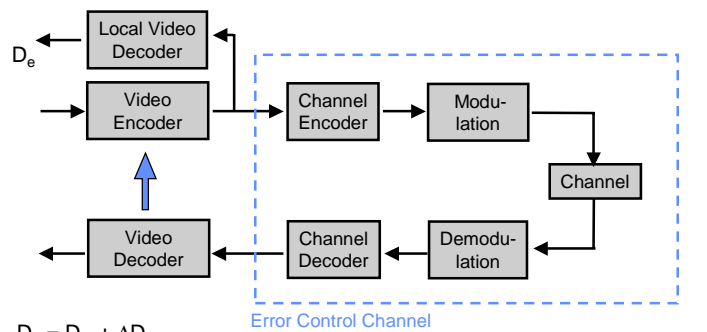# Video Transmission

- 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



$D_d = D_e + \Delta D$

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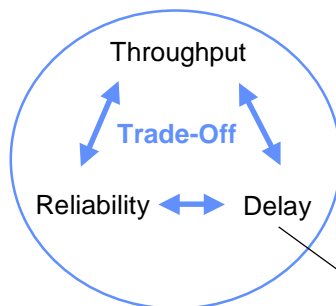
$(PSNR = 10 \log(255^2/D) \text{ [dB]})$

How do system components interact?

From: Färber

# Error Control Channel

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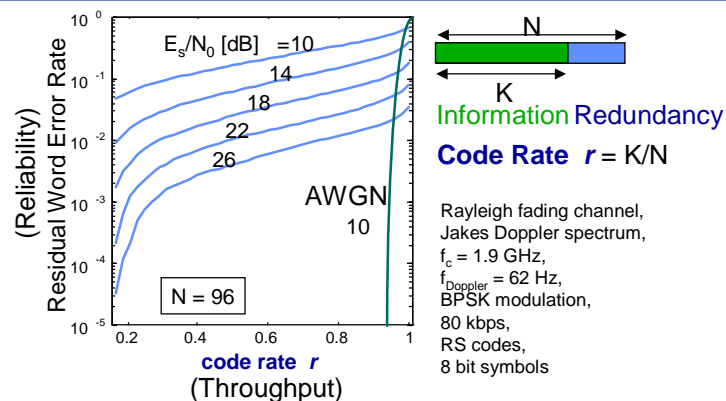  - Modulation
  - Channel
- Interface to video codec

Throughput

**Trade-Off**

Reliability ⟷ Delay

Low (RTD<300 ms) for conversational services

---

# AWGN and Rayleigh Channel

(Reliability)
Residual Word Error Rate

$E_s/N_0$ [dB]  =10
14
18
22
26

AWGN
10

N = 96

0.2   0.4   0.6   0.8   1

**code rate  r**
(Throughput)

N

K

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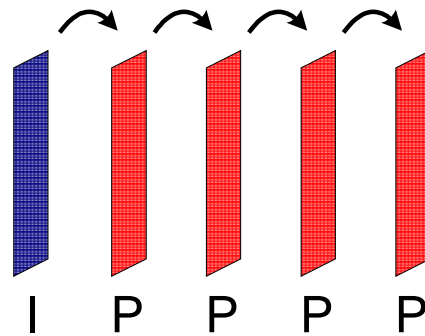
- **Code rate r** controls bit allocation between source and channel coding
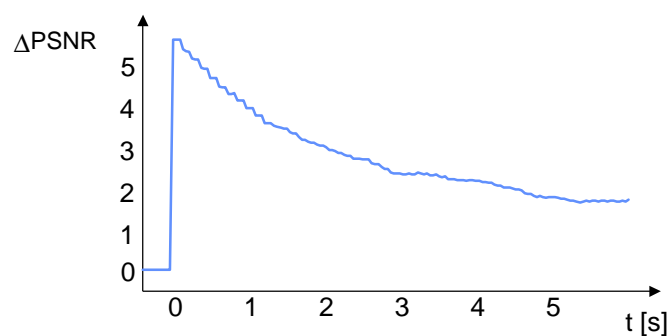- Trade-off reliability vs. throughput depends on ECC

# Motion-Compensated Coding of Video



I    P    P    P    P

- 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
  - $\approx$ 2-3 s or more play-out delay for unicast streaming
  - $\approx$ 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
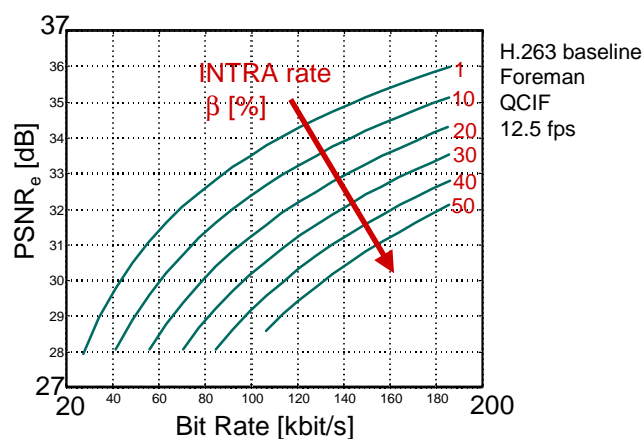    - Intra-picture **scalability: syntax** (spatial, SNR)

# 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.26L...)
- Motion-compensated prediction provides efficiency
- Transform coding of prediction error
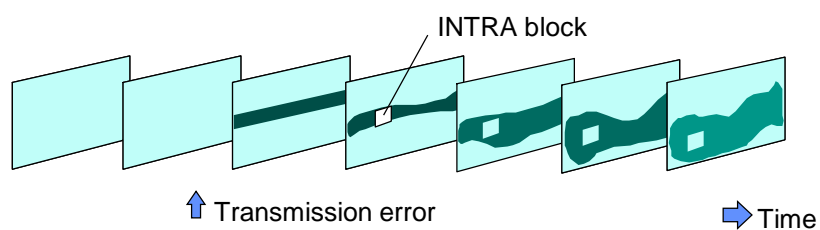- INTRA/INTER mode decision on block basis (INTRA rate $\beta$)
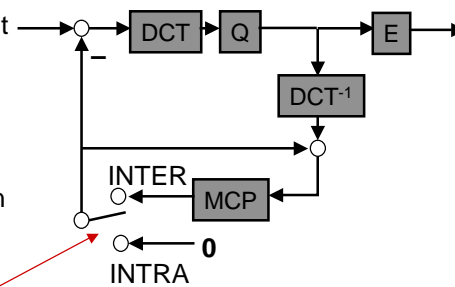
# Rate-Distortion Performance

# 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

INTRA block

⬆ Transmission error
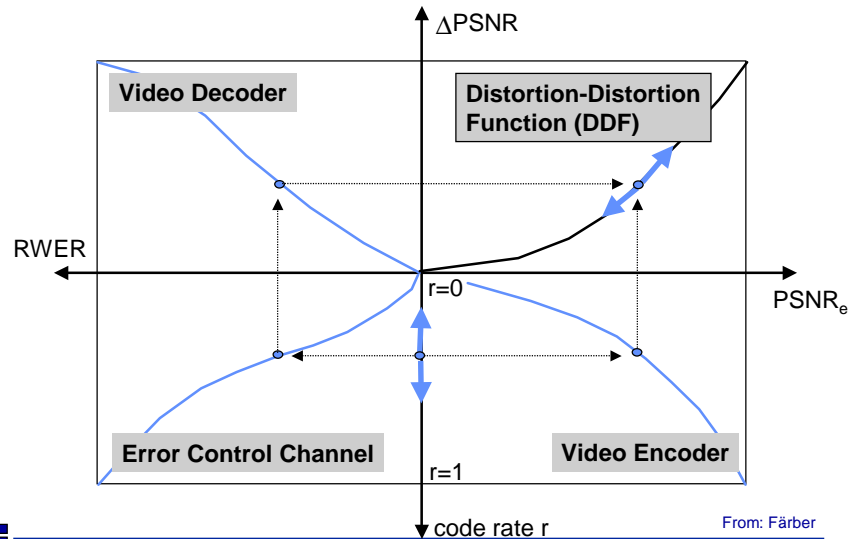
➡ Time

# Error Resilience: MPEG-4 vs. H.26L

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

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

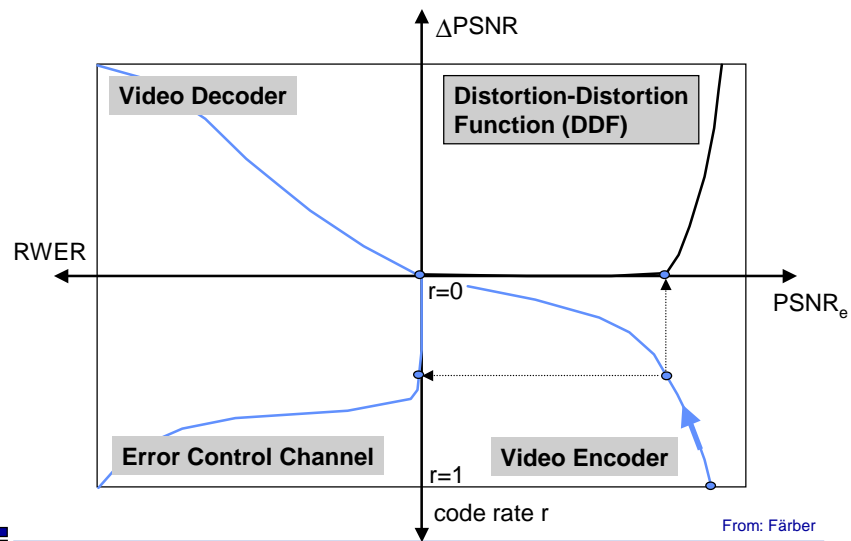H.26L @ 64 kbit/s
10 Hz, QCIF

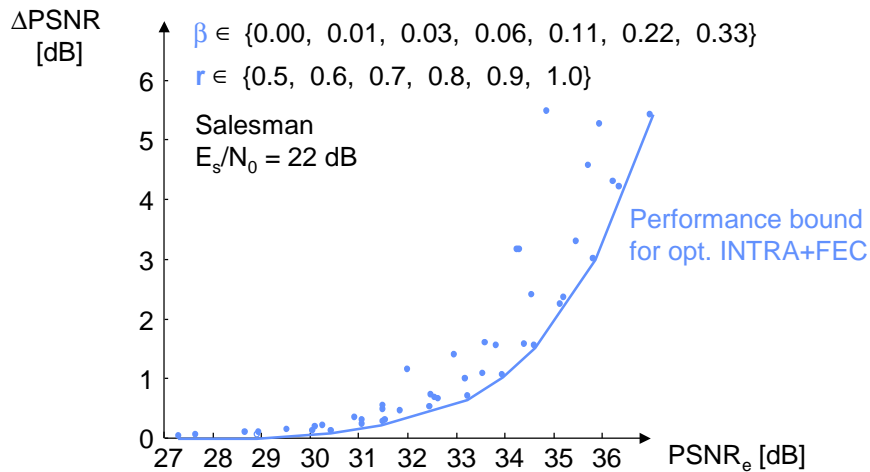# Interaction of System Components

From: Färber

# When Channel Coding Does the Job

From: Färber

# Performance Bound for INTRA+FEC

$\beta \in \{0.00,\ 0.01,\ 0.03,\ 0.06,\ 0.11,\ 0.22,\ 0.33\}$

$r \in \{0.5,\ 0.6,\ 0.7,\ 0.8,\ 0.9,\ 1.0\}$

Salesman
$E_s/N_0 = 22$ dB

Performance bound
for opt. INTRA+FEC

ΔPSNR [dB] (vertical axis)

$PSNR_e$ [dB] (horizontal axis)

# 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
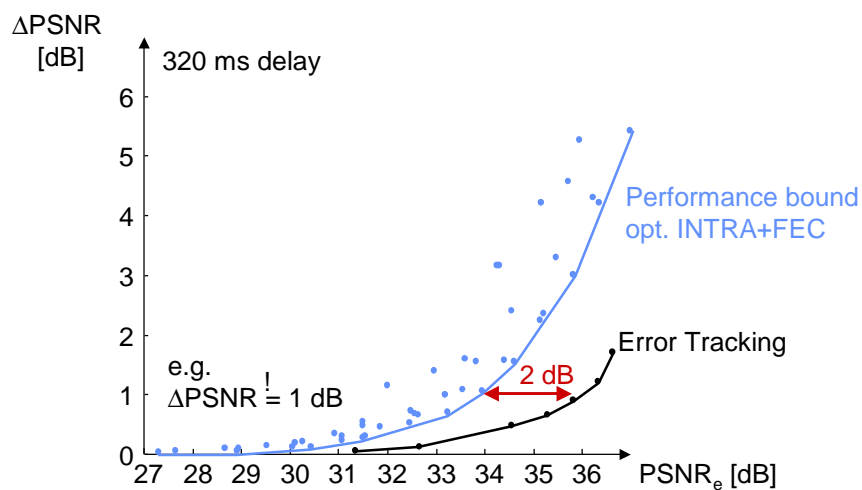- Use INTRA-mode for macroblocks affected by transmission errors to stop error propagation

⬆ Transmission error    ⬆ NAK received    ➡ Time
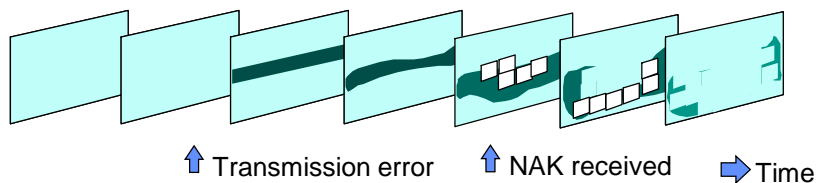
# Recovery from Single Burst
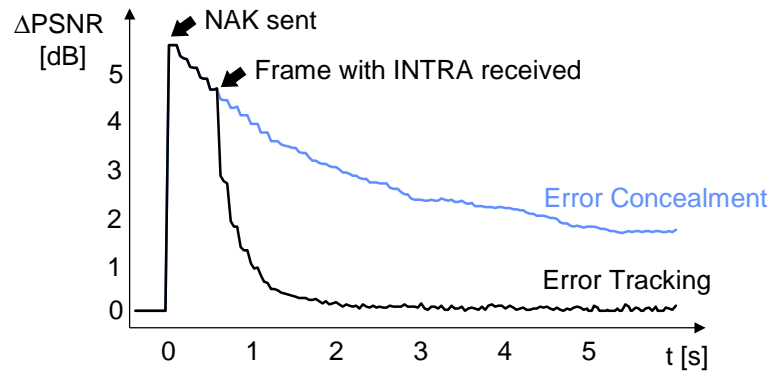


- Same conditions as above
- 700 ms RTD

# Comparison of DDFs

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

From: Färber

## 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 **B-pictures**
    - Concealment and intra-picture methods of less importance
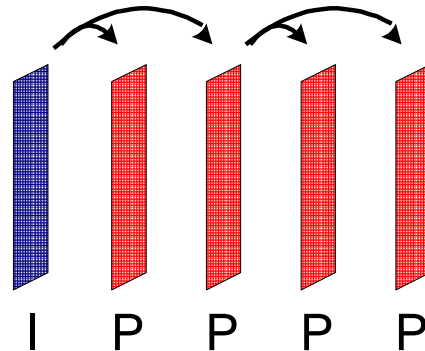
# Temporal Scalability with B-Pictures



I   B   P   B   P
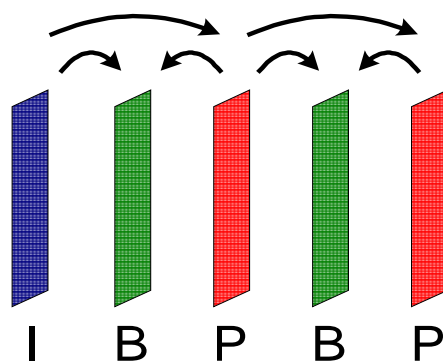
- B-pictures maybe discarded
- Requires large delay
- Unequal protection

# P-Picture with Switched Reference



I     P     P     P     P

- 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