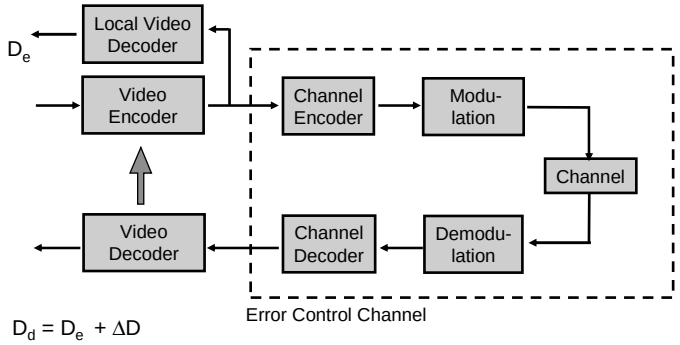
Video Transmission

- Transmission of Hybrid Coded Video
- Error Control Channel
- Motion-compensated Video Coding
- Error Mitigation
- Scalable Approaches
- Intra Coding
- Distortion-Distortion Functions
- Feedback-based Error Control

Transmission of Hybrid Coded Video



$D_d = D_e + \Delta D$

$PSNR_d = PSNR_e - \Delta PSNR$ (PSNR = 10 log(255^2/D) [dB])

How do system components interact?

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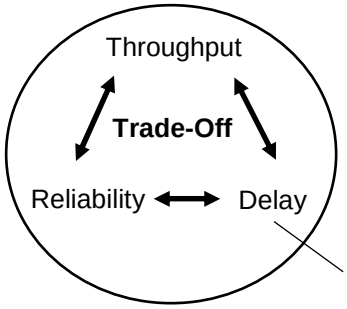
Error Control Channel

- Combination of
  - Channel codec
  - Modulation
  - Channel
- Interface to video codec



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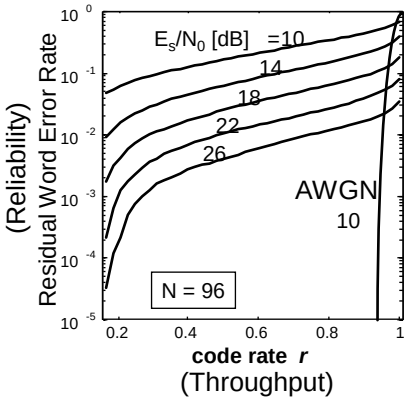
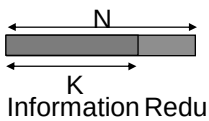
Low (RTD<250 ms) for conversational services

AWGN and Rayleigh Channel





Information Redundancy

Code Rate ***r*** = K/N

Rayleigh fading channel,
Jakes Doppler spectrum,
f_c = 1.9 GHz,
$f_{Doppler}$ = 62 Hz,
BPSK modulation,
80 kbps,
RS codes,
8 bit symbols

- **Code rate *r*** controls bit allocation between source and channel coding
- Trade-off reliability vs. throughput depends on ECC

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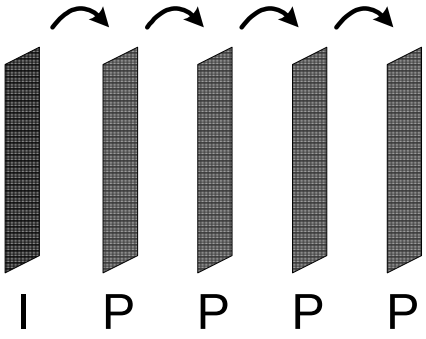
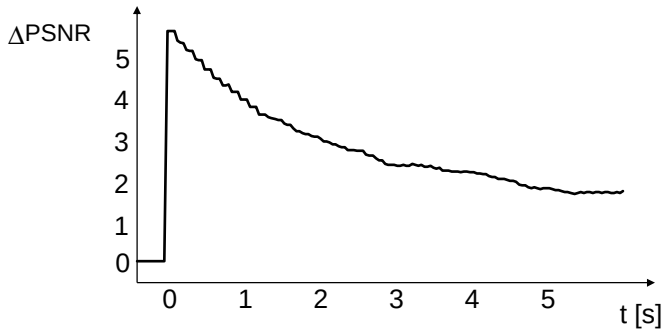
Motion-Compensated Coding of Video



- If just one frame is missing ➔ reference pictures at coder and decoder differ ➔ error propagation
- Error decays slowly ➔ mitigate error propagation

Recovery from Single Burst



- Single burst covering 1/3 of a frame
- Previous frame concealment
- Average over many trials
- No Intra

From: Färber

Temporal Error Propagation

- 1 picture = 1 packet
- 10 % packet loss probability

Sources of Bad Video at the Decoder

- Source coding distortions
  - Not enough bit-rate available for targeted spatio-temporal resolution
  - Large activity in the video signal
  - Many scene cuts
- Transmission errors and throughput variation
  - Channel noise
  - Fading
  - Cell overload and variations

Set source coding and transmission system parameters for best decoder video quality given the application constraints

Applications and Constraints

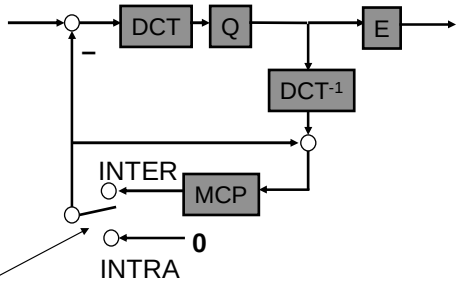
- Conversational vs. non-conversational services
- Unicast vs. multicast: single vs. multiple possibly heterogeneous transmission conditions
- Delay constraints:
  - 250 ms RTT for conversational services
  - ≈ 2-3 s or more play-out delay for unicast streaming
  - ≈ 0.5 s for multicast streaming
- High vs. low bit-rate coding: source coding performance
- Off-line vs. on-line encoding: adaptation possibilities
- Feedback: with or w/o per picture or statistical feedback

Videoconferencing: On-line Encoding, Low Delay

- Conversational services:
  - Low bit-rates (< 100 kbit/s): QCIF/CIF pictures @ 10/15 Hz
  - Low RTT < 250 ms corresponding to 2-3 picture intervals
- Methods for improvement
  - Reduce number of errors
    - **Increased FEC**: decreases source bit-rate/quality
    - No retransmissions possible
  - Mitigate impact of errors
    - **Concealment** of lost pictures
    - **Intra** block coding: stop temporal error propagation
    - **Multi-frame prediction** from acknowledged references
    - Intra-picture **scalability: syntax** (spatial, SNR)

Video Encoder

- Hybrid video coding is the most successful compression scheme and used in all current standards (MPEG-1/2/4, H.261, H.263, H.264/AVC...)
- Motion-compensated prediction provides efficiency
- Transform coding of prediction error
- INTRA/INTER mode decision on block basis (INTRA rate β)



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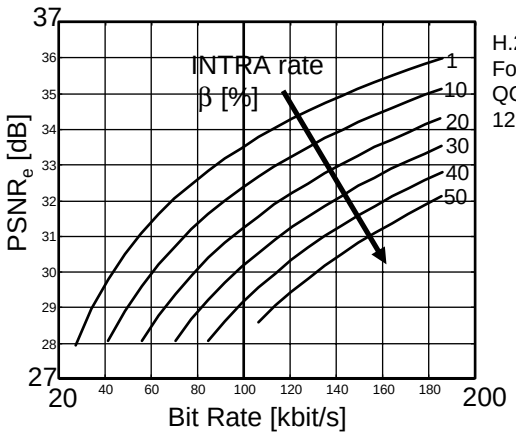
Rate-Distortion Performance



H.263 baseline
Foreman
QCIF
12.5 fps

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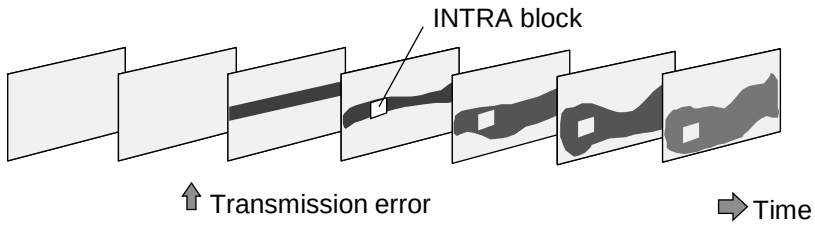
Video Decoder

- MCP causes spatio-temporal error propagation in case of a transmission error
- Resynch. and error concealment of limited help
- INTRA coding helps but reduces coding efficiency
- Loop filter introduces leakage



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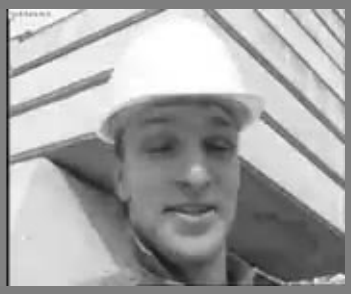
Error Resilience: MPEG-4 vs. H.264/AVC

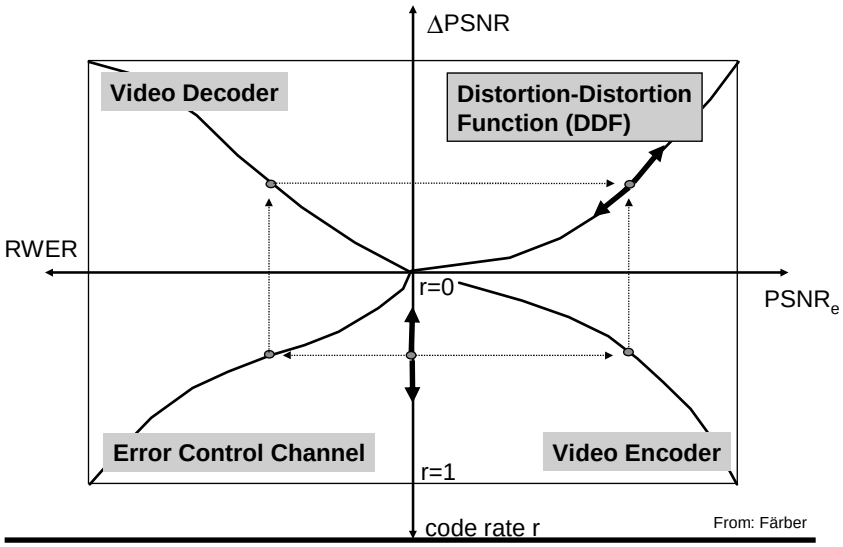
10 % Packet loss, 20 % of each picture Intra coded

MPEG-4 ASP @ 64 kbit/s
10 Hz, QCIF

H.264/AVC @ 64 kbit/s
10 Hz, QCIF



Interaction of System Components



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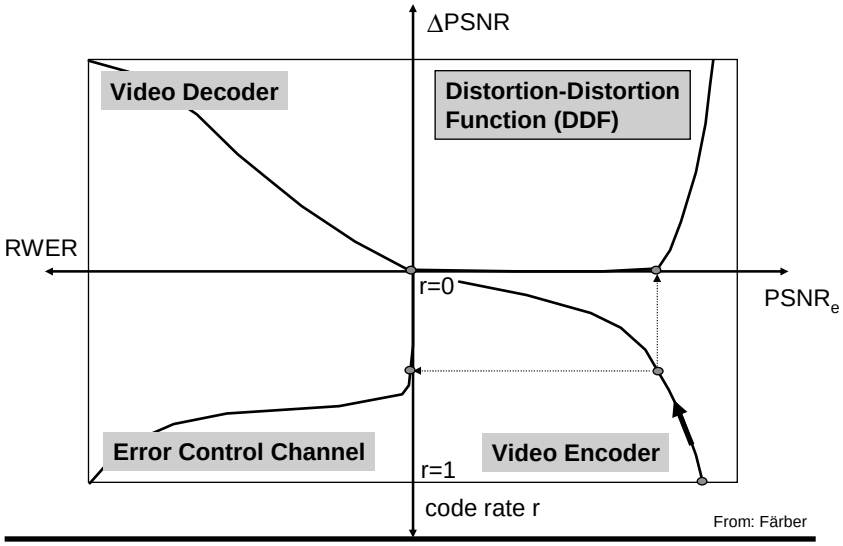
When Channel Coding Does the Job



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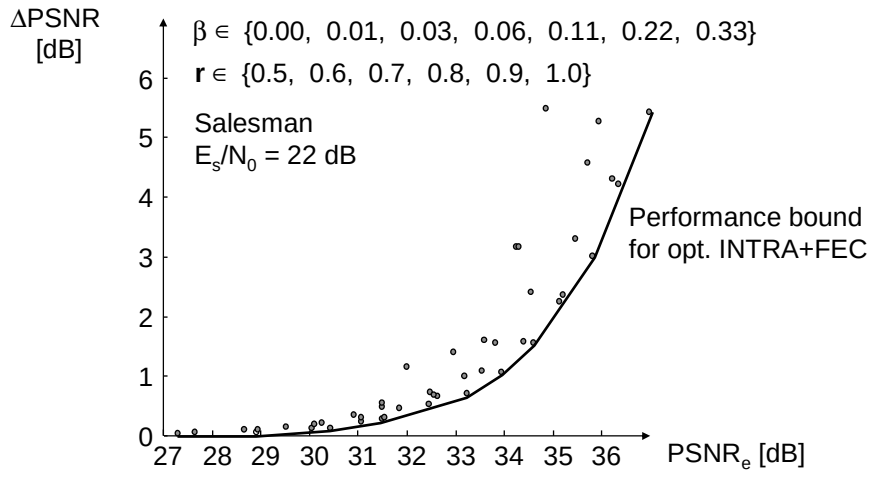
Performance Bound for INTRA+FEC



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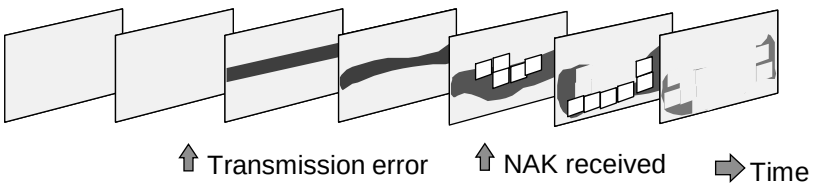
Feedback-Based Error Control

- Spatio-temporal error propagation can be reconstructed at the encoder using an Error Tracking algorithm and **feedback** from the decoder
- Feedback consists of sending Negative Acknowledgements (NAKs) for lost image parts
- Use INTRA-mode for macroblocks affected by transmission errors to stop error propagation



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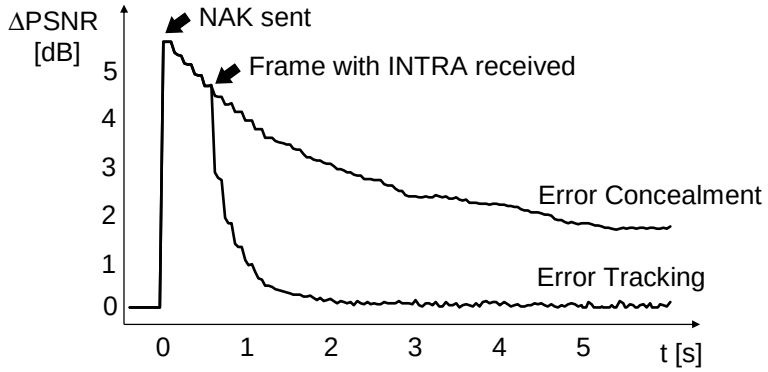
Recovery from Single Burst



- Same conditions as above
- 700 ms RTD

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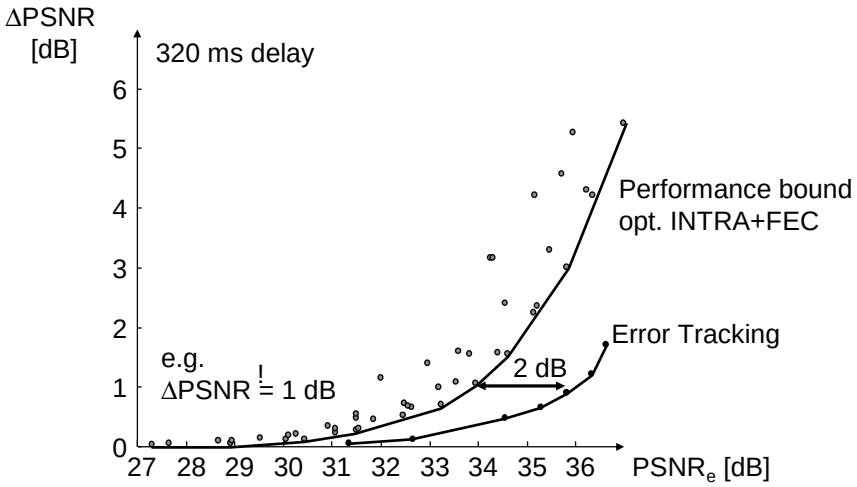
Comparison of DDFs



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Demo

- Sequence: Salesman, frames 0-300, 15 fps
- Rayleigh Fading, E_S/N_0 = 22 dB, f_D = 62 Hz
- FEC block size: 88 byte (1 GOB)
- BPSK, f_c = 1900 MHz, 80 kbps

High error resilience Low coding efficiency β = 33/99 r = 48/88 $PSNR_e$ = 26.8 $PSNR_d$ = 26.7 ΔPSNR = 0.1	High coding efficiency Low error resilience β = 1/99 r = 88/88 $PSNR_e$ = 37.2 $PSNR_d$ = 28.8 ΔPSNR = 8.4
Max PSNR at decoder (Good compromise) β = 6/99 r = 72/88 $PSNR_e$ = 34.3 $PSNR_d$ = 32.7 ΔPSNR = 1.6	Error Tracking τ = 3 r = 72/88 $PSNR_e$ = 35.6 $PSNR_d$ = 34.5 ΔPSNR = 1.1

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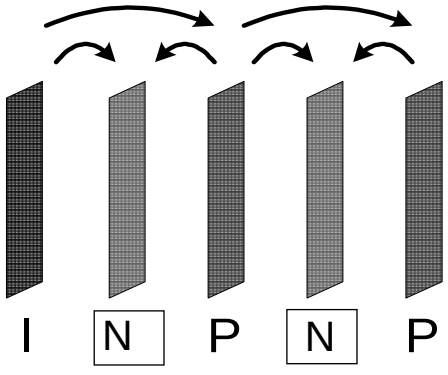
Video Streaming: Off-line Encoding, High Delay

- Wireless streaming services
  - Medium bit-rates (100-300 kbit/s): QCIF/CIF pictures @ 15/30 Hz
  - High delay ≈ 2-3 s corresponding to 30/60 – 45/90 pictures
- Methods for improvement
  - Reduce number of errors
    - **Retransmissions**
    - Inc. FEC (Multicast)

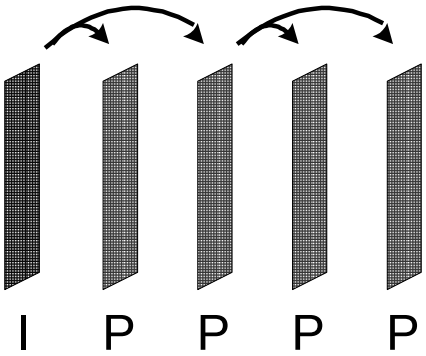
    } decrease source bit-rate/quality
    - Adjust source bit-rate to average throughput
  - Mitigate impact of errors
    - Inter-picture scalability: insertion of **non reference pictures**
    - Concealment and intra-picture methods of less importance

Temporal Scalability with B-Pictures



- non-reference pictures (N) maybe discarded
- Requires large delay
- Unequal protection

P-Picture with Switched Reference



- Every other P picture maybe discarded
- Rate-Distortion performance problems
- Unequal protection

Summary: Video Transmission

- Transmission of video requires consideration of source coding and transmission channel
- Transmission channel is often lumped into unit called: Error Control Channel
- In videoconferencing, transmission errors are often not avoidable
- Motion-compensated prediction leads to spatio-temporal error propagation if error concealment is applied at decoder
- Video encoder can be controlled to stop spatio-temporal error propagation
- Trade-off must be balanced considering the complete system
- Distortion-distortion functions evaluate trade-off
- Feedback provides improved performance
- In video streaming, channel coding (i.e. re-transmissions) and temporal scalability can do the job