Lab 2: Packet Losses and Their Impact on Streaming Video Quality

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I. Introduction

In this Lab, you are to investigate packet losses and their impact on streaming video quality through the evaluation of the decodable frame rate (DFR) [1], [2] with and without forward error correction (FEC) and convolutional interleaving/deinterleaving based on the loss models you studied in Lab 1.

You need to submit a Lab report and program source code through the Learning Mall Online by the end of Sunday, 7 May 2023.

II. Evaluation of Decodable Frame Rate (DFR) in Video Streaming

Fig. 1 shows a video streaming model for the analysis of packet loss impact on video quality, which consists of one server and one client connected through a lossy channel.

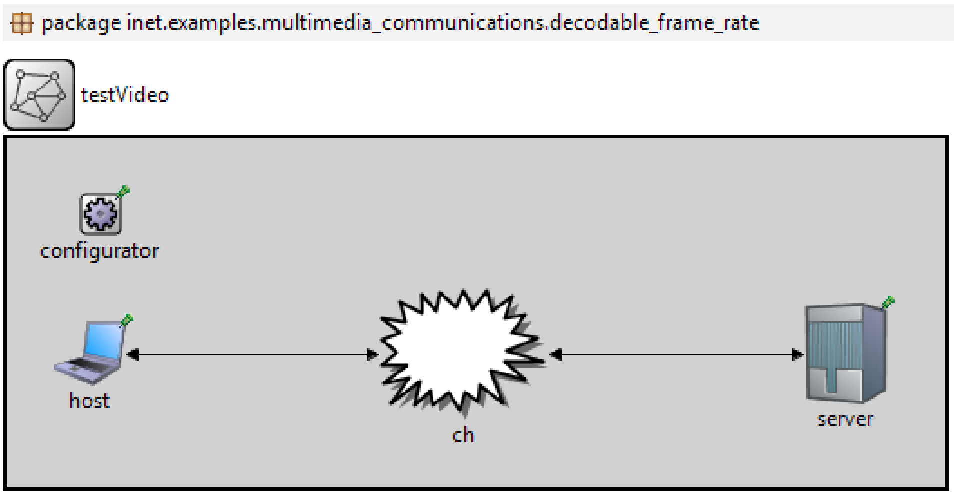

Fig. 1. A video streaming model.

You are to evaluate DFR [1] to quantify the impact of packet losses on streaming video quality step by step as follows:

1) Generate symbol loss sequences using the Simple Gilbert model (SGM) [3] (i.e., the model studied in Lab 1).

2) Map symbol losses to packet losses based on the number of symbols per packet under the following conditions:
   - Without FEC.
   - With FEC.

- With FEC and convolutional interleaving/deinterleaving.

We assume 8 bits per symbol and 188 symbols per packet. In case of FEC, a Reed-Solomon code of RS(204, 188, t=8) from the digital video broadcasting (DVB) standard is applied to each packet, resulting in 204-symbol packets. We assume that there are *no other overhead, randomization, and interpolation during the packetization*.

3) Map packet losses to frame losses based on the number of bits per frame for a given video trace. For this Lab assignment, we use *Star Wars 4* video trace from H.264/AVC video trace library, which is shown below and can be downloaded from Learning Mall Online.

```
# Frame   Time [ms]   Type   Size [Bit] ...
0         0.0000      I      8776
4         0.1333      P      456
1         0.0333      B      64
2         0.0667      B      64
3         0.1000      B      64
8         0.2667      P      456
5         0.1667      B      64
6         0.2000      B      64
7         0.2333      B      64
12        0.4000      P      456
9         0.3000      B      64
10        0.3333      B      64
11        0.3667      B      64
16        0.5333      I      8776
13        0.4333      B      3232
14        0.4667      B      3232
15        0.5000      B      3232
...
```

For simplicity, we treat any *partially-filled* packets at the end of frames (e.g., the second packet from a frame of 1664 bits ($\sim$1.1064 packets) as normal 188-symbol packets (before FEC) during the loss mapping.

4) Calculate DFR based on the GOP structure and the coding dependencies of frames. The GOP structure of *Star Wars 4* video trace is IBBBPBBBPBBBPBBBI (i.e., M=4, N=16).

Fig. 2 illustrates the whole procedure for evaluating DFR from symbol losses.

III. Task: Analysis of Packet Loss Impact on Streaming Video Quality

For this task, you need to submit a Lab report and program source code summarizing the following activities:

#1 [**30 points**] Read the types and sizes of 10,000 video frames from the *Star Wars 4* trace and generate symbol loss sequences for two symbol loss rates (p_L) of 1×10^{-4} and 1×10^{-3} using the SGM with p=1×10^{-4}. Based on the procedure described in Sec. II, calculate DFR for each loss rate.

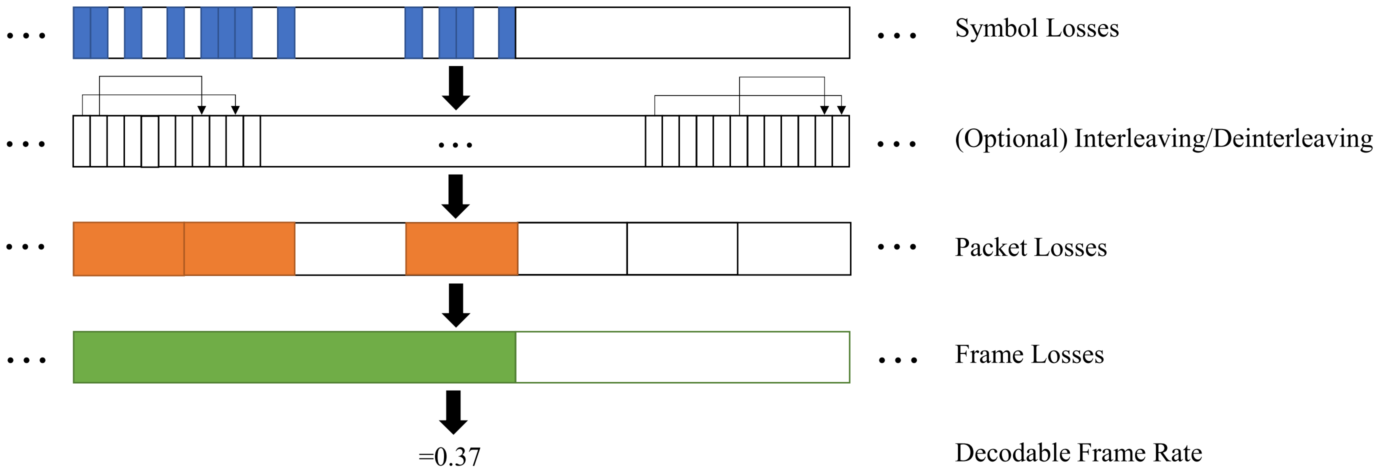

Fig. 2. Evaluating DFR from symbol losses.

Solution

Sample scripts:

- `conv_interleave.py`
- `dfr_plot.py`
- `dfr_simulation.py`
- `sgm_generate.py`

The scripts need to be on the same directory. Then, you can run it for this task by typing the following on the command line, where you need to replace `XXX` with `1e-4` or `1e-3`:

```
python dfr_simulation.py -P XXX
```

- DFR=9.9460×10^{-1} for p_L=1×10^{-4}.
- DFR=9.9370×10^{-1} for p_L=1×10^{-3}.

#2 [**25 points**] Repeat #1 with RS(204, 188, t=8).

Solution

Type the following on the command line, where you need to replace `XXX` with `1e-4` or `1e-3`:

```
python dfr_simulation.py -P XXX --fec
```

- DFR=1.0 for p_L=1×10^{-4}.
- DFR=9.9980×10^{-1} for p_L=1×10^{-3}.

#3 [**25 points**] Repeat #2 with convolutional interleaving/deinterleaving.

Solution

Type the following on the command line, where you need to replace `XXX` with `1e-4` or `1e-3`:

```
python dfr_simulation.py -P XXX --fec --ci
```

- DFR=1.0 for p_L=1×10^{-4}.
- DFR=1.0 for p_L=1×10^{-3}.

#4 [**20 points**] Generate a plot comparing the resulting DFRs (similar to the one shown in the Lab slides for DFR) and discuss the advantages and disadvantages of using RS code and/or convolutional interleaving/deinterleaving.

Solution

Type the following on the command line to generate the plot shown in Fig. 3, which also provides additional the results for p_L=$2 \times 10^{-4}, 3 \times 10^{-4}, \ldots, 9 \times 10^{-4}$:[1]

```
python dfr_plot.py
```

The results shown in Fig. 3 demonstrate that using RS code and/or convolutional interleaving/deinterleaving can improve DFR, which is their clear advantage. The use of RS code and that of convolutional interleaving/deinterleaving, however, increase the bit rate and the delay of the resulting video stream, respectively, which are their disadvantages.

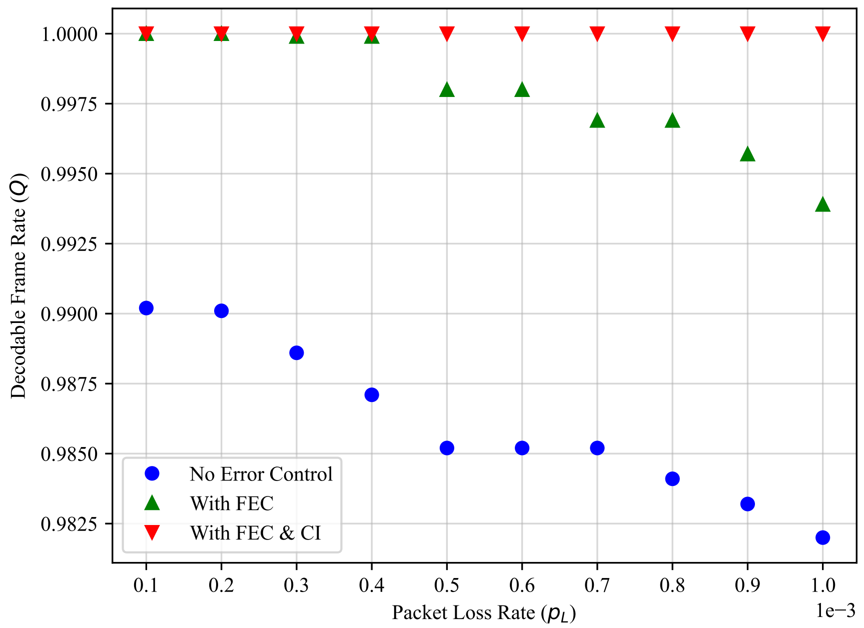

Fig. 3. DFRs vs. packet loss rate with and without forward error correction (FEC) and/or convolutional interleaving/deinterleaving (CI).

Note that The following files are provided on Learning Mall Online for this task:

- *conv_interleave.py*: Code for convolutional
- *dfr_simulation.py*: Skeleton code for the simulation.
- *starWars4_verbose*: Video trace file for the simulation. interleaving/deinterleaving.

REFERENCES

[1] A. Ziviani, B. E. Wolfinger, J. F. Rezende, O. C. Duarte, and S. Fdida, "Joint adoption of QoS schemes for MPEG streams," Multimedia Tools Appl., vol. 26, no. 1, pp. 59–80, 2005.

[2] K. S. Kim, "The effect of ISP traffic shaping on user-perceived performance in broadband shared access networks," Computer Networks, vol. 70, pp. 192–209, Sep. 2014.

[1]Note that, because the DFR results are highly dependent on the random number generation (i.e., the value of the Numpy random seed), you results may look quite different from those shown in Fig. 3.

[3] M. Yajnik, S. Moon, J. Kurose, and D. Towsley, "Measurement and modelling of the temporal dependence in packet loss," in Proc. 1999 IEEE INFOCOM, vol. 1, Mar. 1999, pp. 345–352.