Rate-Distortion control for H.264/AVC in video compression systems with memory restriction

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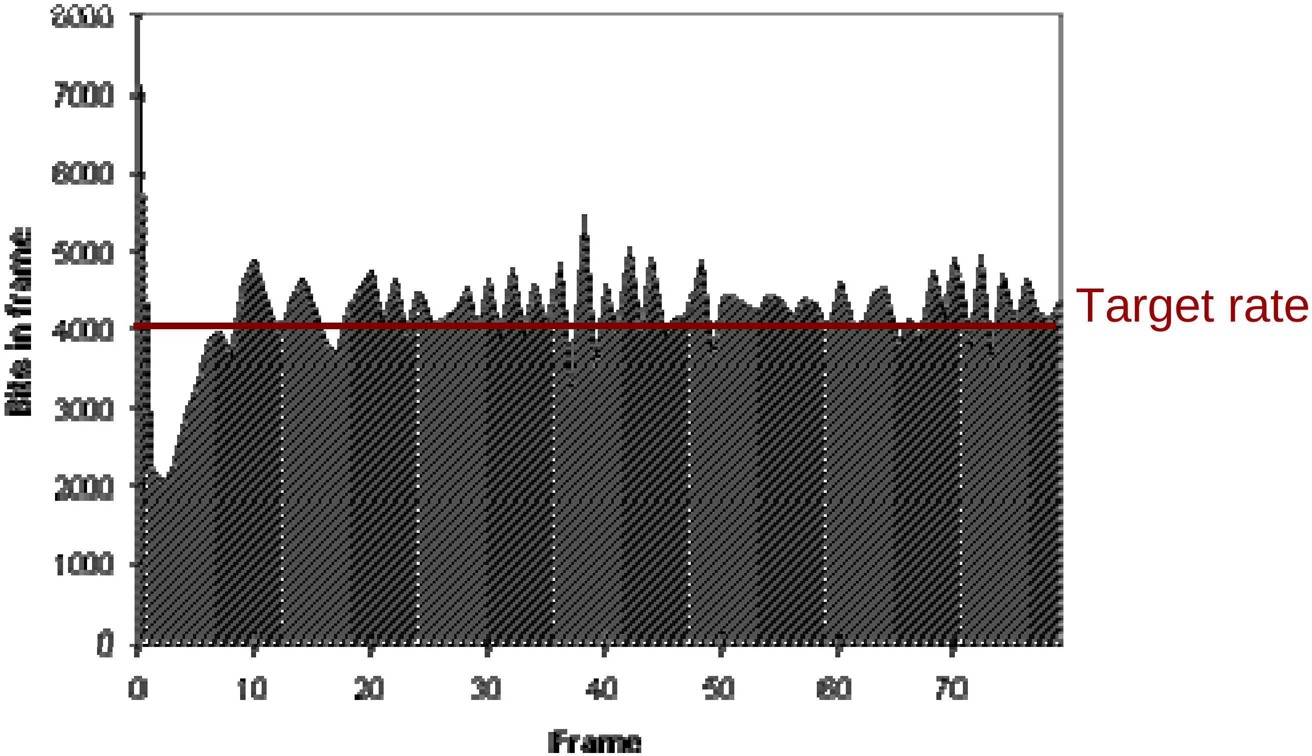
Rate Control

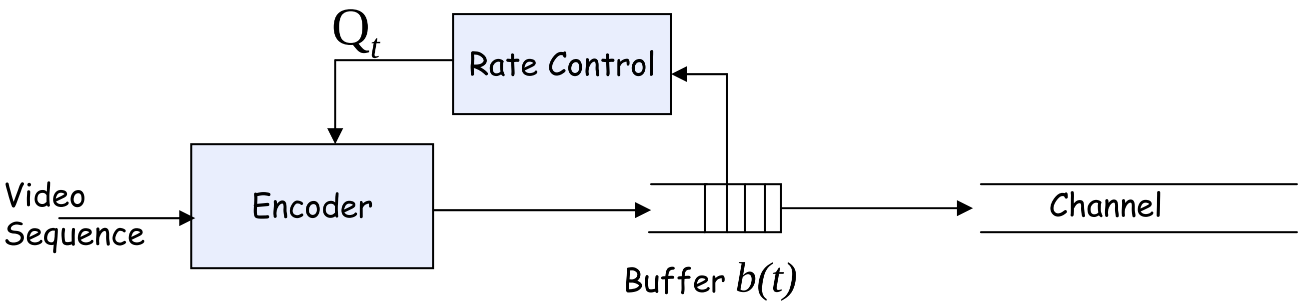
Rate control guarantees that the resulting image size is not higher than the given threshold value



Rate control mechanism is required to map varying encoder output bit rate onto the constant bit rate channel

Rate Control algorithm in H.264

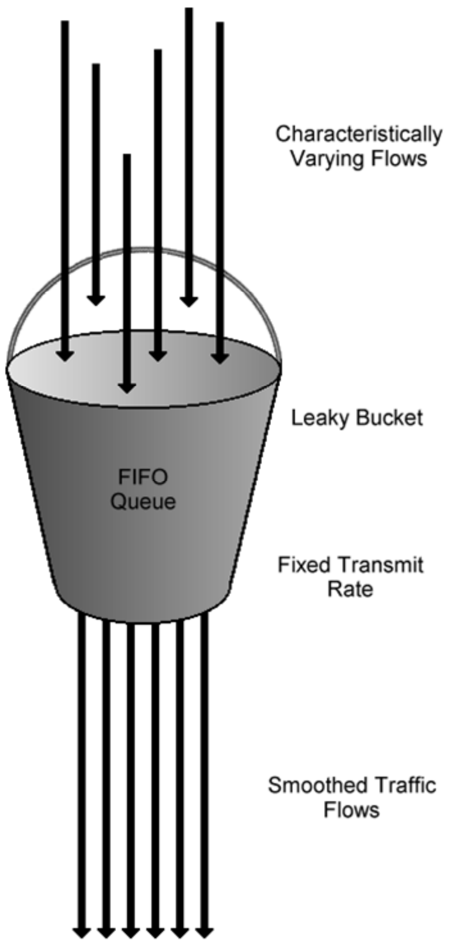
Main idea: choose Q_t so that $b(t) \approx B'$



Problem: $r(Q_t)$ can't be computed in advance before encoding and can be only predicted

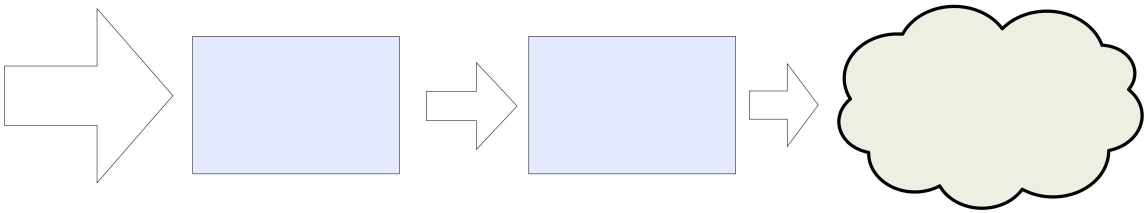
- Buffer filling up
  - the **quantization step size** in the encoder is increased which increases the compression factor and reduces the output bit rate
- Buffer starts to empty
  - the **quantization step size** is reduced which reduces compression and increases the output bit rate

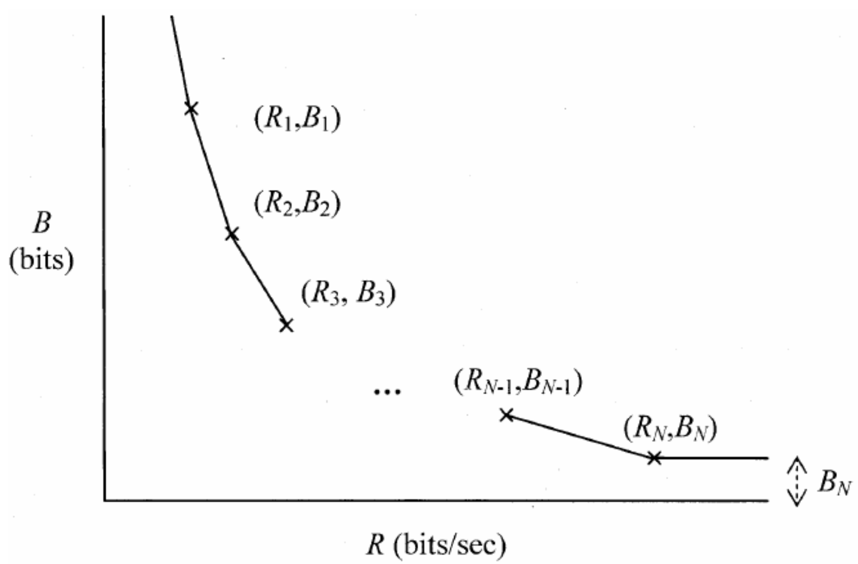
Hypothetical Reference Decoder



A **leaky bucket** is a direct metaphor for the encoder's buffer

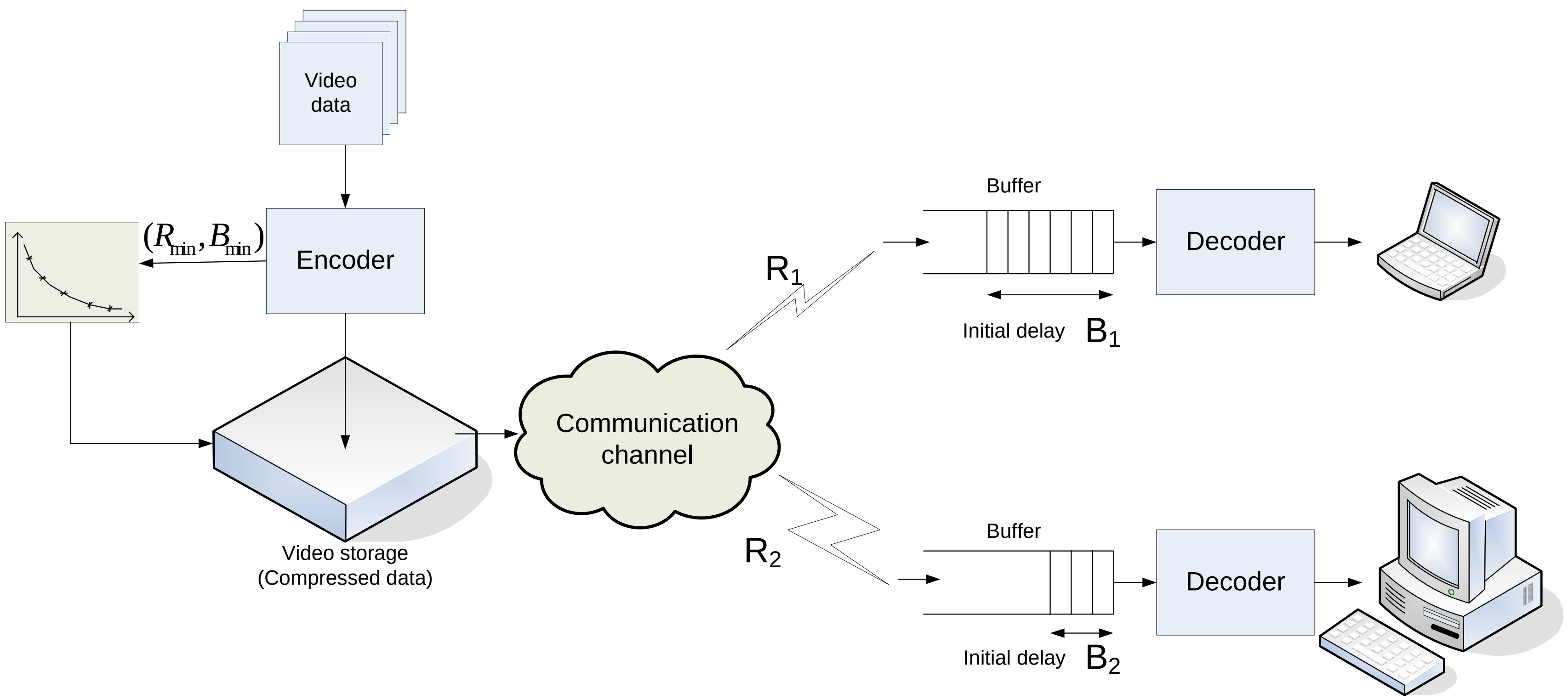
Hypothetical reference decoder of a given buffer size should decode the video bit stream without suffering from buffer overflow or underflow





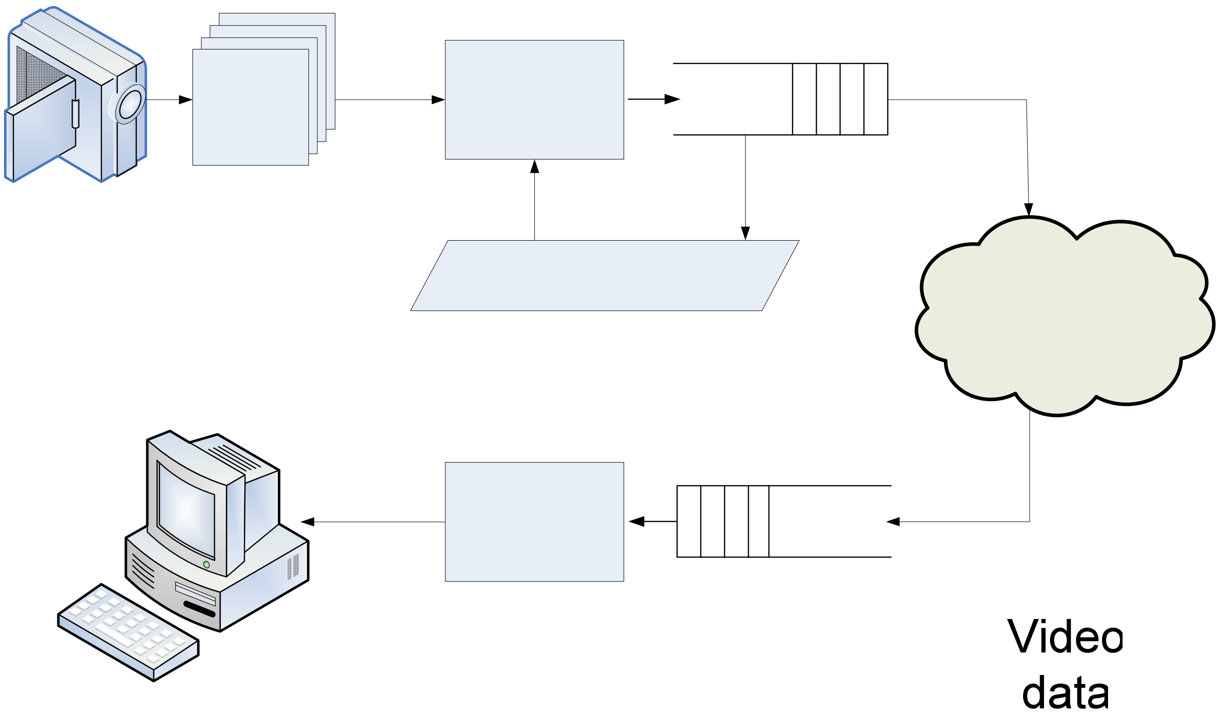
Transmission system with preliminary compression

Depending on the channel rate decoder chooses the initial start-up delay according to the information about pairs (R_{min}, B_{min}) received from the encoder



$$R_1 < R_2 \;\Rightarrow\; B_1 > B_2$$

Real-time compression and transmission system



$$b(t) = \max\{0, b(t-1) - r\} + r(Q_t),$$

where $b(t)$ – number of bits in the buffer at time moment t,

r – channel rate

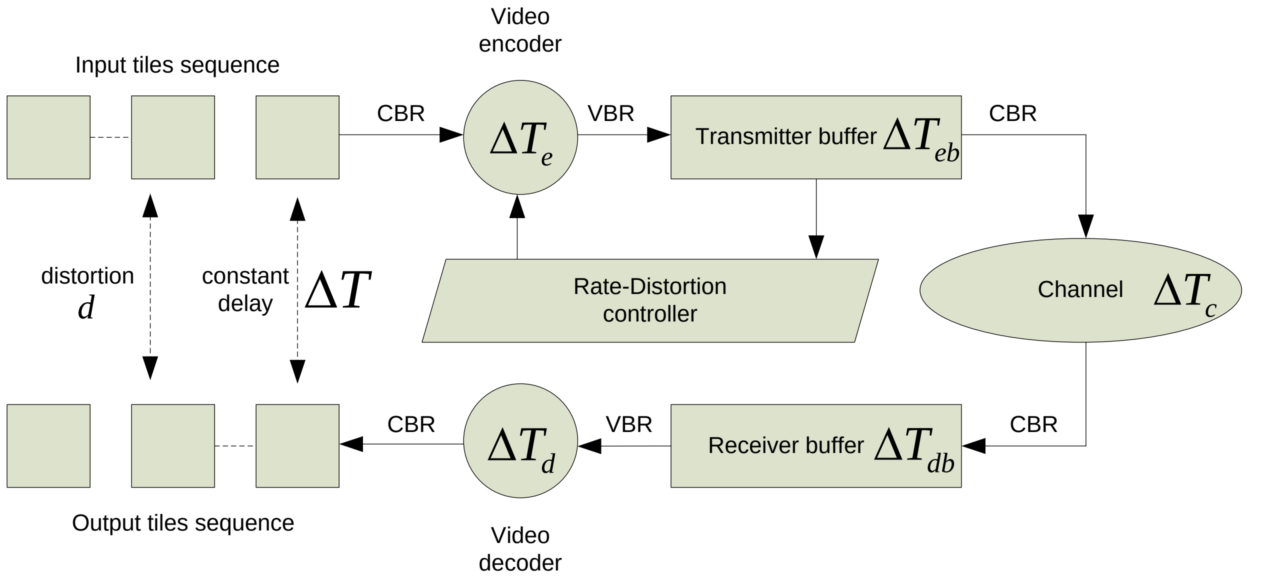
Problem statement

- System of video compression and transmission (based on H.264/AVC)
  - small memory consumption at transmitter/receiver (256x16)
  - single video frame 1024x768, 25 Fps

Resume: No motion compensation, only Intra frames

Goal: provide the acceptable level of quality for video sequence for a given channel throughput

Delay requirements



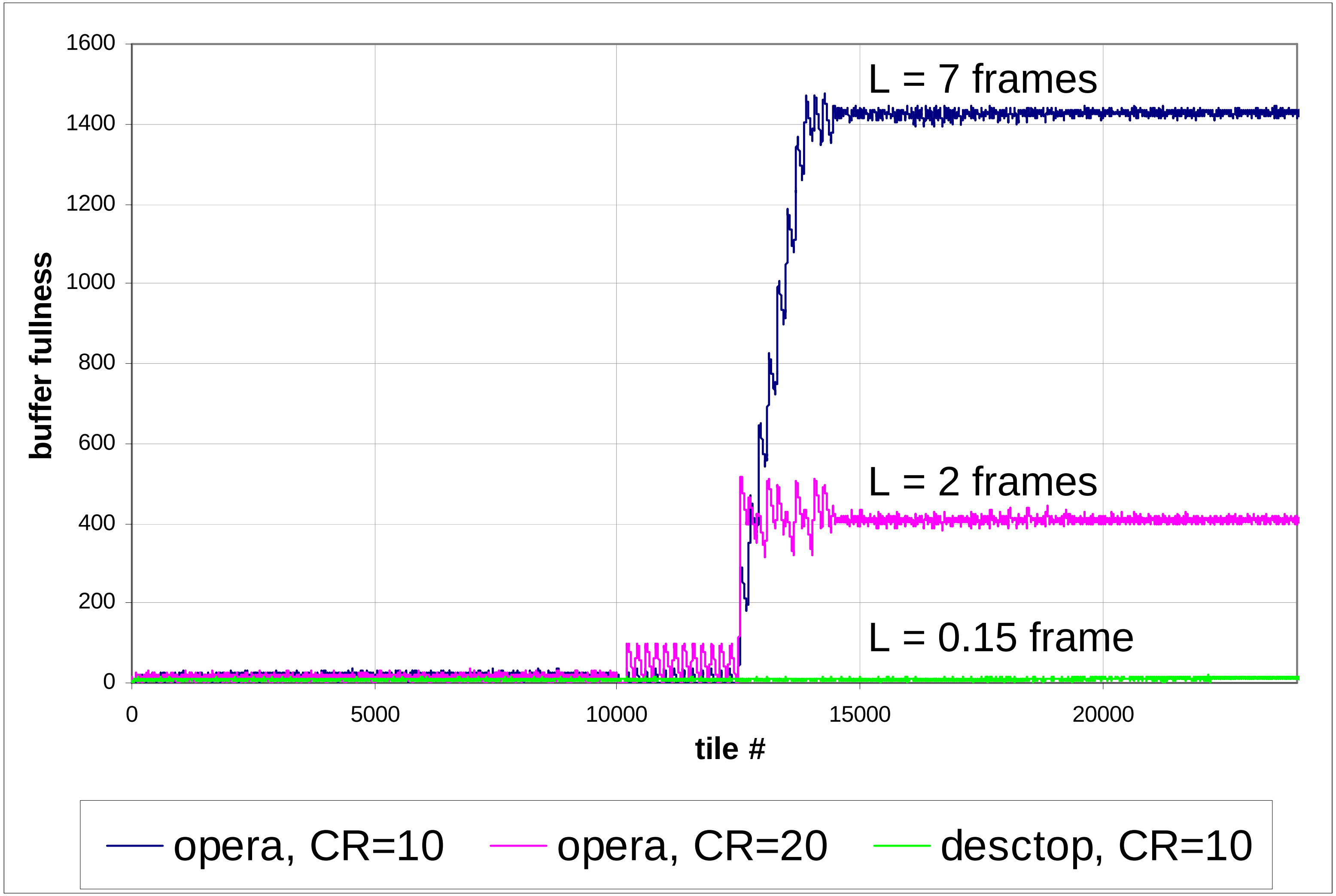
$$\Delta T = \Delta T_e + \Delta T_{eb} + \Delta T_c + \Delta T_{db} + \Delta T_d$$

$$\Delta T_e = \Delta T_d = \frac{1}{Fps \cdot N}$$

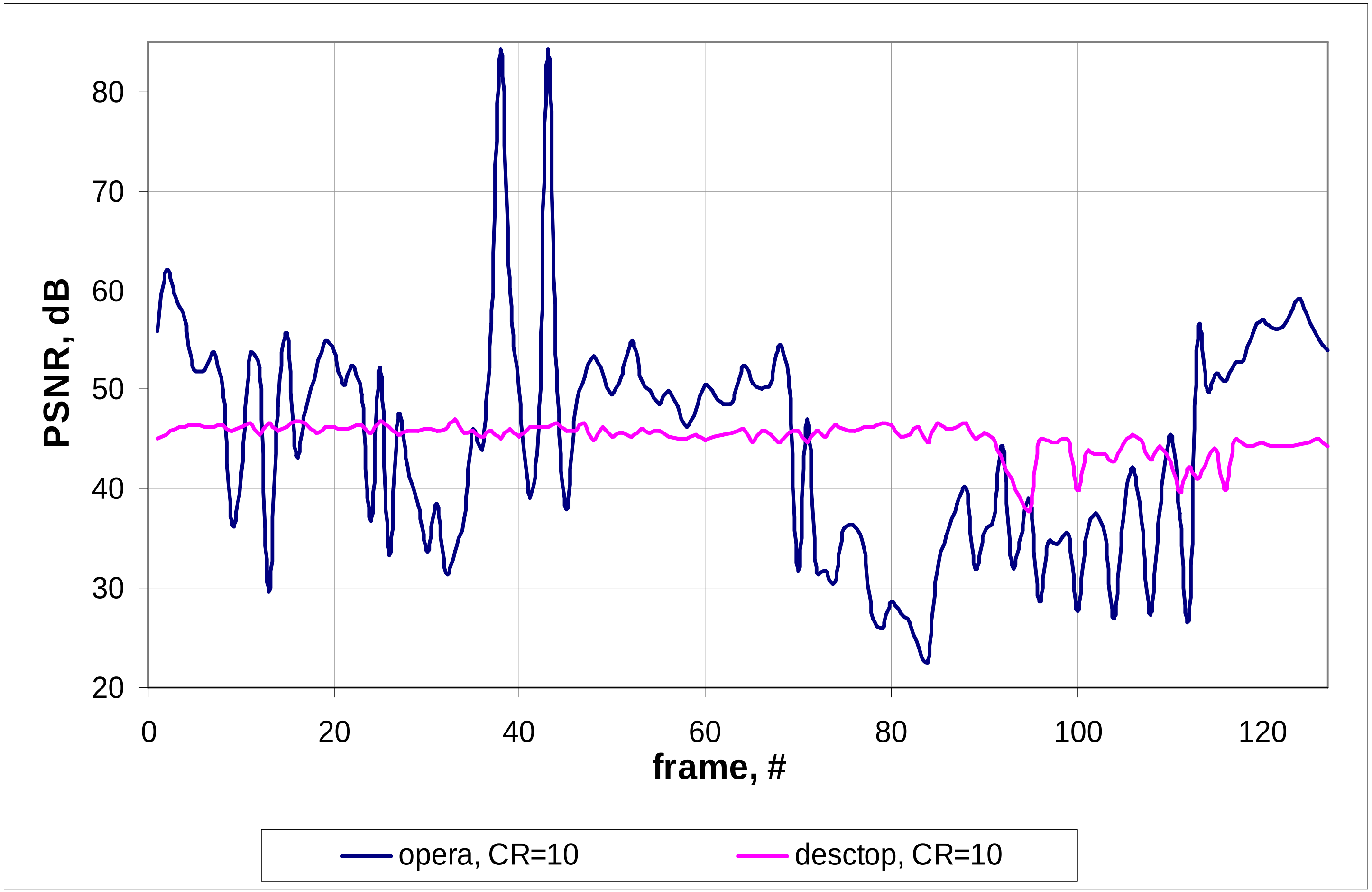
$$\Delta T_{eb} + \Delta T_c + \Delta T_{db} = L$$

$$\begin{cases} B^e{}_{\max} = B^d{}_{\max} = L \cdot r \\ b^e(t) \le B^e{}_{\max} \end{cases}$$

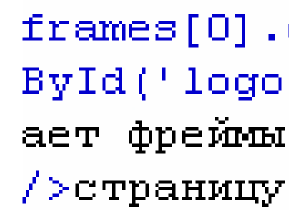
Delay values for H.264



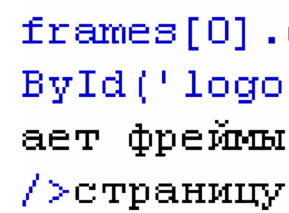
PSNR fluctuations for H.264



25 dB



55 dB



original

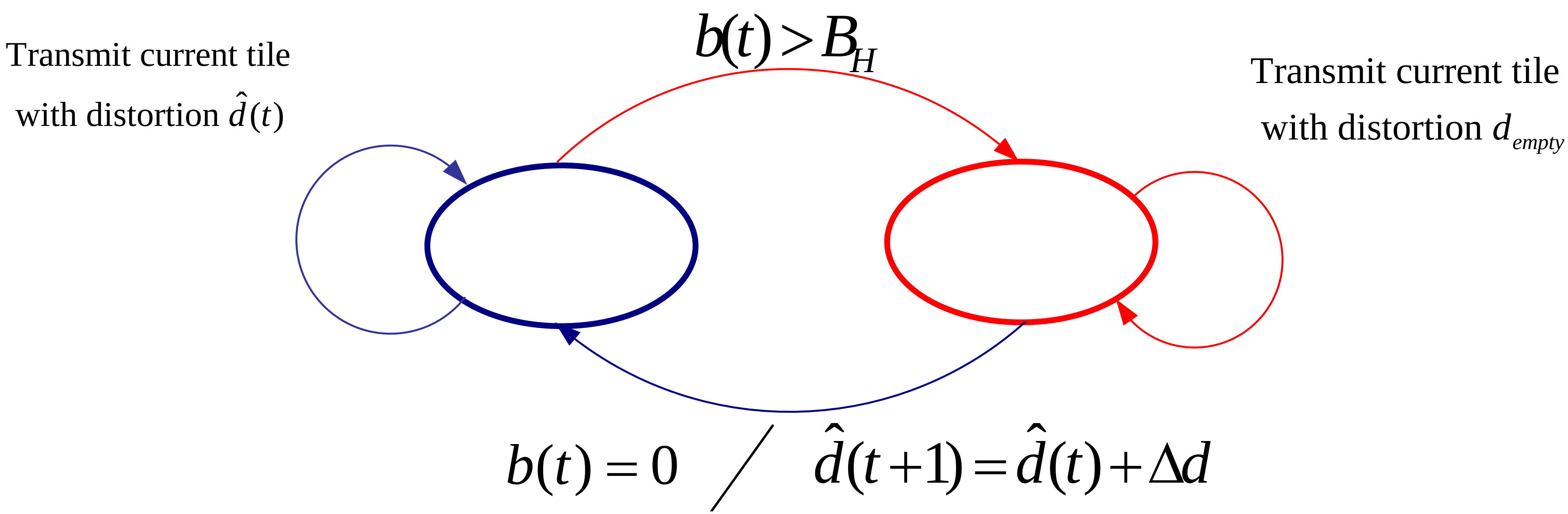
Proposed RD-control

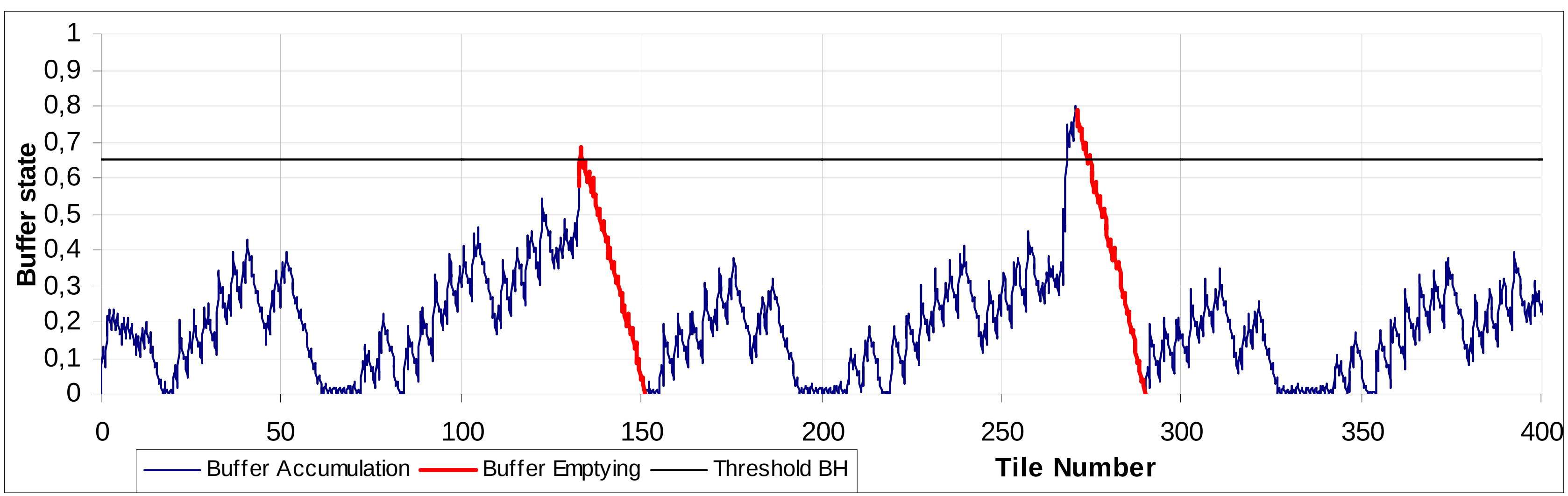
Optimization task (for all tiles):

$$\begin{cases} minimize \max\limits_{t} d(Q_t) \\ b(t) \le B_0 \end{cases},$$

where $b(t) = \max\{0, b(t-1) - r\} + r(Q_t)$,

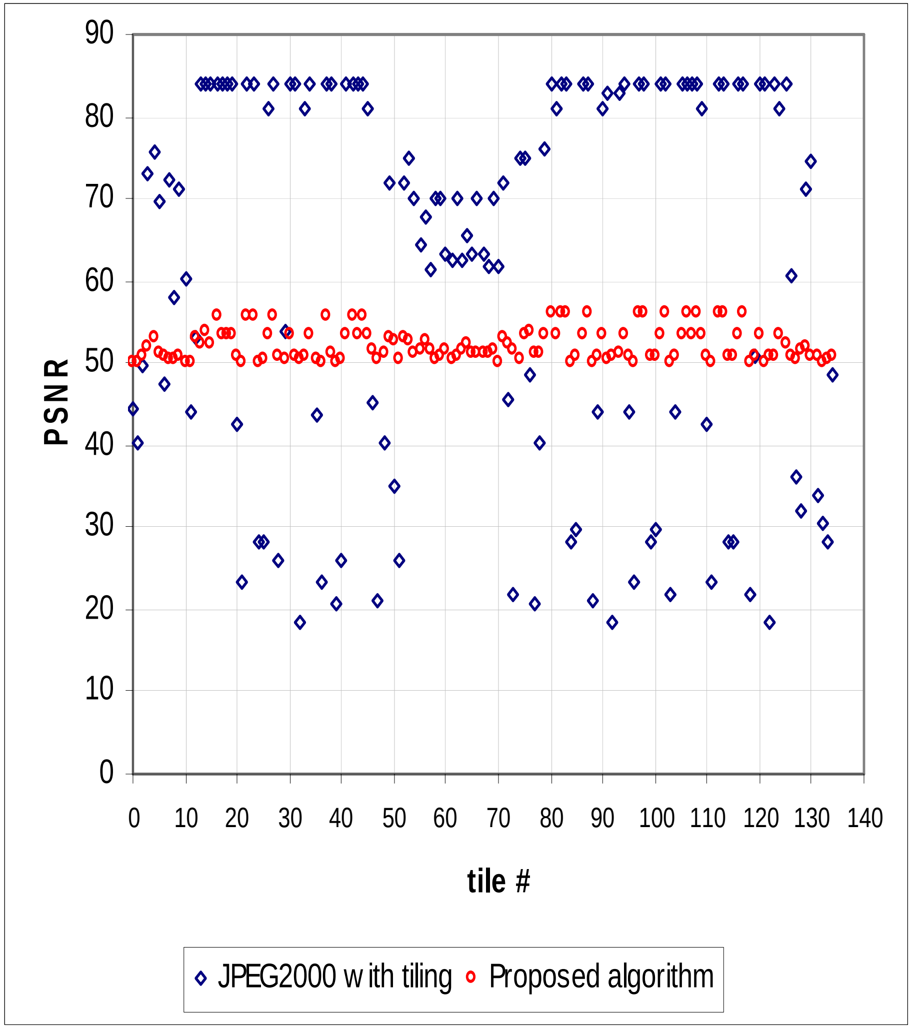
Proposed algorithm



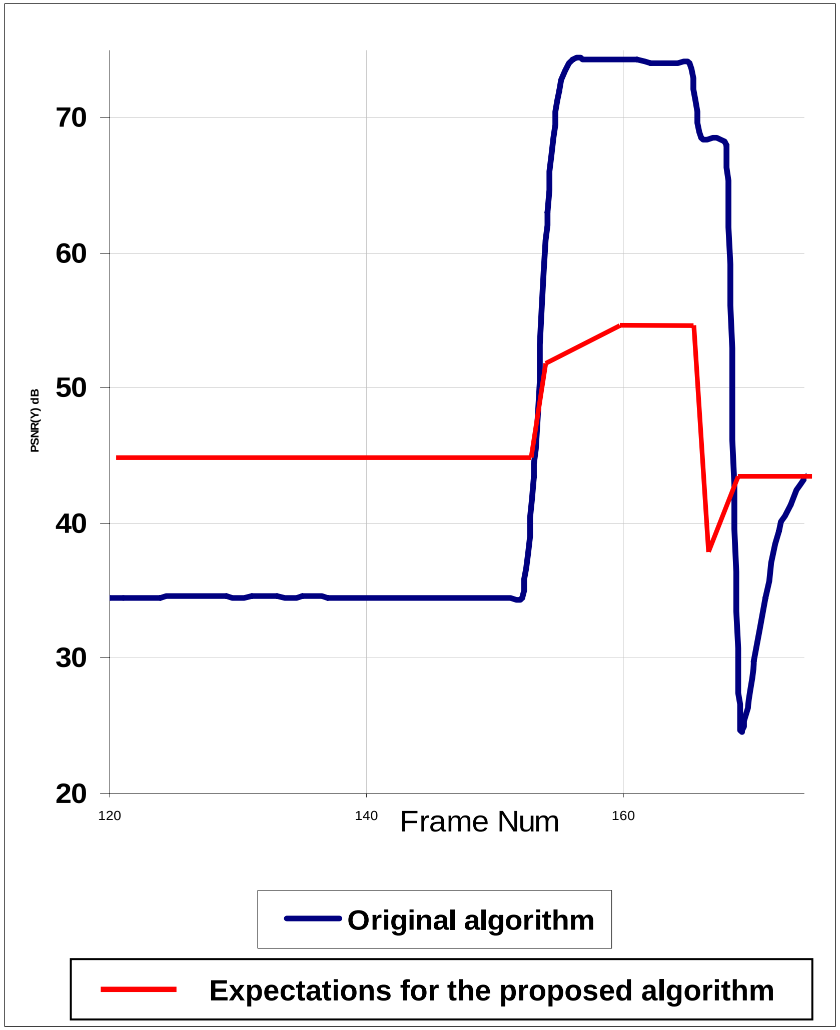


Original vs. proposed algorithms

JPEG2000



H.264/AVC



Summary

- H.264 original Rate Control algorithm is good for transmission scheme with preliminary compression

- For real-time compression and transmission another approaches should be used

Other papers on this theme

- *F. Jelinek*, “Buffer Overflow in Variable Length Coding of Fixed Rate Sources”, IEEE Transactions on Information Theory, vol. IT-14, No. 3, May 1968
- *A.R. Reibman,* “Constraints on Variable bit-rate Video for ATM Networks”, IEEE Transactions on circuits and systems for video technology , vol.2, No. 4, December 1992
- *C.-Y. Hsu, A. Ortega, M.Khansari* , “Rate Control for Robust Video Transmission over Burst-Error Wireless Channels”, IEEE Journal on Selected Areas in Communications, vol. 17, No. 5, May 1999