Binomial	Lognormal
9. Silence of the Lambs	04-04-04	Lognormal	Negative Binomial	Lognormal
10. Star Wars IV	30-30-30	Lognormal	Lognormal	Lognormal
11. Star Wars IV	10-14-16	Geometric	Negative Binomial	Geometric
12. Star Wars IV	04-04-04	Lognormal	Geometric	Lognormal
13. Terminator One	30-30-30	Pearson V	Exponential	Pearson V
14. Terminator One	10-14-16	Pearson V	Negative Binomial	Pearson V
15. Terminator One	04-04-04	Pearson V	Exponential	Pearson V
16. Aladdin	30-30-30	Lognormal	Lognormal	Lognormal
17. Aladdin	10-14-16	Lognormal	Exponential	Lognormal
18. Aladdin	04-04-04	Lognormal	Lognormal	Lognormal
19. Cinderella	30-30-30	Lognormal	Lognormal	Lognormal
20. Cinderella	10-14-16	Weibull	Lognormal	Weibull
21. Cinderella	04-04-04	Lognormal	Geometric	Lognormal
22. Tonight Show with Commercials	30-30-30	Lognormal	Lognormal	Lognormal
23. Tonight Show with Commercials	10-14-16	Weibull	Negative Binomial	Weibull
24. Tonight Show with Commercials	04-04-04	Lognormal	Negative Binomial	Lognormal
25. Tonight Show without Commercials	30-30-30	Lognormal	Lognormal	Lognormal
26. Tonight Show without Commercials	10-14-16	Lognormal	Negative Binomial	Lognormal
27. Tonight Show without Commercials	04-04-04	Lognormal	Geometric	Lognormal

28. Lecture-Reisslein	30-30-30	Gamma	Lognormal	Gamma
29. Lecture-Reisslein	10-14-16	Lognormal	Geometric	Lognormal
30. Lecture-Reisslein	04-04-04	Weibull	Negative Binomial	Weibull
31. Lecture HQ-Reisslein	30-30-30	----------	Lognormal	Lognormal
32. Lecture HQ-Reisslein	10-14-16	Weibull	Negative Binomial	Weibull
33. Lecture HQ-Reisslein	04-04-04	Gamma	Geometric	Gamma
34. Lecture-Gupta	30-30-30	Lognormal	Negative Binomial	Lognormal
35. Lecture-Gupta	10-14-16	Weibull	Weibull	Weibull
36. Lecture-Gupta	04-04-04	Gamma	Negative Binomial	Gamma
37. Baseball with Commercials	30-30-30	Lognormal	Lognormal	Lognormal
38. Baseball with Commercials	10-14-16	Lognormal	Exponential	Lognormal
39. Baseball with Commercials	04-04-04	Lognormal	Exponential	Lognormal
40. Friends vol.4 DVD	30-30-30	Lognormal	Lognormal	Lognormal
41. Friends vol.4 DVD	10-14-16	Lognormal	Lognormal	Lognormal
42. Friends vol.4 DVD	04-04-04	Lognormal	Lognormal	Lognormal
43. Tokyo Olympics DVD	30-30-30	Weibull	Geometric	Weibull
44. Tokyo Olympics DVD	10-14-16	Lognormal	Negative Binomial	Lognormal
45. Tokyo Olympics DVD	04-04-04	Weibull	Negative Binomial	Weibull
46. O Brother DVD	30-30-30	Lognormal	Negative Binomial	Lognormal
47. O Brother DVD	10-14-16	Lognormal	Negative Binomial	Lognormal
48. O Brother DVD	04-04-04	Weibull	Exponential	Weibull
49. Die Another Day DVD	30-30-30	Lognormal	Lognormal	Lognormal
50. Die Another Day DVD	10-14-16	Lognormal	Lognormal	Lognormal
51. Die Another Day DVD	04-04-04	Lognormal	Exponential	Lognormal
52. The Transporter DVD	30-30-30	Lognormal	Lognormal	Lognormal
53. The Transporter DVD	10-14-16	Lognormal	Lognormal	Lognormal
54. The Transporter DVD	04-04-04	Lognormal	Exponential	Lognormal
55. Charlie's Angels DVD	30-30-30	Weibull	Lognormal	Weibull
56. Charlie's Angels DVD	10-14-16	Lognormal	Lognormal	Lognormal

57. Charlie's Angels DVD	04-04-04	Lognormal	Lognormal	Lognormal
58. Ice Age DVD	30-30-30	Lognormal	Negative Binomial	Lognormal
59. Ice Age DVD	10-14-16	Lognormal	Lognormal	Lognormal
60. Ice Age DVD	04-04-04	Lognormal	Lognormal	Lognormal
61. Oprah without Commercials	30-30-30	Exponential	Lognormal	Exponential
62. Oprah without Commercials	10-14-16	Lognormal	Geometric	Lognormal
63. Oprah without Commercials	04-04-04	Weibull	Negative Binomial	Weibull

CASE STUDY: HYBRID MODELING FOR MULTIPLEXED TRAFFIC

TABLE A.3.3 INFORMATION ON HYBRID VARIATION MODELING OF P/B FRAMES OF LOW ACTIVITY

Video Trace	QL	BEST FIT	Max Frame Size (Bytes)	States In DAR	Autocorrelation
1. Die Hard One	30-30-30	Geometric	1013	22	0,1505
2. Die Hard One	10-14-16	Lognormal	2531	53	0,1126
3. Die Hard One	04-04-04	Lognormal	28315	142	0,1176
4. Citizen Kane	30-30-30	Gamma	2612	55	0,1421
5. Citizen Kane	10-14-16	Weibull	3001	63	0,1431
6. Citizen Kane	04-04-04	Weibull	28885	145	0,1018
7. Silence of the Lambs	30-30-30	Lognormal	3867	81	0,2625
8. Silence of the Lambs	10-14-16	Weibull	1091	23	0,1982
9. Silence of the Lambs	04-04-04	Lognormal	16565	83	0,2068
10. Star Wars IV	30-30-30	Lognormal	1422	30	0,0516
11. Star Wars IV	10-14-16	Lognormal	1329	28	0,0653
12. Star Wars IV	04-04-04	Gamma	13517	68	0,1235
13. Terminator One	30-30-30	Lognormal	2621	55	0,2153
14. Terminator One	10-14-16	Lognormal	2880	61	0,2317
15. Terminator One	04-04-04	Lognormal	55068	276	0,1781
16. Aladdin	30-30-30	Geometric	1984	42	0,2111
17. Aladdin	10-14-16	Weibull	4641	97	0,1930

18. Aladdin	04-04-04	Weibull	42405	213	0,0936
19. Cinderella	30-30-30	Exponential	1752	37	0,0224
20. Cinderella	10-14-16	Exponential	2675	56	0,1359
21. Cinderella	04-04-04	Exponential	26061	131	0,0801
22. Tonight Show with Commercials	30-30-30	Lognormal	11690	244	0,1049
23. Tonight Show with Commercials	10-14-16	Exponential	103772	519	0,0237
24. Tonight Show with Commercials	04-04-04	Lognormal	120679	604	0,2747
25. Tonight Show without Commercials	30-30-30	Lognormal	7153	150	-0,0138
26. Tonight Show without Commercials	10-14-16	Lognormal	8068	41	-0,0067
27. Tonight Show without Commercials	04-04-04	Exponential	12484	63	-0,0011
28. Lecture-Reisslein	30-30-30	Geometric	8756	183	-0,1687
29. Lecture-Reisslein	10-14-16	Gamma	19070	96	-0,0042
30. Lecture-Reisslein	04-04-04	Gamma	387924	1940	0,3147
31. Lecture HQ-Reisslein	30-30-30	Gamma	21283	444	-0,2575
32. Lecture HQ-Reisslein	10-14-16	Negative Binomial	14407	73	-0,2441
33. Lecture HQ-Reisslein	04-04-04	Geometric	181485	908	-0,1939
34. Lecture-Gupta	30-30-30	Weibull	15409	322	-0,1166
35. Lecture-Gupta	10-14-16	Gamma	41702	209	-0,0934
36. Lecture-Gupta	04-04-04	Weibull	421933	2110	0,3455
37. Baseball with Commercials	30-30-30	Lognormal	3152	66	0,1048
38. Baseball with Commercials	10-14-16	Lognormal	4679	98	0,0406
39. Baseball with Commercials	04-04-04	Weibull	86277	432	0,0802
40. Friends vol.4 DVD	30-30-30	Lognormal	2061	43	0,2729
41. Friends vol.4 DVD	10-14-16	Weibull	1075	23	0,2600
42. Friends vol.4 DVD	04-04-04	Lognormal	10918	55	0,1266
43. Tokyo Olympics DVD	30-30-30	Weibull	1879	40	0,0439
44. Tokyo Olympics DVD	10-14-16	Weibull	2207	46	0,2060
45. Tokyo Olympics DVD	04-04-04	Lognormal	14654	74	0,2601

46. O Brother DVD	30-30-30	Weibull	3052	64	0,0322
47. O Brother DVD	10-14-16	Weibull	3471	73	0,0638
48. O Brother DVD	04-04-04	Lognormal	22418	113	0,0622
49. Die Another Day DVD	30-30-30	Lognormal	2814	59	0,0724
50. Die Another Day DVD	10-14-16	Lognormal	1431	30	0,0913
51. Die Another Day DVD	04-04-04	Lognormal	5012	26	0,0621
52. The Transporter DVD	30-30-30	Lognormal	2142	45	0,1548
53. The Transporter DVD	10-14-16	Lognormal	1191	25	0,0443
54. The Transporter DVD	04-04-04	Lognormal	7553	38	0,1132
55. Charlie's Angels DVD	30-30-30	Lognormal	2092	44	0,1396
56. Charlie's Angels DVD	10-14-16	Lognormal	1326	28	0,0892
57. Charlie's Angels DVD	04-04-04	Lognormal	8277	42	0,1362
58. Ice Age DVD	30-30-30	Lognormal	1545	33	0,2457
59. Ice Age DVD	10-14-16	Lognormal	1455	31	0,0855
60. Ice Age DVD	04-04-04	Geometric	5068	26	0,0998
61. Oprah without Commercials	30-30-30	Lognormal	4457	93	0,0554
62. Oprah without Commercials	10-14-16	Weibull	7480	38	0,2732
63. Oprah without Commercials	04-04-04	Lognormal	113347	567	-0,0355

Packet size = 48 Bytes/packet for the 30-30-30 movie traces and the traces highlighted red, 200 Bytes/packet for the rest

TABLE A.3.4 INFORMATION ON HYBRID VARIATION MODELING OF P/B FRAMES OF HIGH ACTIVITY

Video Trace	QL	BEST FIT	Max Frame Size (Bytes)	States In DAR	Autocorrelation
1. Die Hard One	30-30-30	Lognormal	3377	71	0,0577
2. Die Hard One	10-14-16	Lognormal	5585	28	0,0494
3. Die Hard One	04-04-04	Weibull	44334	222	0,1885
4. Citizen Kane	30-30-30	Lognormal	11558	241	0,0360
5. Citizen Kane	10-14-16	Lognormal	11136	56	0,1702
6. Citizen Kane	04-04-04	Lognormal	90285	452	0,2523
7. Silence of the Lambs	30-30-30	Gamma	3582	75	0,1920
8. Silence of the Lambs	10-14-16	Lognormal	8737	44	0,1585
9. Silence of the Lambs	04-04-04	Lognormal	64323	322	0,1224
10. Star Wars IV	30-30-30	Lognormal	7512	157	0,0295
11. Star Wars IV	10-14-16	Geometric	20612	104	0,0219
12. Star Wars IV	04-04-04	Lognormal	107037	536	0,0308
13. Terminator One	30-30-30	Pearson V	17033	355	0,0455
14. Terminator One	10-14-16	Pearson V	45875	230	0,0682
15. Terminator One	04-04-04	Pearson V	154592	773	0,1269
16. Aladdin	30-30-30	Lognormal	6244	131	0,1490
17. Aladdin	10-14-16	Lognormal	10833	55	0,2077
18. Aladdin	04-04-04	Lognormal	107556	538	0,0516
19. Cinderella	30-30-30	Lognormal	3770	79	0,0259
20. Cinderella	10-14-16	Weibull	5487	28	0,1701
21. Cinderella	04-04-04	Lognormal	94425	473	0,0751
22. Tonight Show with Commercials	30-30-30	Lognormal	3305	69	0,2608
23. Tonight Show with Commercials	10-14-16	Weibull	48001	241	0,2691
24. Tonight Show with Commercials	04-04-04	Lognormal	922437	4613	0,1226
25. Tonight Show without Commercials	30-30-30	Lognormal	6813	142	-0,0099
26. Tonight Show without Commercials	10-14-16	Lognormal	23945	120	0,0476

27. Tonight Show without Commercials	04-04-04	Lognormal	387988	1940	0,0154
28. Lecture-Reisslein	30-30-30	Gamma	18087	377	0,2802
29. Lecture-Reisslein	10-14-16	Lognormal	45569	228	-0,1377
30. Lecture-Reisslein	04-04-04	Weibull	523999	2620	0,2567
31. Lecture HQ-Reisslein	30-30-30	Lognormal	22929	478	-0,2327
32. Lecture HQ-Reisslein	10-14-16	Weibull	14479	73	0,1455
33. Lecture HQ-Reisslein	04-04-04	Gamma	215884	1080	-0,2667
34. Lecture-Gupta	30-30-30	Lognormal	12541	262	0,6105
35. Lecture-Gupta	10-14-16	Weibull	37417	188	0,3424
36. Lecture-Gupta	04-04-04	Gamma	258626	1294	0,1007
37. Baseball with Commercials	30-30-30	Lognormal	4110	86	0,1238
38. Baseball with Commercials	10-14-16	Lognormal	13786	69	0,2940
39. Baseball with Commercials	04-04-04	Lognormal	94568	473	0,1879
40. Friends vol.4 DVD	30-30-30	Lognormal	2347	49	0,1703
41. Friends vol.4 DVD	10-14-16	Lognormal	2521	53	0,2093
42. Friends vol.4 DVD	04-04-04	Lognormal	13713	69	0,1475
43. Tokyo Olympics DVD	30-30-30	Weibull	4730	99	0,2030
44. Tokyo Olympics DVD	10-14-16	Lognormal	9307	47	0,2289
45. Tokyo Olympics DVD	04-04-04	Weibull	50461	253	0,1738
46. O Brother DVD	30-30-30	Lognormal	3257	68	0,3732
47. O Brother DVD	10-14-16	Lognormal	8293	42	0,1105
48. O Brother DVD	04-04-04	Weibull	32577	163	0,1597
49. Die Another Day DVD	30-30-30	Lognormal	2576	54	0,0010
50. Die Another Day DVD	10-14-16	Lognormal	4938	25	0,1123
51. Die Another Day DVD	04-04-04	Lognormal	21757	109	0,1140
52. The Transporter DVD	30-30-30	Lognormal	2965	62	0,0277
53. The Transporter DVD	10-14-16	Lognormal	4558	95	0,0748
54. The Transporter DVD	04-04-04	Lognormal	29425	148	0,1295
55. Charlie's Angels DVD	30-30-30	Weibull	3433	72	0,1192

56. Charlie's Angels DVD	10-14-16	Lognormal	5239	27	0,1016
57. Charlie's Angels DVD	04-04-04	Lognormal	22870	115	0,1874
58. Ice Age DVD	30-30-30	Lognormal	2258	48	0,0961
59. Ice Age DVD	10-14-16	Lognormal	3061	64	0,1282
60. Ice Age DVD	04-04-04	Lognormal	17504	88	0,1067
61. Oprah without Commercials	30-30-30	Exponential	4432	93	0,1698
62. Oprah without Commercials	10-14-16	Lognormal	18241	92	0,0900
63. Oprah without Commercials	04-04-04	Weibull	248016	1241	0,0830

CASE STUDY: AUTOCORRELATION COEFFICIENT OF MODELED SOURCES

TABLE A.3.5 AUTOCORRELATION COEFFICIENT OF MODELED SOURCES FOR P/B FRAMES OF LOW ACTIVITY

Video Trace	QL	5 sources		10 sources		15 sources	
		Actual ρ	Modeled ρ	Actual ρ	Modeled ρ	Actual ρ	Modeled ρ
Die Hard One	30-30-30	0,0721	0,1467	0,1325	0,0420	0,0372	0,1698
Die Hard One	10-14-16	0,1665	0,0901	0,0777	0,1025	0,0725	0,2568
Die Hard One	04-04-04	0,0816	0,2540	0,1703	0,2237	0,0929	0,0609
Citizen Kane	30-30-30	0,1735	0,1736	0,0663	0,1596	-0,0092	0,0043
Citizen Kane	10-14-16	0,1401	0,1402	0,1829	0,0910	0,0173	0,0870
Citizen Kane	04-04-04	0,0902	0,1232	0,0326	0,0321	0,1192	0,2227
Silence of the Lambs	30-30-30	0,1393	0,2318	0,1493	0,2966	0,1731	0,2703
Silence of the Lambs	10-14-16	0,2040	0,2425	0,2208	0,1676	0,1119	0,2301
Silence of the Lambs	04-04-04	0,2074	0,2143	0,2694	0,2323	0,1113	0,3154
Star Wars IV	30-30-30	0,0514	0,0317	-0,0434	0,0574	0,0993	0,0519
Star Wars IV	10-14-16	0,1338	0,0756	0,1640	0,0851	-0,0675	0,1005
Star Wars IV	04-04-04	0,2054	0,0814	0,0419	0,0758	0,1639	0,1992
Terminator One	30-30-30	0,1939	0,2197	0,1782	0,1622	0,2330	0,1086
Terminator One	10-14-16	0,2168	0,2281	0,1803	0,2284	0,2452	0,2466
Terminator One	04-04-04	0,1669	0,1834	0,1282	0,1555	0,1300	0,1873
Aladdin	30-30-30	0,2413	0,1653	0,1445	0,0815	0,1422	0,1846
Aladdin	10-14-16	0,1687	0,2590	0,1581	0,1675	0,1378	0,1489
Aladdin	04-04-04	0,1279	0,0528	0,2774	0,0703	0,0568	0,0566
Cinderella	30-30-30	-0,0172	0,0347	0,1095	0,0454	0,0680	0,0975
Cinderella	10-14-16	0,1656	0,2296	0,1344	0,1803	0,1927	0,0993
Cinderella	04-04-04	0,1659	0,0548	-0,0214	0,0843	0,0276	0,0543
Tonight Show with Commercials	30-30-30	0,0499	0,2042	-0,0051	-0,0450	0,0178	0,0898
Tonight Show with Commercials	10-14-16	0,0143	0,0601	0,0252	0,0345	0,0546	-0,0281

Tonight Show with Commercials	04-04-04	0,2749	0,2201	0,2420	0,2633	0,1687	0,2279
Tonight Show without Commercials	30-30-30	-0,0836	0,4013	0,1532	-0,0322	0,0085	0,2714
Tonight Show without Commercials	10-14-16	-0,0212	0,1436	-0,0526	0,0632	0,0115	-0,0679
Tonight Show without Commercials	04-04-04	0,0149	0,1434	-0,2159	0,2524	-0,1990	-0,1588
Lecture-Reisslein	30-30-30	0,2240	0,0360	-0,3074	-0,2285	-0,1492	0,4053
Lecture-Reisslein	10-14-16	0,1559	-0,1602	-0,2575	0,1171	0,0617	-0,1321
Lecture-Reisslein	04-04-04	0,4286	0,3348	0,4488	0,2378	0,2723	-0,0428
Lecture HQ-Reisslein	30-30-30	-0,2158	-0,1366	-0,1371	-0,1784	-0,1310	-0,1122
Lecture HQ-Reisslein	10-14-16	0,0010	-0,4133	-0,1000	0,0847	-0,4028	-0,3679
Lecture HQ-Reisslein	04-04-04	-0,1591	-0,1455	0,0259	-0,2162	0,0560	0,1295
Lecture-Gupta	30-30-30	0,0071	0,1745	-0,3012	-0,2718	-0,2408	0,1051
Lecture-Gupta	10-14-16	0,0104	0,1573	0,0389	-0,0618	-0,2751	-0,0369
Lecture-Gupta	04-04-04	0,2193	0,2999	-0,1586	0,0113	0,5219	0,2243
Baseball with Commercials	30-30-30	0,1053	0,1272	0,1493	0,0483	0,0041	0,1210
Baseball with Commercials	10-14-16	0,0397	0,0702	-0,0059	0,0555	-0,0313	0,0158
Baseball with Commercials	04-04-04	0,0487	0,0622	0,1482	-0,0067	0,0152	0,2023
Friends vol.4 DVD	30-30-30	0,2207	0,3578	0,1121	0,3128	0,1902	0,3610
Friends vol.4 DVD	10-14-16	0,2275	0,2210	0,3054	0,2172	0,2551	0,2346
Friends vol.4 DVD	04-04-04	0,1643	0,1412	0,1268	0,0610	0,0944	0,0775
Tokyo Olympics DVD	30-30-30	0,0273	0,0879	0,0846	0,1891	0,0326	0,0185
Tokyo Olympics DVD	10-14-16	0,1945	0,2369	0,1841	0,2610	0,2042	0,2453
Tokyo Olympics DVD	04-04-04	0,2665	0,2589	0,2112	0,1928	0,3219	0,2856
O Brother DVD	30-30-30	-0,0117	-0,0475	-0,0197	-0,0864	0,1501	0,1319
O Brother DVD	10-14-16	0,0841	0,0755	0,1318	0,1072	-0,0843	0,1037
O Brother DVD	04-04-04	0,0577	0,0966	0,1936	0,0723	0,0886	0,0876
Die Another Day DVD	30-30-30	0,1282	0,0857	0,0521	0,1594	0,0405	0,0595
Die Another Day DVD	10-14-16	0,0927	0,0825	0,0295	0,1140	0,0983	-0,0223
Die Another Day DVD	04-04-04	0,0365	0,0696	-0,0115	-0,0091	0,0790	0,0681
The Transporter DVD	30-30-30	0,2341	0,0940	0,1165	0,1749	0,3111	0,1239
The Transporter DVD	10-14-16	0,0188	0,0744	0,0730	0,0658	0,0672	-0,0186
The Transporter DVD	04-04-04	0,1072	0,0891	0,1025	0,0829	0,0988	0,1445
Charlie's Angels DVD	30-30-30	0,1693	0,1222	0,1084	0,1069	0,2265	0,0794
Charlie's Angels DVD	10-14-16	0,2954	0,0768	0,0905	0,0447	0,0393	0,0979
Charlie's Angels DVD	04-04-04	0,1461	0,1400	0,0591	0,1215	0,1628	0,0961
Ice Age DVD	30-30-30	0,2532	0,2513	0,1743	0,1501	0,2766	0,1916
Ice Age DVD	10-14-16	0,0950	0,0800	0,0666	0,0808	0,1873	0,0822
Ice Age DVD	04-04-04	0,0570	0,0948	0,1801	0,0556	0,1238	0,0876
Oprah without Commercials	30-30-30	0,2193	0,1533	-0,0117	0,0270	-0,1020	0,0922
Oprah without Commercials	10-14-16	0,2691	0,3470	0,2187	0,2447	0,2577	0,3402
Oprah without Commercials	04-04-04	0,0508	-0,1414	-0,0003	0,0139	0,0215	0,0651

TABLE A.3.6 AUTOCORRELATION COEFFICIENT OF MODELED SOURCES FOR P/B FRAMES OF HIGH ACTIVITY

Video Trace	QL	5 sources		10 sources		15 sources	
		Actual ρ	Modeled ρ	Actual ρ	Modeled ρ	Actual ρ	Modeled ρ
Die Hard One	30-30-30	0,0384	0,0911	0,0534	0,0282	0,0163	0,1411
Die Hard One	10-14-16	0,0107	0,0309	0,0133	0,0181	0,0280	0,0283
Die Hard One	04-04-04	0,1597	0,1325	0,2701	0,1909	0,1793	0,1604
Citizen Kane	30-30-30	-0,0362	-0,0623	-0,0002	-0,0202	0,0977	0,0964
Citizen Kane	10-14-16	0,0895	0,1152	0,2499	0,2622	0,1849	0,2388
Citizen Kane	04-04-04	0,1590	0,2846	0,1403	0,2861	0,2899	0,3304
Silence of the Lambs	30-30-30	0,1675	0,3065	0,1576	0,2382	0,1494	0,1732
Silence of the Lambs	10-14-16	0,1990	0,1477	0,1093	0,2240	0,1634	0,1933
Silence of the Lambs	04-04-04	0,0216	-0,0218	0,1591	0,0197	0,1055	0,1243
Star Wars IV	30-30-30	-0,0321	0,0923	-0,0625	0,0991	0,0314	0,0718
Star Wars IV	10-14-16	0,0254	-0,0253	0,0110	-0,0461	0,0154	0,0919
Star Wars IV	04-04-04	0,0748	-0,0140	0,0086	-0,0042	0,0196	0,0280
Terminator One	30-30-30	0,0655	0,0339	0,2454	0,0111	0,0823	0,0491
Terminator One	10-14-16	0,1206	0,0503	0,1105	0,1049	0,0788	0,1166
Terminator One	04-04-04	0,1492	0,0696	0,1509	0,0791	0,1326	0,0639
Aladdin	30-30-30	0,1252	0,1602	0,1227	0,1071	0,2215	0,1567
Aladdin	10-14-16	0,2298	0,1373	0,2878	0,2242	0,2037	0,1840
Aladdin	04-04-04	0,0451	0,1200	0,1571	0,0350	-0,0610	0,0160
Cinderella	30-30-30	-0,0125	0,0281	0,0637	-0,0119	-0,0715	0,0267
Cinderella	10-14-16	0,1070	0,1820	0,2222	0,2547	0,2461	0,2766
Cinderella	04-04-04	0,0545	0,0037	0,2343	-0,0644	-0,0723	0,1932
Tonight Show with Commercials	30-30-30	0,2903	0,3162	0,2711	0,2762	0,2292	0,2646
Tonight Show with Commercials	10-14-16	0,2684	0,1519	0,2151	0,1579	0,2583	0,3619
Tonight Show with Commercials	04-04-04	0,1526	0,1217	0,2213	0,3272	0,0713	0,0649
Tonight Show without Commercials	30-30-30	0,0258	-0,0369	0,0168	-0,0026	0,1854	0,0036
Tonight Show without Commercials	10-14-16	-0,0550	0,1058	0,0755	0,0113	0,0633	0,1220
Tonight Show without Commercials	04-04-04	-0,0059	0,0544	-0,0227	0,0310	-0,1201	0,1116
Lecture-Reisslein	30-30-30	0,3422	0,2932	-0,0003	0,1786	-0,0934	0,2615
Lecture-Reisslein	10-14-16	0,1426	0,0548	-0,1519	0,1508	0,1852	-0,3205
Lecture-Reisslein	04-04-04	0,1460	0,1566	0,3637	-0,0555	0,2705	0,0862
Lecture HQ-Reisslein	30-30-30	-0,1825	-0,2146	-0,0236	-0,0724	-0,3245	-0,5777
Lecture HQ-Reisslein	10-14-16	-0,0339	0,1495	0,1482	0,2077	0,3266	-0,1486
Lecture HQ-Reisslein	04-04-04	-0,4278	0,1156	-0,0461	-0,5587	-0,5111	0,1061
Lecture-Gupta	30-30-30	0,5716	0,5427	0,5833	0,6401	0,6390	0,4004
Lecture-Gupta	10-14-16	0,5124	0,3146	0,2604	0,2851	0,0705	0,1586

Lecture-Gupta	04-04-04	-0,0002	-0,2386	0,2095	0,2026	0,0709	0,0318
Baseball with Commercials	30-30-30	0,0901	0,1266	0,2639	0,1204	0,0504	0,0964
Baseball with Commercials	10-14-16	0,2482	0,2738	0,3060	0,2680	0,3425	0,2812
Baseball with Commercials	04-04-04	0,2030	0,1718	0,2722	0,1457	0,1535	0,1985
Friends vol.4 DVD	30-30-30	0,1390	0,1698	0,2742	0,2155	0,1362	0,1927
Friends vol.4 DVD	10-14-16	0,2383	0,2090	0,2790	0,2442	0,2727	0,2298
Friends vol.4 DVD	04-04-04	0,1377	0,1879	0,2606	0,1183	0,1338	0,2199
Tokyo Olympics DVD	30-30-30	0,1732	0,1740	0,1242	0,2584	0,3537	0,1404
Tokyo Olympics DVD	10-14-16	0,2907	0,2533	0,1513	0,2753	0,2100	0,2024
Tokyo Olympics DVD	04-04-04	0,1719	0,2189	0,1331	0,1430	0,3889	0,1886
O Brother DVD	30-30-30	0,5520	0,3244	0,4354	0,3379	0,3417	0,3791
O Brother DVD	10-14-16	0,1470	0,1107	-0,0368	0,1040	0,1350	0,0164
O Brother DVD	04-04-04	0,2453	0,2044	0,0644	0,1566	0,1448	0,1728
Die Another Day DVD	30-30-30	-0,0698	-0,0433	-0,0335	-0,0158	-0,0338	0,0637
Die Another Day DVD	10-14-16	0,1843	0,1128	0,1269	0,0900	0,1330	0,0987
Die Another Day DVD	04-04-04	0,1026	0,1116	0,2422	0,0777	0,1203	0,1652
The Transporter DVD	30-30-30	0,0224	-0,0018	-0,0074	-0,0260	0,0943	0,0560
The Transporter DVD	10-14-16	0,0443	0,0143	0,0610	0,0274	0,0215	0,0877
The Transporter DVD	04-04-04	0,1210	0,1549	0,1124	0,1618	0,1863	0,1028
Charlie's Angels DVD	30-30-30	0,1886	0,0572	0,1540	0,0810	0,0872	0,0809
Charlie's Angels DVD	10-14-16	0,1329	0,0480	0,0920	0,1557	0,1469	0,0963
Charlie's Angels DVD	04-04-04	0,0864	0,2533	0,2315	0,1575	0,1932	0,1955
Ice Age DVD	30-30-30	0,1081	0,1604	0,0993	0,0215	0,0294	0,0097
Ice Age DVD	10-14-16	0,1267	0,0671	0,1023	0,1126	0,1666	0,1476
Ice Age DVD	04-04-04	0,0953	0,1417	0,1068	0,1234	0,0900	0,1584
Oprah without Commercials	30-30-30	0,0811	0,2238	0,1233	0,1742	0,0957	0,1171
Oprah without Commercials	10-14-16	0,1708	-0,0635	0,0701	0,1442	0,0623	0,1330
Oprah without Commercials	04-04-04	0,0590	0,2012	0,2649	0,0526	0,0477	-0,0683

CASE STUDY: FINAL MODELING RESULTS WITH THE VARIATION OF THE HYBRID MODEL

TABLE A.3.7 PACKET SIZE USED IN FINAL HYBRID VARIATION MODELING (SECTION 4.8)

Movie Trace	Packet Size
Die Hard One, 30-30-30	48 Bytes/Packet
Die Hard One, 10-14-16	48 Bytes/Packet
Die Hard One, 04-04-04	200 Bytes/Packet
Citizen Kane, 30-30-30	48 Bytes/Packet
Citizen Kane, 10-14-16	48 Bytes/Packet
Citizen Kane, 04-04-04	200 Bytes/Packet
Silence of the Lambs, 30-30-30	48 Bytes/Packet
Silence of the Lambs, 10-14-16	48 Bytes/Packet
Silence of the Lambs, 04-04-04	200 Bytes/Packet
Star Wars IV, 30-30-30	48 Bytes/Packet
Star Wars IV, 10-14-16	48 Bytes/Packet
Star Wars IV, 04-04-04	200 Bytes/Packet
Terminator One, 30-30-30	48 Bytes/Packet
Terminator One, 10-14-16	48 Bytes/Packet
Terminator One, 04-04-04	200 Bytes/Packet
Aladdin, 30-30-30	48 Bytes/Packet
Aladdin, 10-14-16	48 Bytes/Packet
Aladdin, 04-04-04	200 Bytes/Packet
Cinderella, 30-30-30	48 Bytes/Packet
Cinderella, 10-14-16	48 Bytes/Packet
Cinderella, 04-04-04	200 Bytes/Packet
Tonight Show with Commercials, 30-30-30	48 Bytes/Packet
Tonight Show with Commercials, 10-14-16	200 Bytes/Packet
Tonight Show with Commercials, 04-04-04	200 Bytes/Packet
Tonight Show without Commercials, 30-30-30	48 Bytes/Packet
Tonight Show without Commercials, 10-14-16	200 Bytes/Packet
Tonight Show without Commercials, 04-04-04	200 Bytes/Packet
Lecture - Reisslein, 30-30-30	48 Bytes/Packet
Lecture HQ - Reisslein, 30-30-30	48 Bytes/Packet
Lecture HQ - Reisslein, 10-14-16	200 Bytes/Packet
Lecture HQ - Reisslein, 04-04-04	200 Bytes/Packet
Lecture - Gupta, 30-30-30	48 Bytes/Packet
Lecture - Gupta, 10-14-16	200 Bytes/Packet
Lecture - Gupta, 04-04-04	200 Bytes/Packet
Baseball with Commercials, 30-30-30	48 Bytes/Packet
Baseball with Commercials, 10-14-16	48 Bytes/Packet
Baseball with Commercials, 04-04-04	200 Bytes/Packet
Friends vol.4 DVD, 30-30-30	48 Bytes/Packet
Friends vol.4 DVD, 10-14-16	48 Bytes/Packet

Friends vol.4 DVD, 04-04-04	200 Bytes/Packet
Tokyo Olympics DVD, 30-30-30	48 Bytes/Packet
Tokyo Olympics DVD, 04-04-04	200 Bytes/Packet
O Brother DVD, 30-30-30	48 Bytes/Packet
O Brother DVD, 10-14-16	48 Bytes/Packet
O Brother DVD, 04-04-04	200 Bytes/Packet
Die Another Day DVD, 30-30-30	48 Bytes/Packet
Die Another Day DVD, 10-14-16	48 Bytes/Packet
Die Another Day DVD, 04-04-04	200 Bytes/Packet
The Transporter DVD, 30-30-30	48 Bytes/Packet
The Transporter DVD, 10-14-16	48 Bytes/Packet
The Transporter DVD, 04-04-04	200 Bytes/Packet
Charlie's Angels DVD, 30-30-30	48 Bytes/Packet
Charlie's Angels DVD, 10-14-16	48 Bytes/Packet
Charlie's Angels DVD, 04-04-04	200 Bytes/Packet
Ice Age DVD, 30-30-30	48 Bytes/Packet
Oprah without Commercials, 30-30-30	48 Bytes/Packet
Oprah without Commercials, 10-14-16	200 Bytes/Packet
Oprah without Commercials, 04-04-04	200 Bytes/Packet