Performance Evaluation of Maximum Likelihood Decoding Combined with Error Resilient Video Coding

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Outline

- Introduction
- Problem statement
- Literature review
- Proposed approach
- Experimental setup and results
- Conclusions

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Introduction

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❑ Digital video communications

Video Chatting

Video Conferencing

Mobile TV & Video Calling

Channel bandwidth limitations

Compression! **e.g. H.264, HEVC**

Video signals high data volume

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HEVC: High Efficiency Video Coding

Problem statement

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Unreliable Channels → **Transmission Errors** → **Visual Quality Degradation**

- Corrupted Video Packets (bit errors)
  (e.g. attenuation, fading)
- Lost Video Packets
  (e.g. network congestion)

Error propagation in **compressed** video!

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Problem statement

- **Retransmissions**
  - ☹ Not always possible in **real-time applications**:
    - ✓Broadcasting: mobile TV, …
    - ✓Conversational services: video conferencing, …
- **Error resilience**
  - ☺ Minimizes the impact of errors on the end-user quality
  - ☹ Reduces the compression efficiency (requiring additional bandwidth)
- **Error correction** and **concealment**
  - ☺ Estimates missing pixels
  - ☺ No additional bandwidth required

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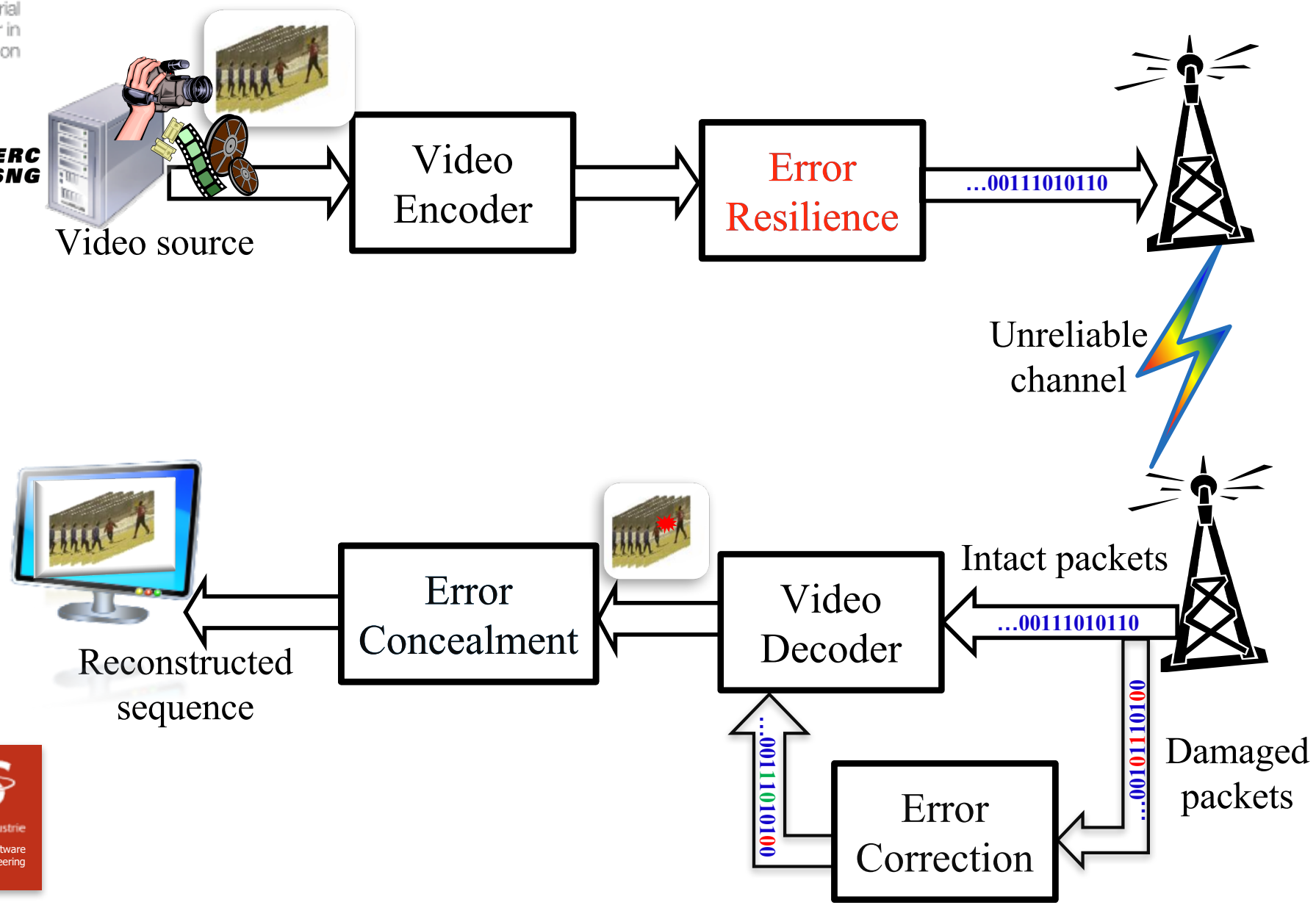
Problem statement



Literature review

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Error Resilience (ER):

- **Intra** Refresh Macroblocks [1]
- ER-**Rate Distortion Optimization** [2]
  - **optimal mode decision (md)**
  - **motion estimation (me)**

  -**RDO:** Minimize the distortion D, given a maximum rate R

$$J_{md} = D_{SSD} + \lambda_{md} . R_{md} \qquad J_{me} = D_{SAD} + \lambda_{me} . R_{me}$$

- **Weighted** Error resilience [3]
  - **Reduce the usage of *sensitive* MBs for prediction**
  - **Motion vectors assigned to MBs with less impact on error propagation**

Sensitive MBs : MBs with high impact on error propagation

$$J_{md} = w_{md} . D_{SSD} + \lambda_{md} . R_{md} \qquad J_{me} = w_{me} . D_{SAD} + \lambda_{me} . R_{me}$$

Weighting factors

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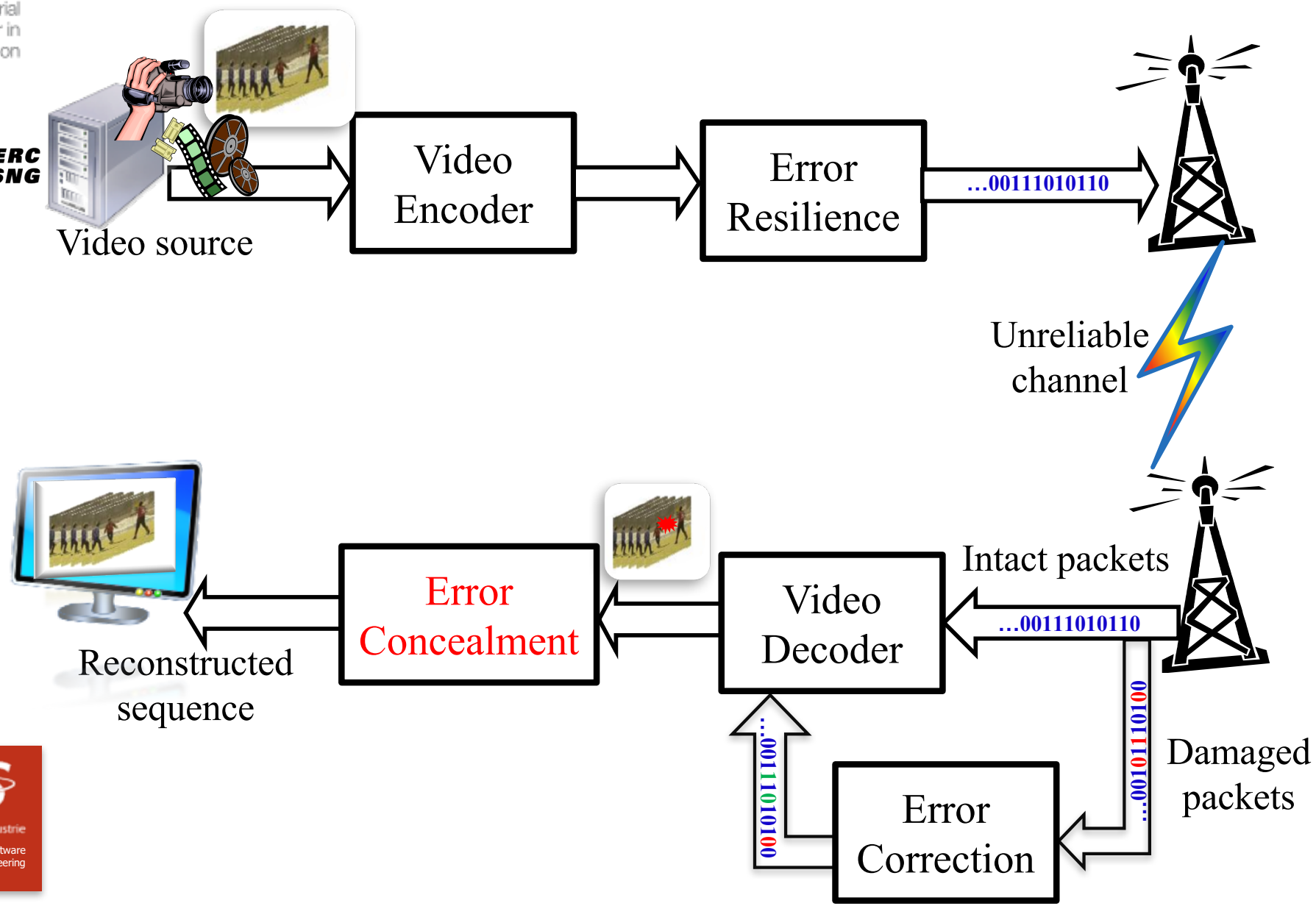
[1] J. Liao, et al., "Adaptive intra block update for robust transmission of H.263", 2000.

[2] T. Stockhammer, et al., "Rate-distortion optimization for JVT/H.26L video coding in packet loss environment", 2002.

[3] S. Nyamweno, et al., "Error resilient video coding via weighted distortion", 2009.

Literature review



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Error Concealment:

Spatial

Using spatial correlation [1]

-Smoothness property of the spatially-adjacent pixels

-Interpolation by using four nearest intact pixels

Multi-directional or edge interpolation

Temporal

Using temporal correlation [2]

Motion information recovery

-Boundary matching algorithm (BMA)

Spatio-Temporal

Using both spatial and temporal correlation

-spatio-temporal boundary matching and partial differential equation **(STBMA)** [3]

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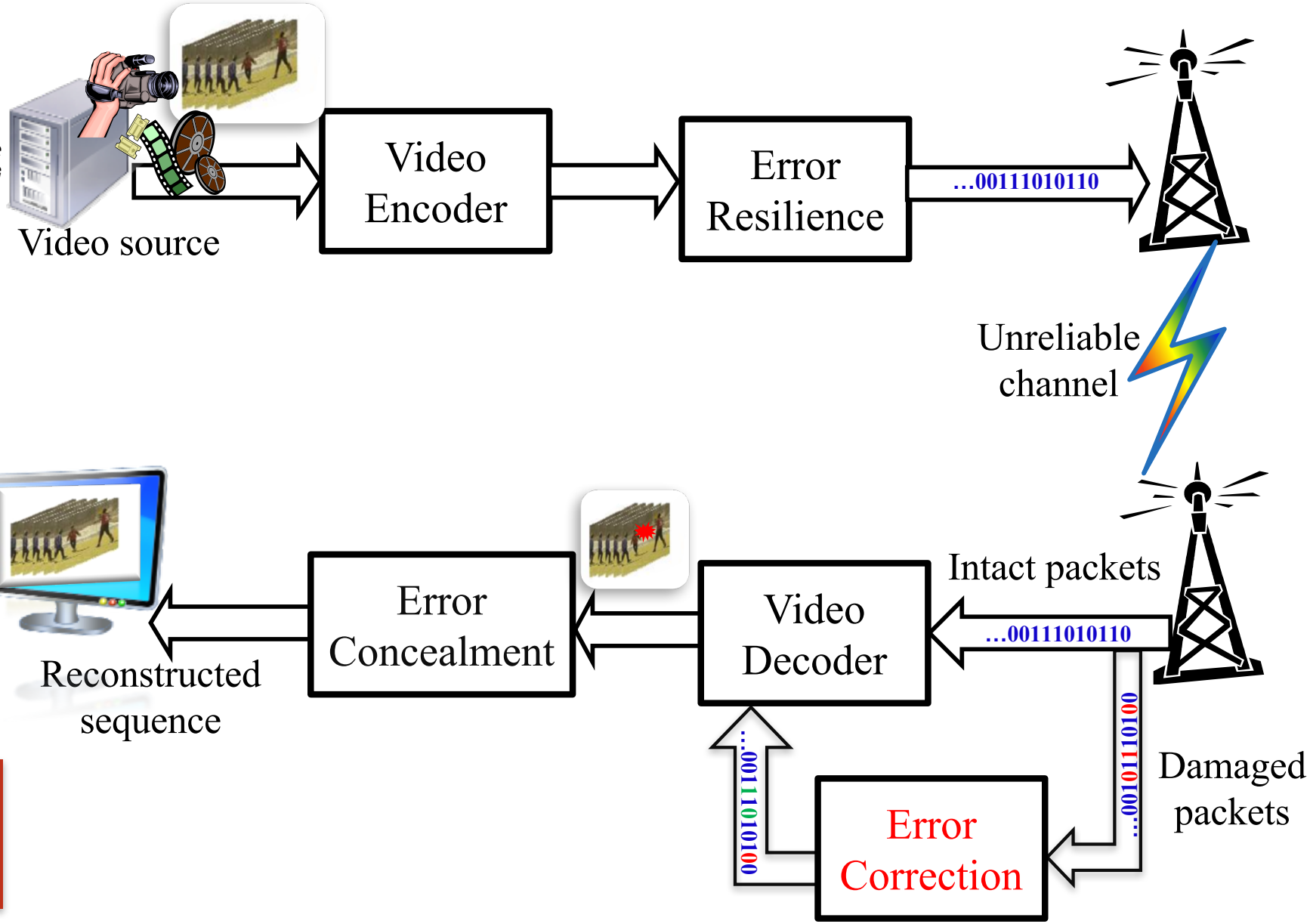
[1] D. Robie, et al., "The Use of Hough Transforms in Spatial Error Concealment", 2000.

[2] Y. Su, et al., "A Non-Iterative Motion Vector Based Global Motion Estimation Algorithm", 2004.

[3] Y. Chen, et al., "Video error concealment using spatio-temporal boundary matching and partial differential equation", 2008.

Literature review



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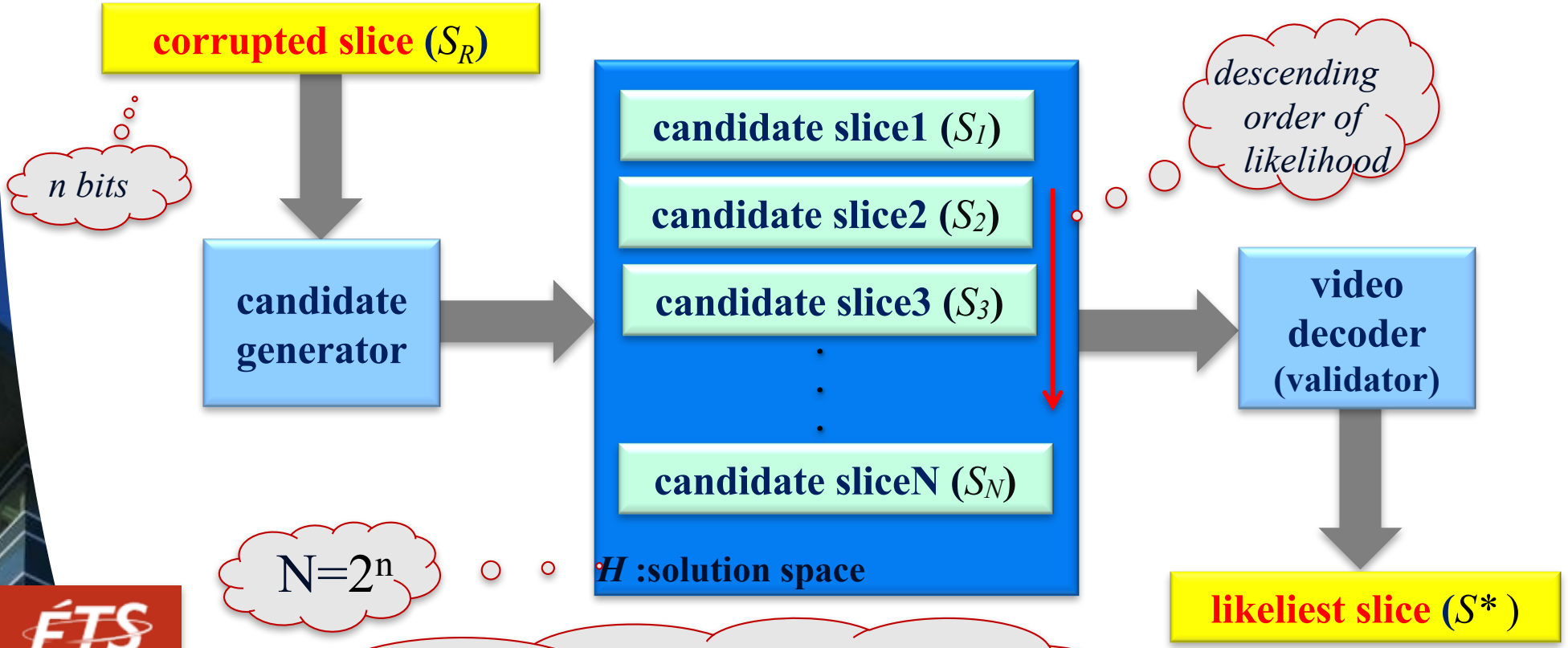
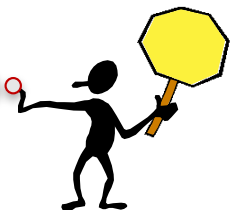
❑ Error Correction: Slice Level

$$S^* = \arg\max_{S_T \in H} \{P(S_T \mid S_R)\}$$



Complexity !?

the number of candidates grows exponentially with the packet size



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❑ Error Correction: Slice Level

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- ➢ **Reduce the Computational Complexity:**
  - ➢ **The number of candidates considered is limited.**
    - ✓ **300 candidates are considered** [1], [2]

- ➢ **Definition of a Valid Slice:**
  - ➢ **The number of macroblocks carried in the slice is used as an additional constraint.**
    - ✓ **assume a slice carries an entire picture** [3]
    - ✓ **assume a slice carries a row of macroblocks** [2]
    - ✓ **use data partitioning (H.264 Extended Profile) to obtain more information about the corrupted slice** [4]

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[1] D. Levine, et al., "Iterative joint source-channel Decoding of H.264 compressed video", 2007.

[2] N. Nguyen, et al., "Iterative joint source- channel decoding for H.264 video transmission using virtual checking method at source decoder", 2010.

[3] G. Sabeva, et al., "Robust decoding of H.264 encoded video transmitted over wireless channels", 2006.

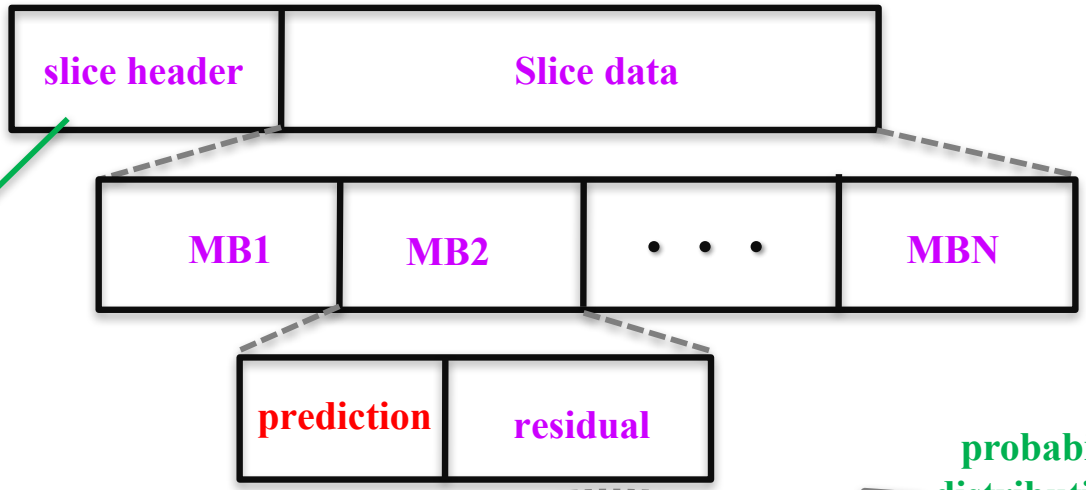
[4] C. Weidmann, et al.," Combined sequential decoding and error concealment of H.264 Video", 2004.

Literature review

Error Correction: Syntax Level

Syntax in slice header:

- *first_mb_in_slice*
- *Slice_type*
- *pic_parameter_set_id*
- *frame_num*
- *pic_order_cnt_lsb*
- *num _ref_ idx _active*
- ⋮



probability distribution of the Syntax

Likeliest Syntax → $s_i^* = \underset{s_{i,T} \in C_i}{\operatorname{argmax}} \left\{ P\left(s_{i,R} \middle| s_{i,T}\right) \times P\left(s_{i,T} \middle| \Psi_i, s_1^*, s_2^*, \ldots, s_{i-1}^*\right) \right\}$

All the candidate for i-th Syntax

Maximum Likelihood Decoding (MLD) — **SE: Syntax Element**

-Generate only a set of valid SEs in each step of correction process

-**Stop correction** : at the end of the slice or more than one bit error in SE

-Modeled probability of first five SEs of slice header: e.g. *first_mb_in_slice,…*

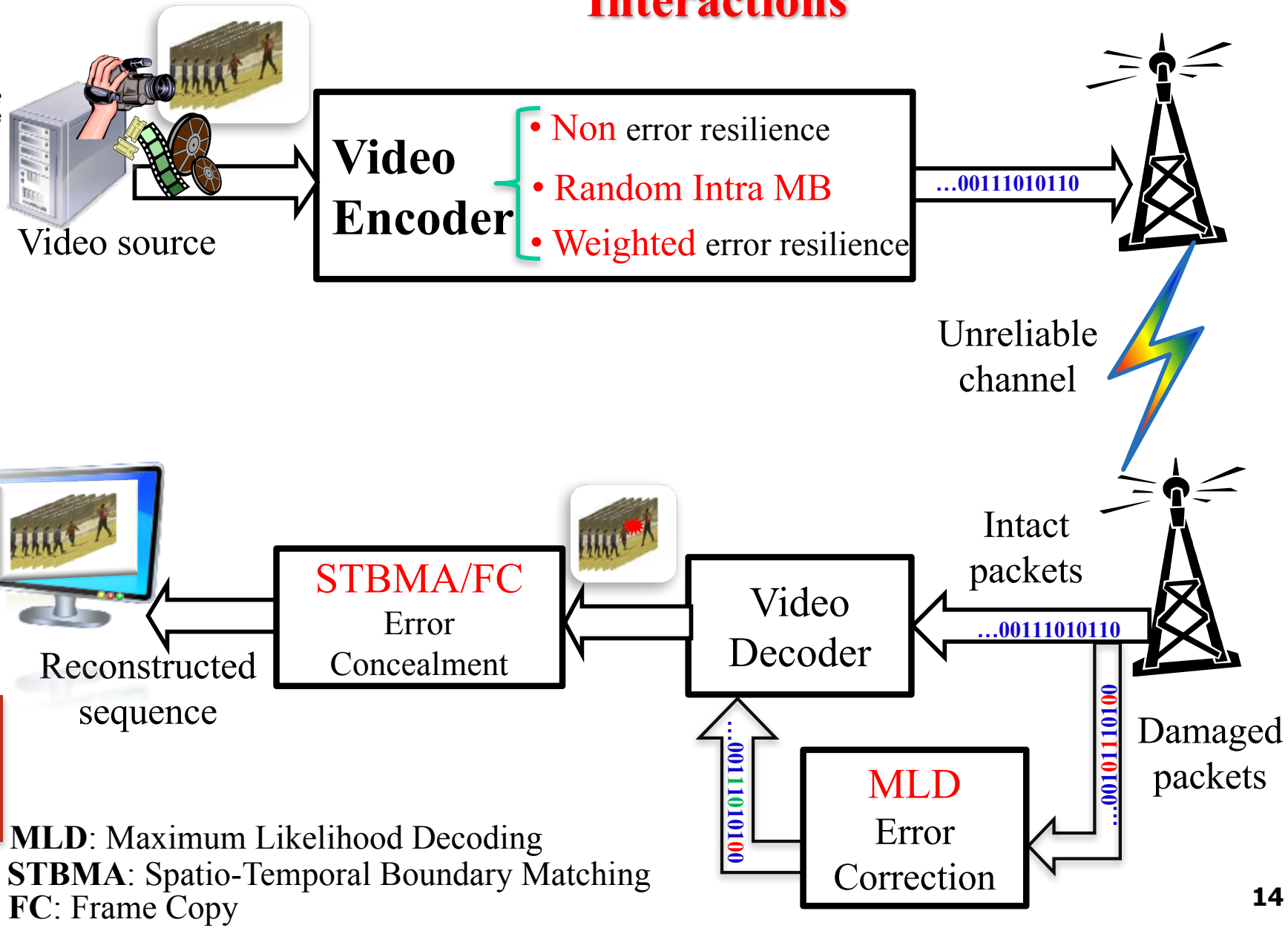
-Modeled SEs in prediction part of slice data : e.g. intra 4*4_pred_mod , … [1],[2]

[1] F. Caron, et al., "A maximum likelihood approach to correct transmission errors for joint source-channel decoding of H.264 coded video", 2013.

[2] F. Caron, et al., "Video error correction using soft-output maximum likelihood decoding applied to H.264 baseline profile".

Proposed approach

Error Resilience and Error Correction Interactions



MLD: Maximum Likelihood Decoding
STBMA: Spatio-Temporal Boundary Matching
FC: Frame Copy

Experimental setup

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❖ **Coding Option :** **Non ER (S)**
20% Random Intra MB Updating (RIU)
Weighted ER (W)

- **Baseline** profile of H.264 (**JM** 18.5)
- First 100 frames **QCIF** sequence (176x144): *Football, Crew, Harbour, Soccer and City*
- Coded in **IPPP…** format, Frame Rate of **15 Hz**
- **Slice:** One **row** of Macroblocks

➢ **Corrupted frame: 21^{th}-80^{th} randomly**
➢ **Channel bit error rate (BER): [10^{-5}, 10^{-4}]**
➢ **average PSNR from frames 21 to 80**

❖ **Decoding Option :** **Frame Copy** Error Concealment (**FC**)
Spatio Temporal Boundary Matching (STBMA)
Maximum Likelihood Decoding (MLD)

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Rate Distortion Curve

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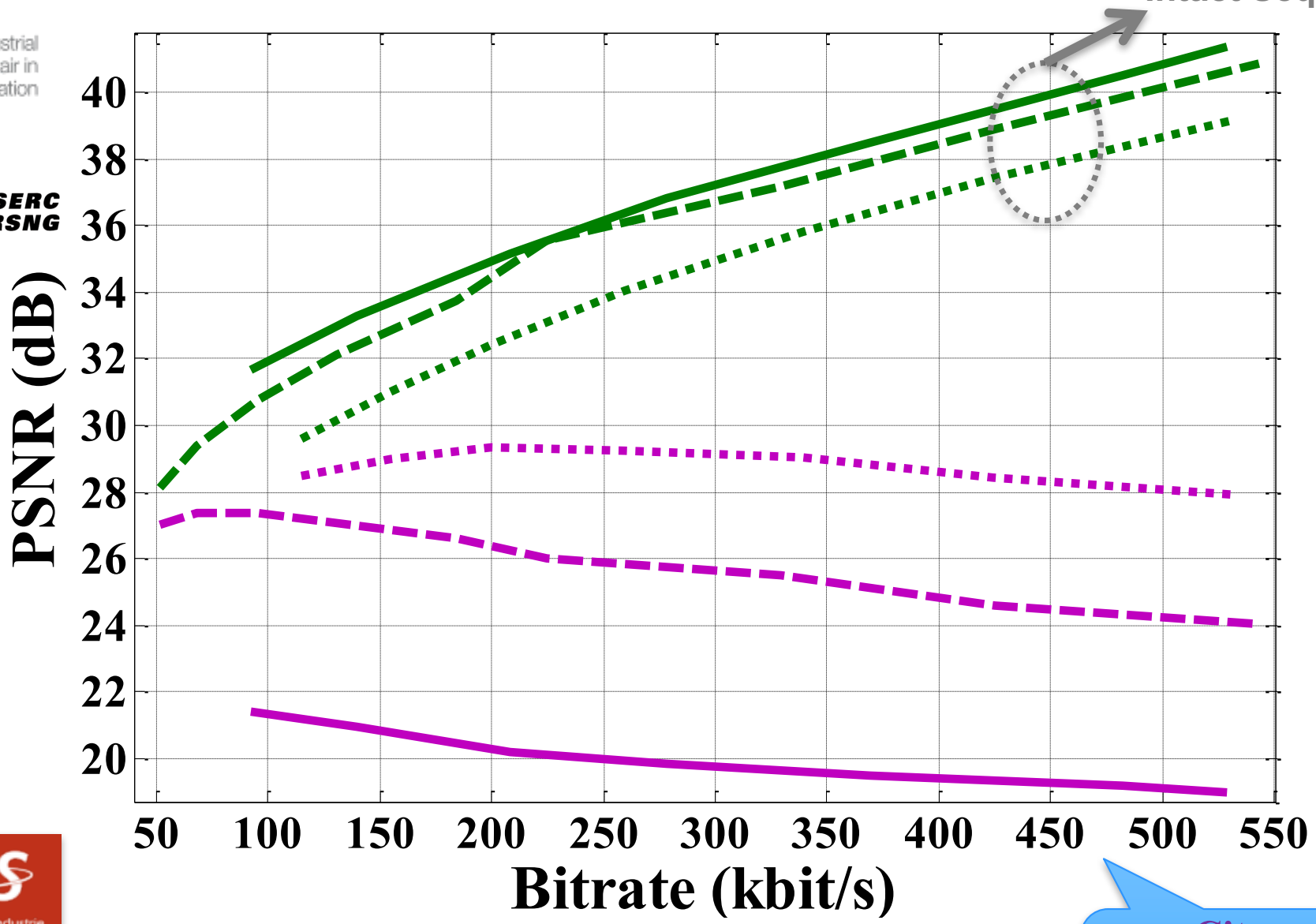

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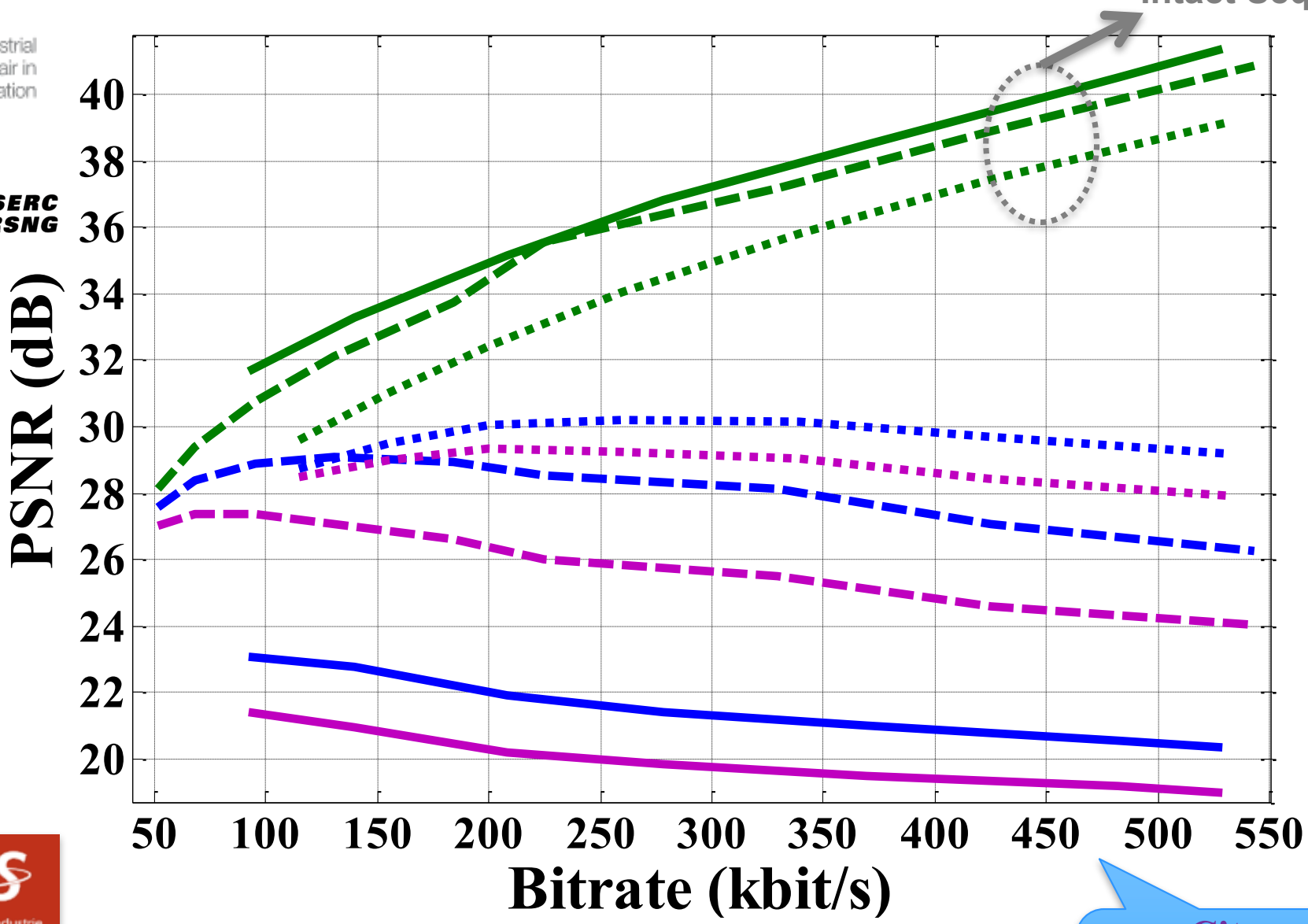

City
SNR=6 (dB)
BER=5×10^{-5}

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Rate Distortion Curve

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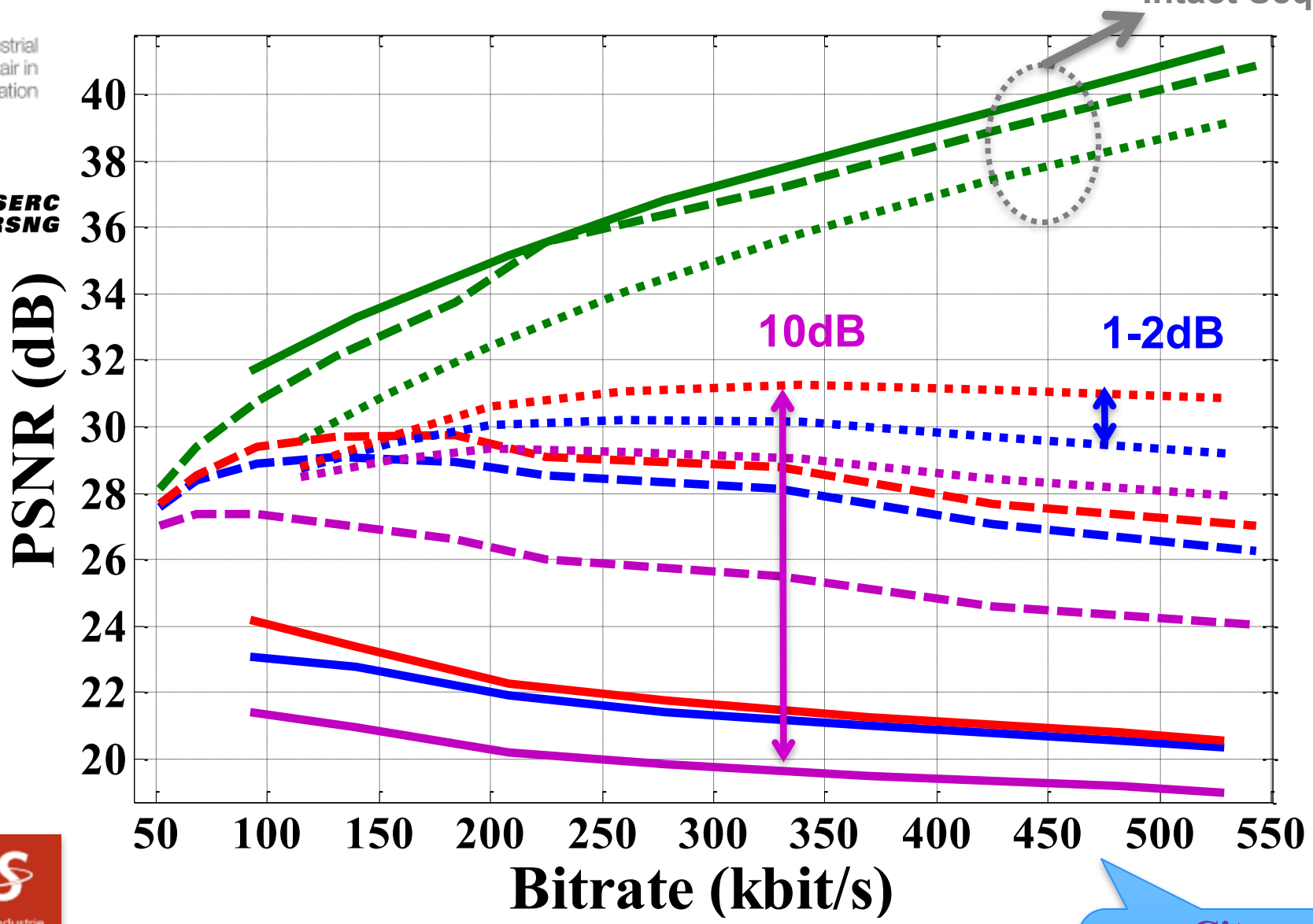

City
SNR=6 (dB)
BER=5×10^{-5}

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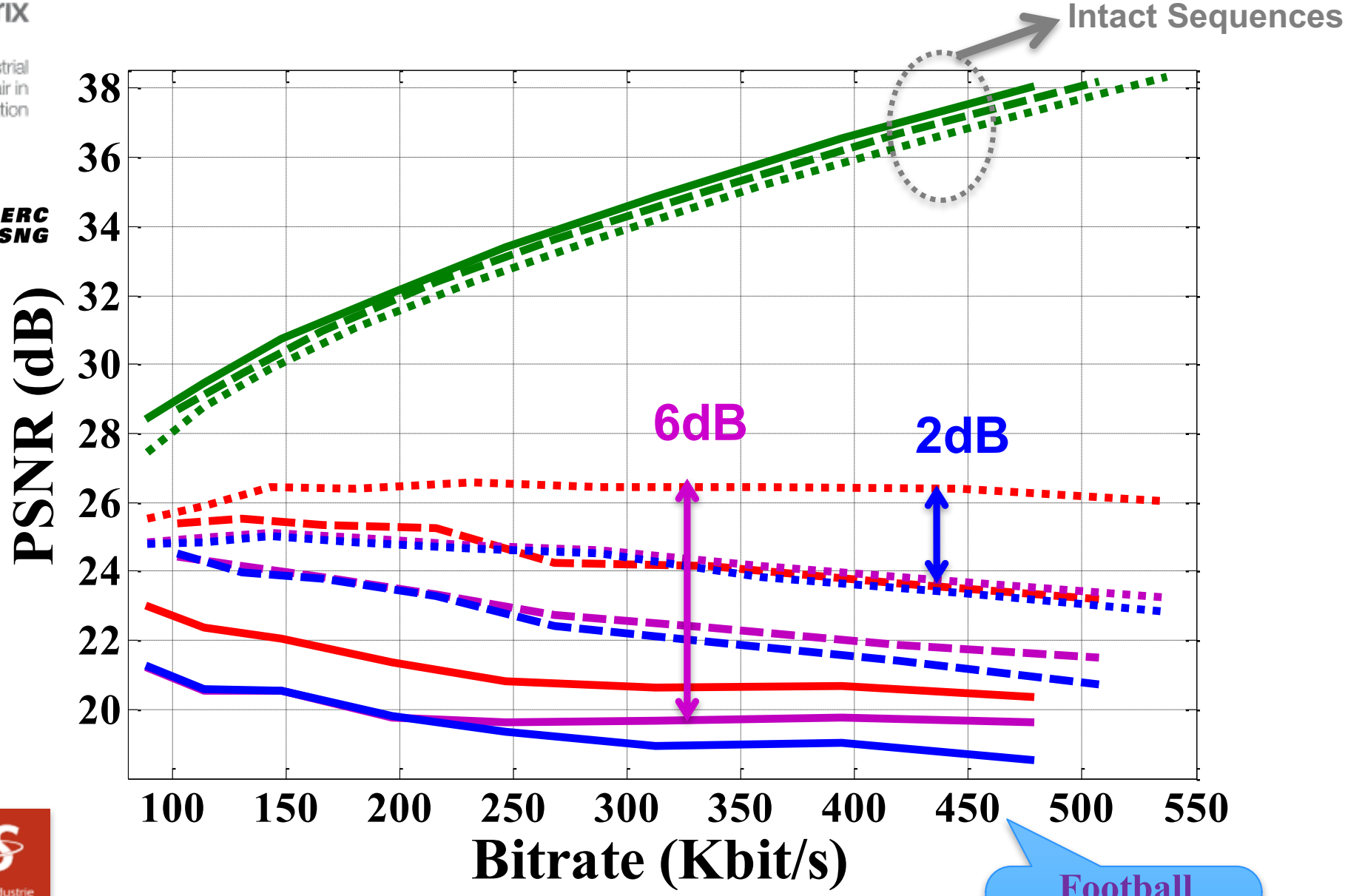
Rate Distortion Curve

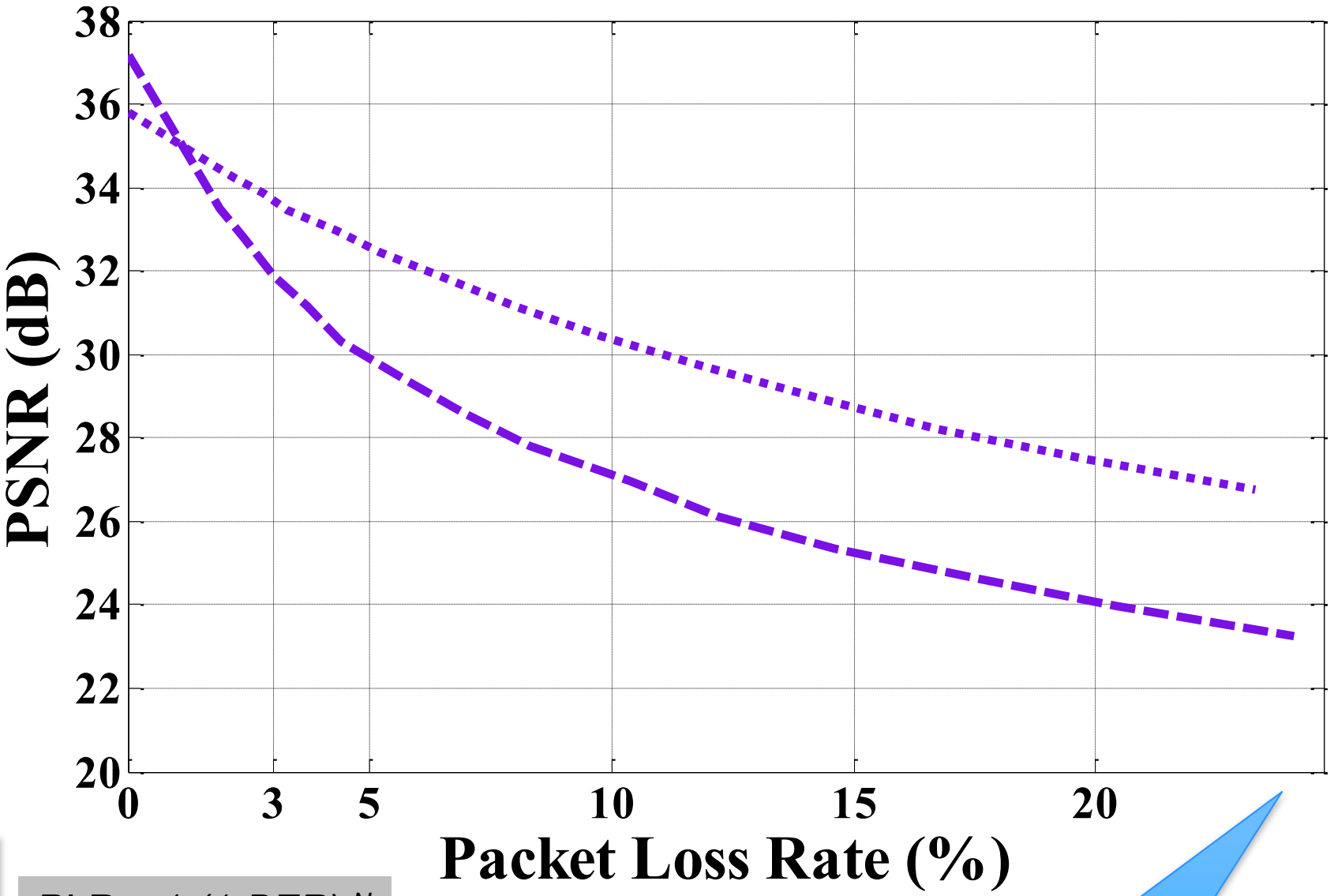


Football

SNR=6 (dB)

BER=5×10^{-5}

PSNR vs PLR



$PLR = 1-(1-BER)^{N}$

FC-RIU

FC-W

City

Bit Rate=229kbps

BER=[10^{-5}, 10^{-4}]

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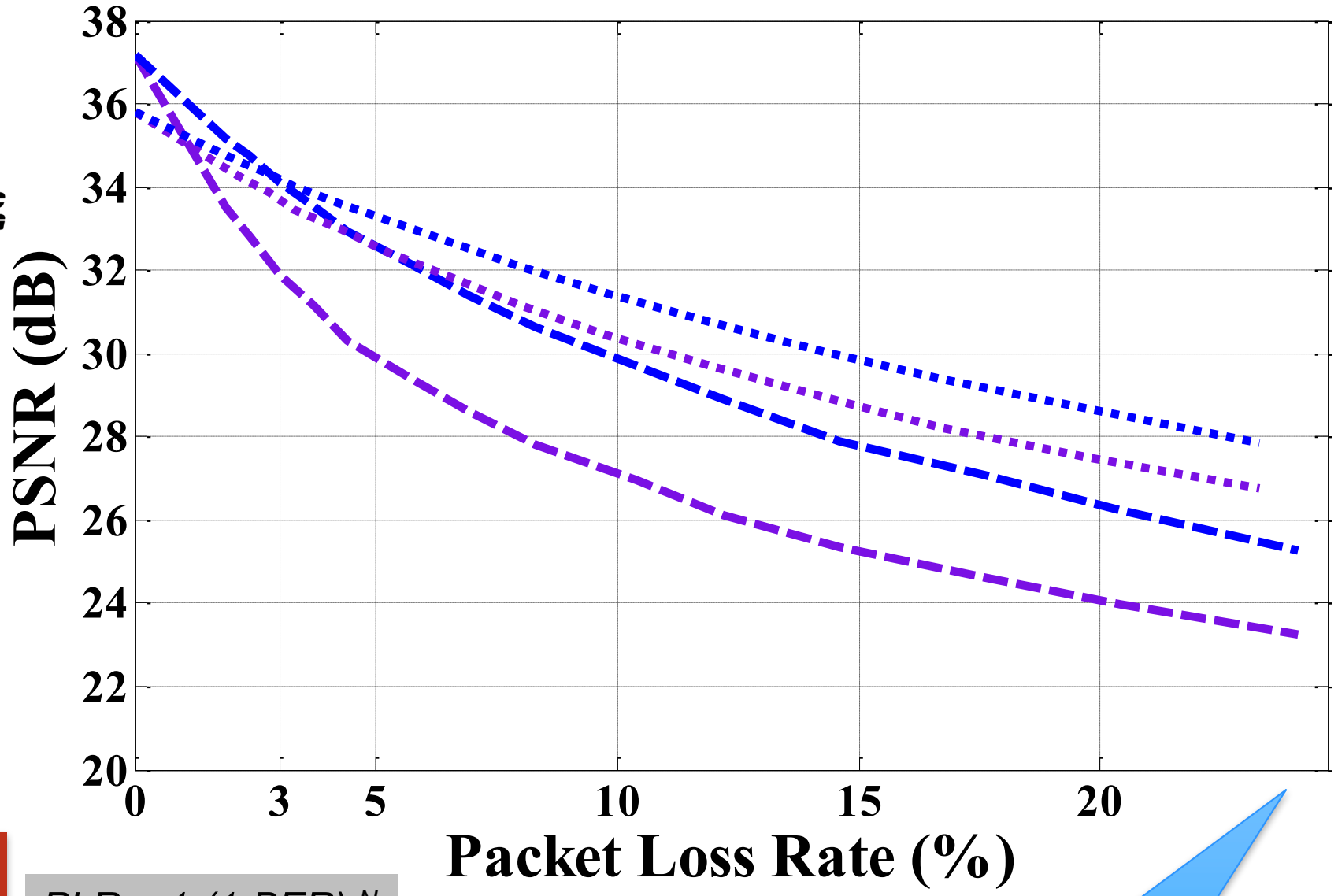
PSNR vs PLR

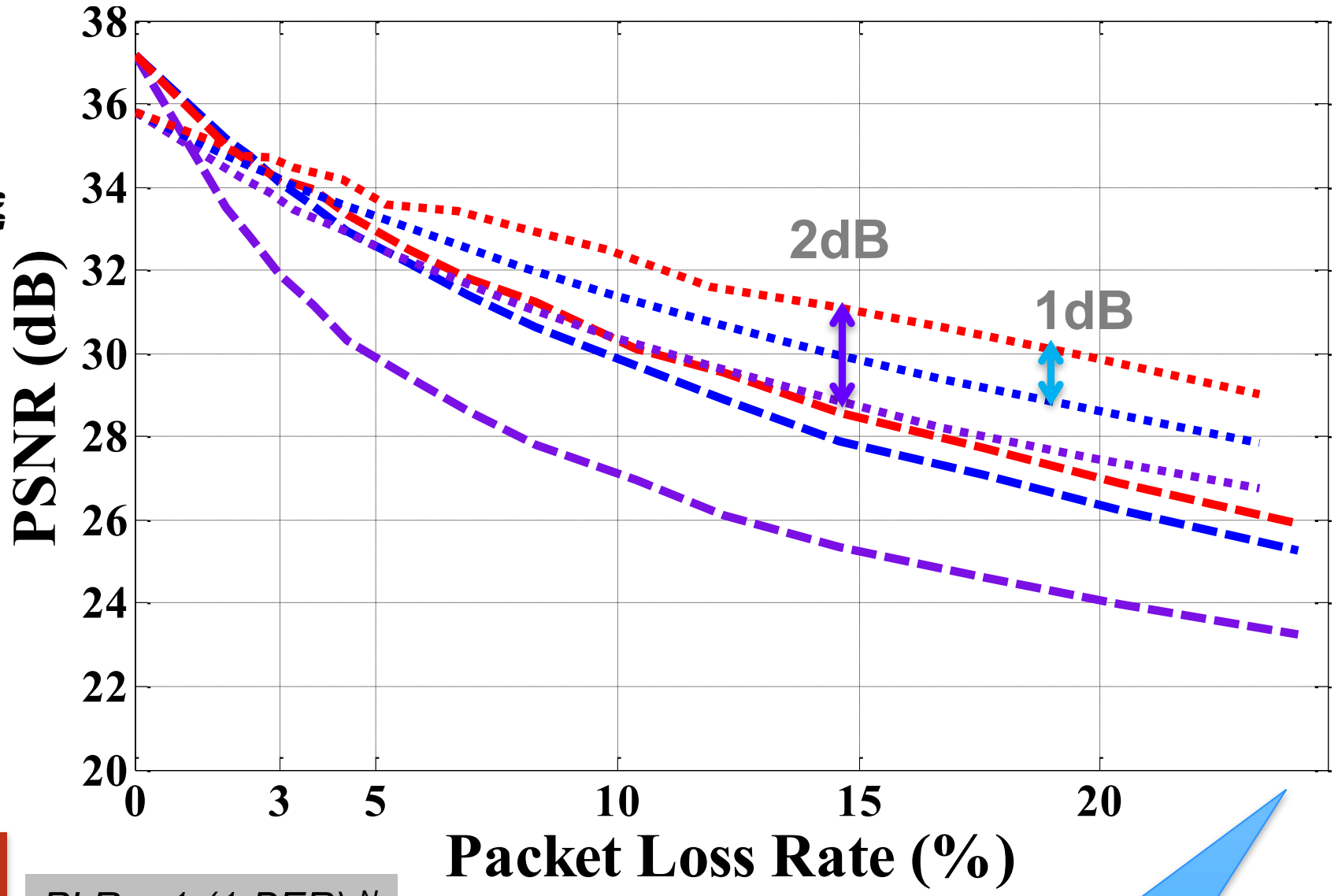


$PLR = 1-(1-BER)^{N}$

FC-RIU
STBMA-RIU
FC-W
STBMA-W

City
Bit Rate=229kbps
BER=[10^{-5}, 10^{-4}]

PSNR vs PLR

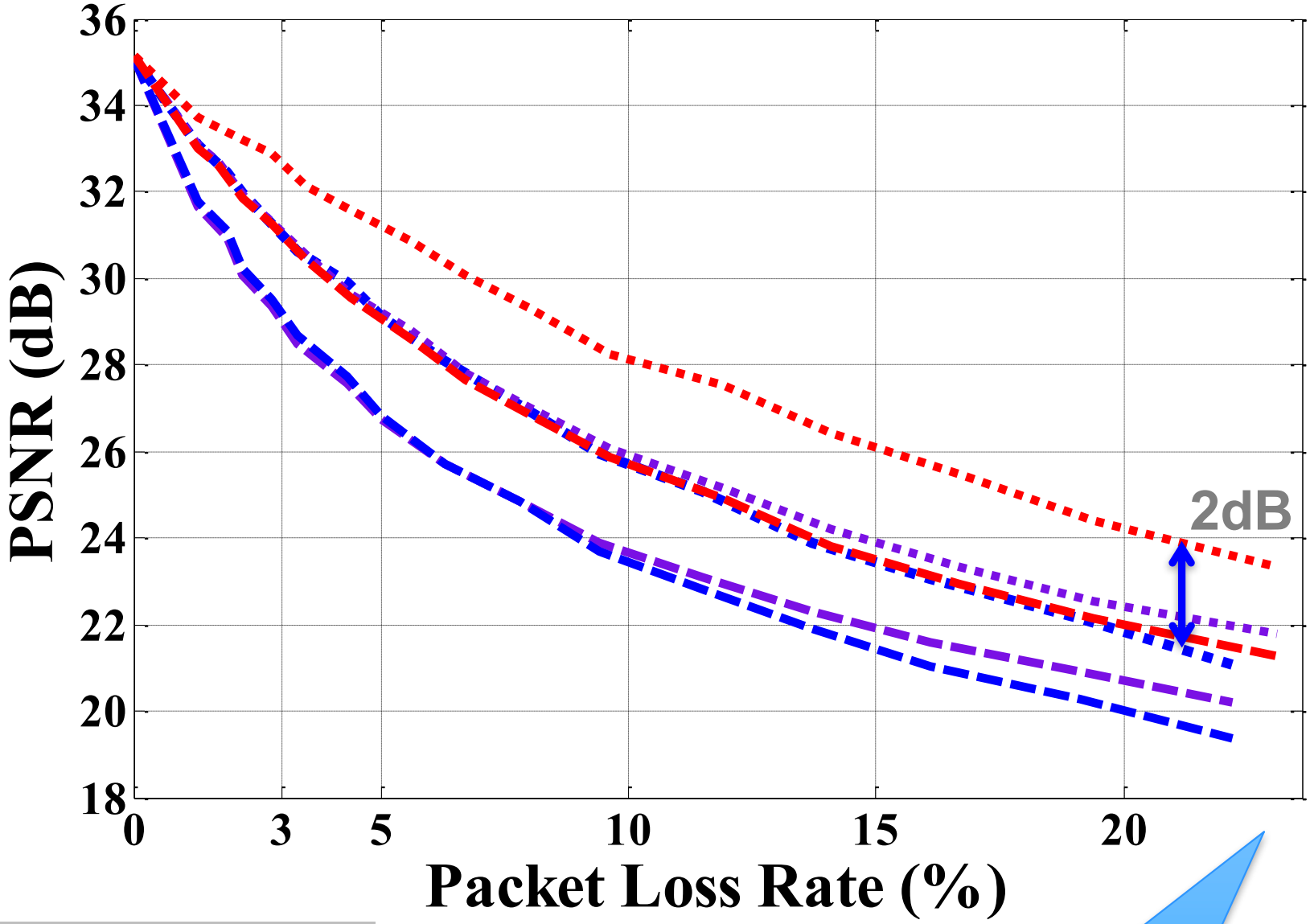


$PLR = 1-(1-BER)^{N}$

FC-RIU
STBMA-RIU
MLD-RIU
FC-W
STBMA-W
MLD-W

City
Bit Rate=229kbps
BER=[10^{-5}, 10^{-4}]

PSNR vs PLR



$PLR = 1-(1-BER)^{N}$

Football

Bit Rate=336kbps

BER=[10^{-5}, 10^{-4}]

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Sequence Name	Encoding Type	Bit Error Rate								
		10^{-5}			5×10^{-5}			10^{-4}		
		FC	STBMA	MLD	FC	STBMA	MLD	FC	STBMA	MLD
City	RIU (329kbps)	32.8	34.74 (1.94)	34.59 (1.79)	26.97	29.71 (2.74)	30.13 (3.16)	23.97	26.23 (2.26)	26.89 (2.92)
	W (339kbps)	34.21	34.6 (0.39)	34.76 (0.55)	30.42	31.44 (1.02)	32.51 (2.09)	27.5	28.66 (1.16)	29.89 (2.39)
Football	RIU (336kbps)	30.07	30.23 (0.16)	31.97 (1.9)	23.09	22.83 (-0.26)	25.08 (1.99)	20.19	19.37 (-0.82)	21.09 (0.90)
	W (359kbps)	31.61	31.55 (-0.06)	33.03 (1.42)	25.14	24.9 (-0.24)	27.52 (2.38)	21.77	21.29 (-0.48)	23.33 (1.56)
Harbour	RIU (350kbps)	31.23	31.37 (0.14)	31.59 (0.36)	27.39	27.85 (0.46)	28.15 (0.76)	24.41	24.89 (0.48)	25.41 (1)
	W (350kbps)	31.09	31.15 (0.06)	31.11 (0.02)	27.53	27.62 (0.09)	27.87 (0.34)	24.74	24.73 (-0.01)	25.28 (0.54)
Crew	RIU (329kbps)	33.72	34.21 (0.49)	34.96 (1.24)	28.01	28.67 (0.66)	29.94 (1.93)	24.81	25.27 (0.46)	26.32 (1.51)
	W (379kbps)	35.12	35.25 (0.13)	36.06 (0.94)	30.21	30.46 (0.25)	32.17 (1.96)	26.93	27.17 (0.24)	28.66 (1.73)
Soccer	RIU (304kbps)	31.13	32.45 (1.32)	33.82 (2.69)	22.81	24.34 (1.53)	26.08 (3.27)	19.47	20.53 (1.06)	21.99 (2.52)
	W (351kbps)	34.27	34.52 (0.25)	36.07 (1.8)	26.4	26.92 (0.52)	29.94 (3.54)	22.07	22.56 (0.49)	25.04 (2.97)

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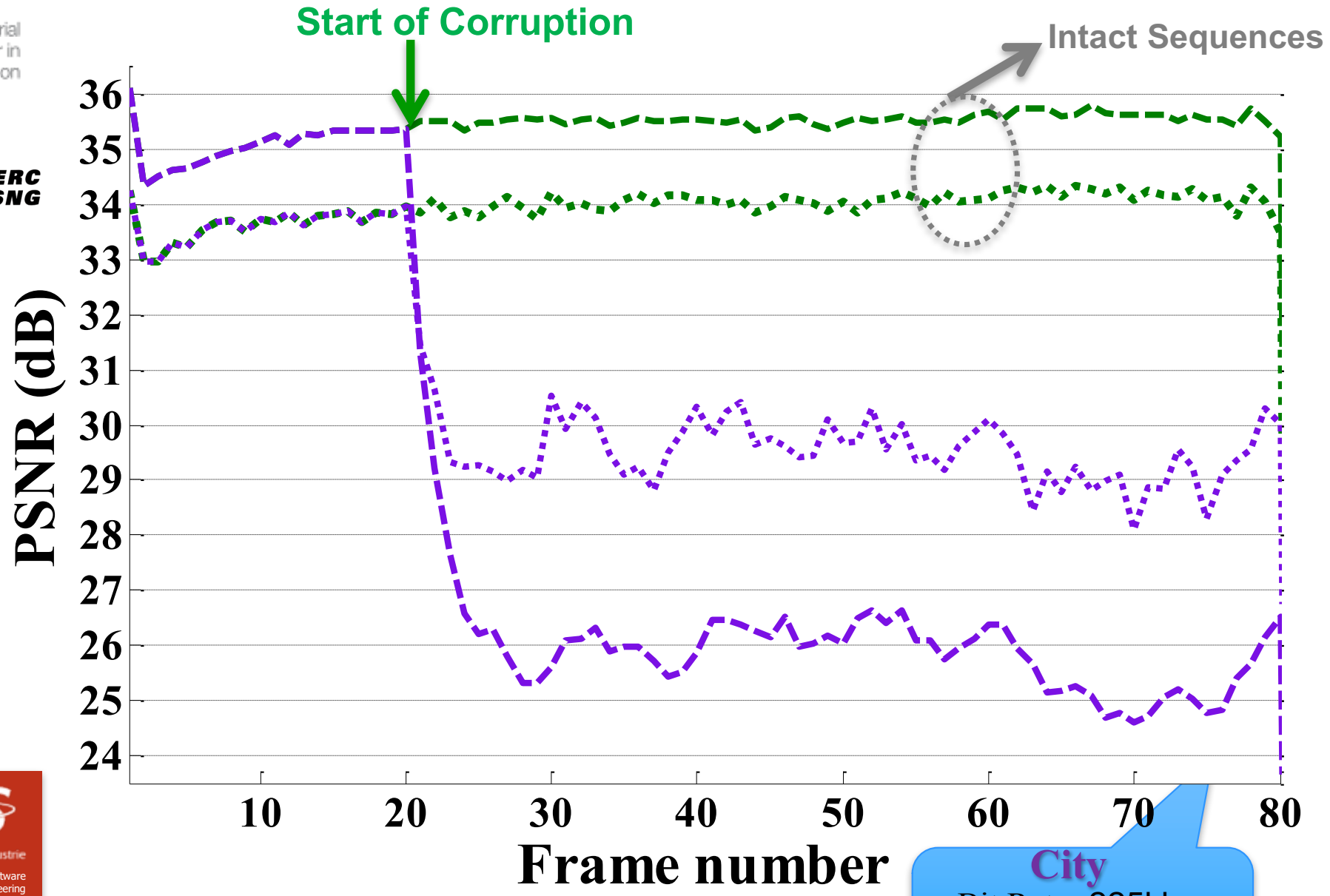
- The difference between each method with the corresponding FC approach appears in parentheses.

Average PSNR

	Encoding Type	Bit Error Rate								
		10^{-5}			5×10^{-5}			10^{-4}		
		FC	*STBMA*	*MLD*	FC	STBMA	*MLD*	FC	STBMA	*MLD*
Average	RIU	31.79	32.6	33.39	25.65	26.68	27.88	22.57	23.26	24.34
	W	33.26	33.41	34.21	27.94	28.27	30	24.6	24.88	26.44

PSNR vs Frame number



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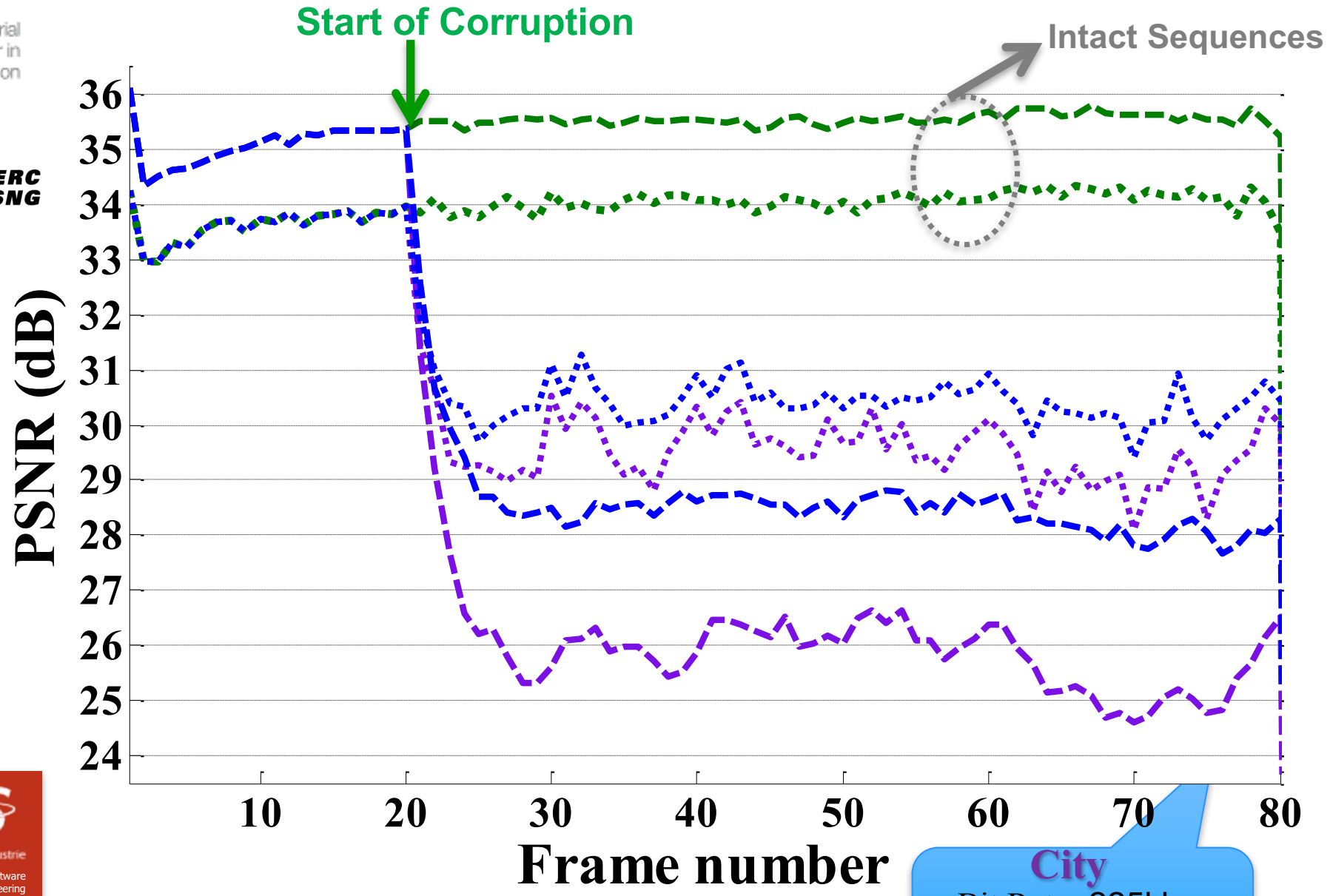
PSNR vs Frame number



City
Bit Rate=225kbps
SNR=6 (dB)
BER=5×10^{-5}

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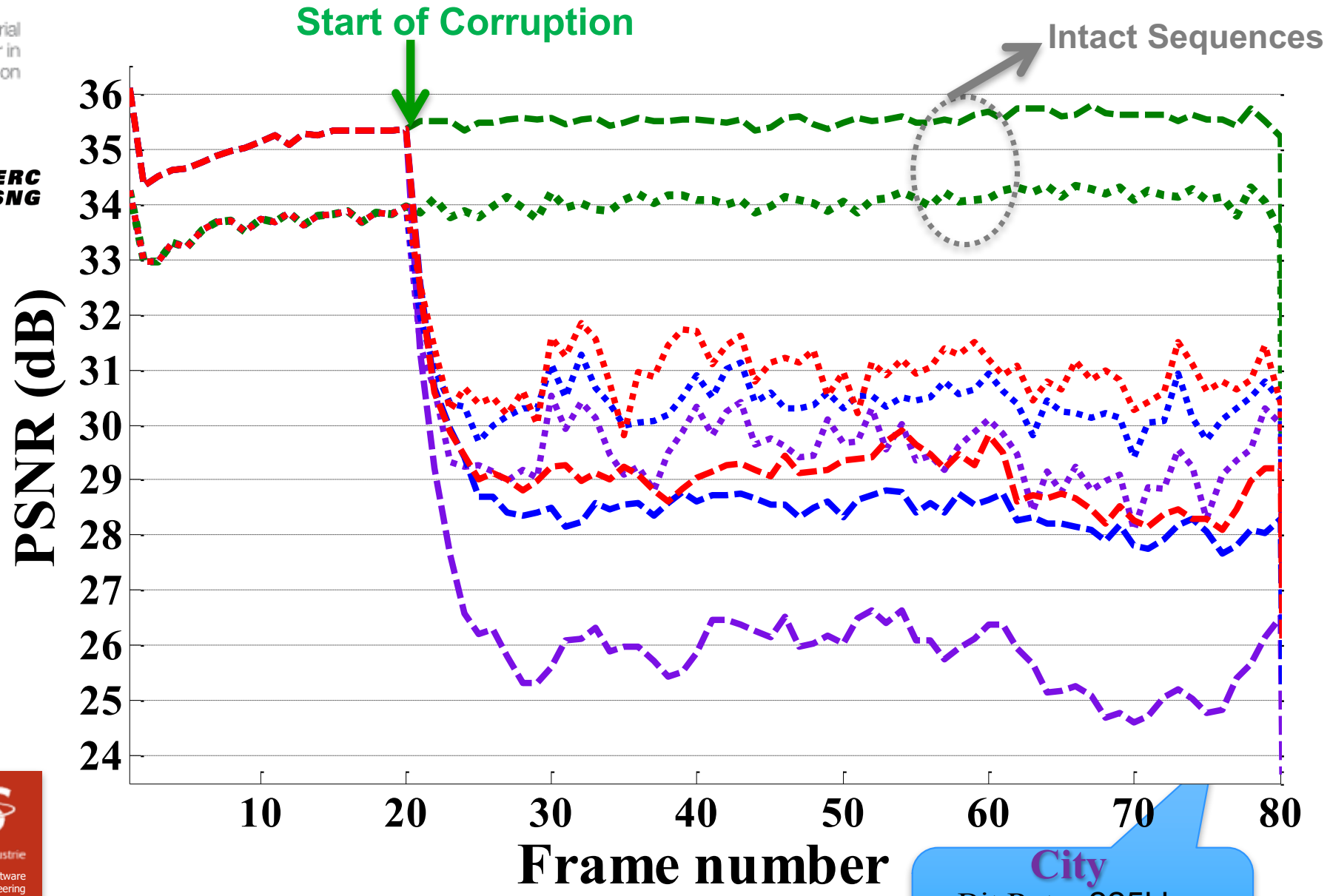
PSNR vs Frame number



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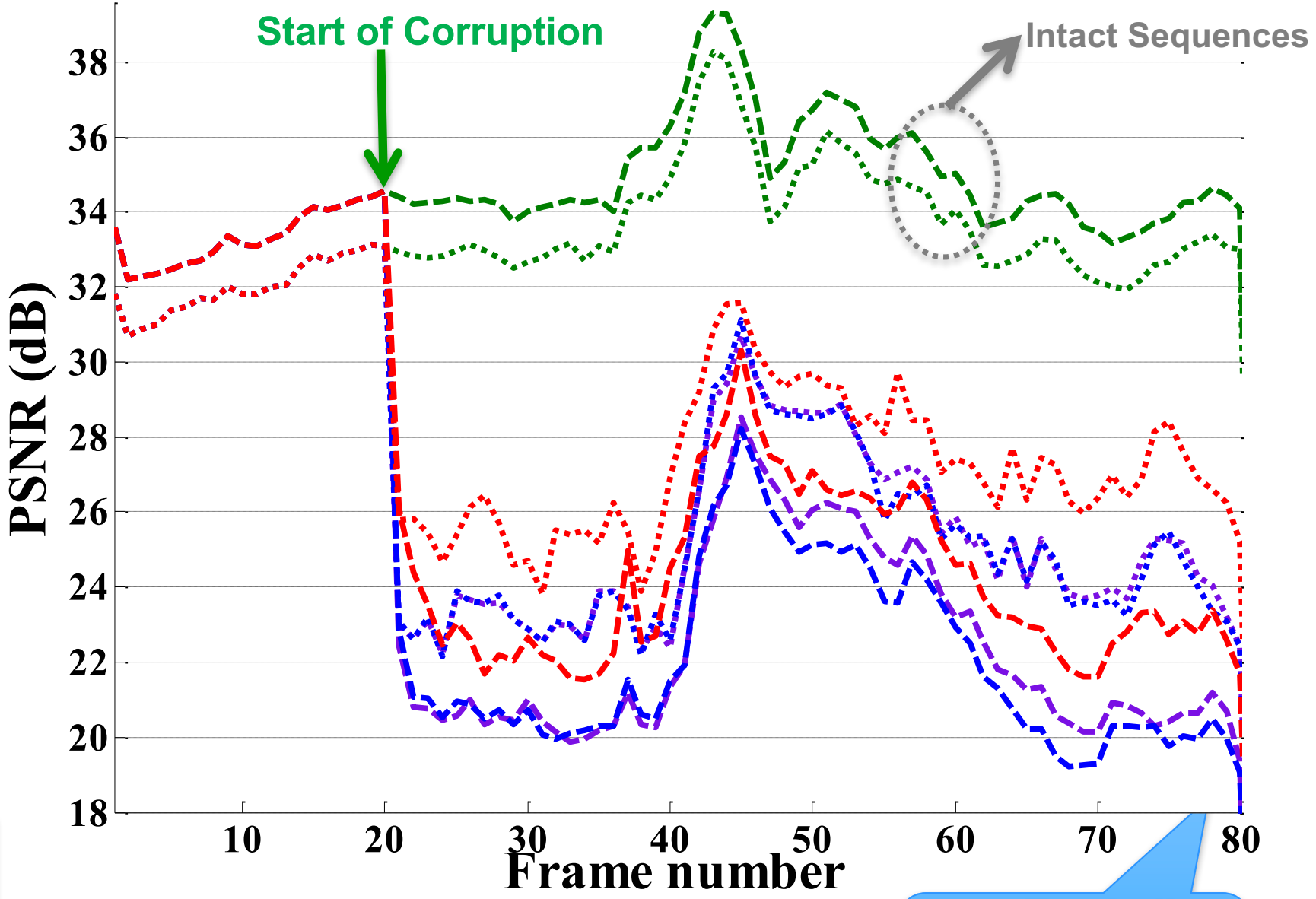
PSNR vs Frame number



Football
Bit Rate=336kbps
SNR=6 (dB)
BER=5×10^{-5}

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Conclusions

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❑ Coding Option :

Non Error Resilience

Random Intra MB Updating

Weighted Error Resilience

❑ Decoding Option :

Frame Copy Error Concealment

Spatio Temporal Boundary Matching

Maximum Likelihood Decoding

On average, the interaction of **weighted** error resilience and **MLD :**

- **2 dB** gains over **FC**
- **1 dB** gains over **STBMA**

→ *with the same weighted error resilience*

- **10 dB** gains over FC with non-error resilience

❑ Future step:

The SEs related to the residuals are not modeled in MLD, we expect this combination to perform even better when the SEs are modeled in future research studies.

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