Video Over Mobile Networks

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INTRODUCTION

- In the 20th century, visual communications via portable handsets were just in the science fiction movies!
- At the turn of the 21st century, it became a reality thanks to :
  - Larger bandwidth in the 3rd generation (3G) mobile networks and,
  - Advances made in very low bit rate video coding.

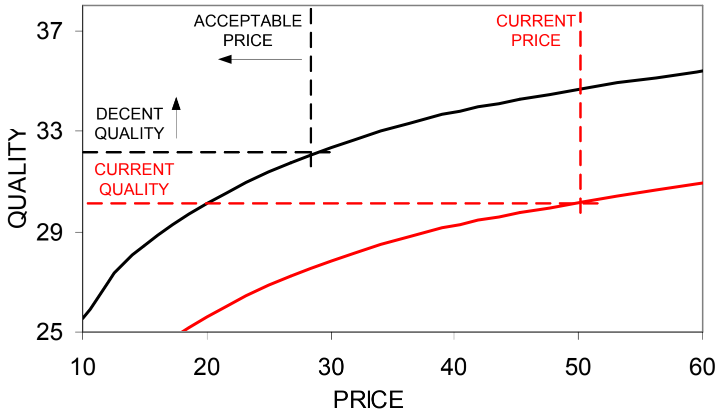
Background

- **3G: Third Generation**
  - Year: 2002
  - Service: Voice, Data, Video, Multimedia
  - System: Intelligent Signal Processing
  - Frequency: 1800-2200 MHz
  - Bandwidth: 128 kb/s – 2 Mb/s

Business View

- Unfortunately, 3G mobiles are NOT as successful as the 2G mobiles…. Why?
  - Mobile operators have paid too much for the licence but have not earned as expected.
  - The quality of service is LOW, the cost of operation is HIGHT.
  - Demand for video services is much less than the audio and text, but increasing.

Quality/Cost



CHALLENGES

- To deliver good quality of service, two main challenges in the wireless communication systems have to be dealt with:
  - Bandwidth Limitation
    - Wireless bandwidth is very scares

    (in contrast to almost unlimited optical bandwidth)
  - Channel Noise
    - Wireless channels are very prone to errors

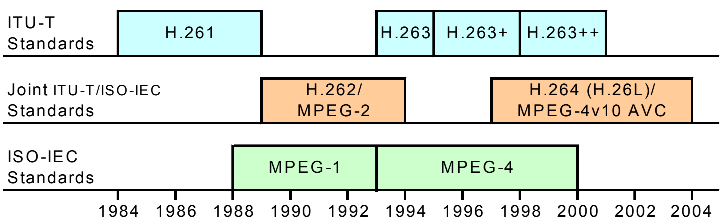
    (normal error rate 10^{-4}, compared to 10^{-12} for optical channels)

BANDWIDTH

- Video services are bandwidth and time thirsty
  - (larger bandwidth and longer duration)
- Video services should not occupy much larger bandwidth than the existing voice like services.
- Raw video services contain a huge amount of data:
  - Raw data rate of VHS quality video ≈37 Mb/s
- Therefore a sophisticated **Video Compression** tool is needed.

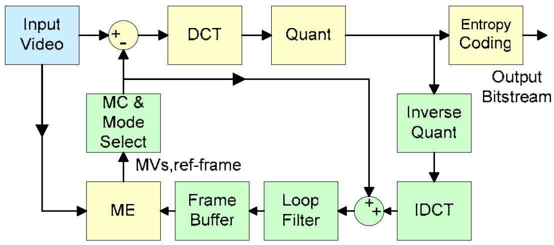
Video coding standards

- Over the past 20 years the Video Coding Experts Group (VCEG) of ITU-T and the Motion Picture Experts Group (MPEG) of ISO/IEC have standardized many video codecs for various applications.
- They have worked either independently or Jointly.



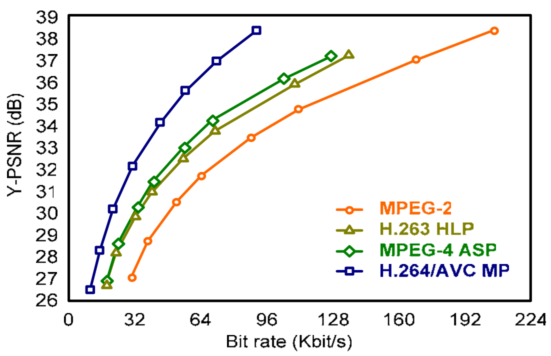
Overview of H.264/AVC

- H.264/AVC is the latest video codec standard of the Joint Video Team (JVT) of ITU-T VCEG and ISO/IEC MPEG.
- It follows the generic standard codec, i.e. DCT, MC, Entropy Coding, etc.



Compression efficiency

- H.264/AVC has achieved a significant improvement in compression efficiency over the previous standard video codecs.

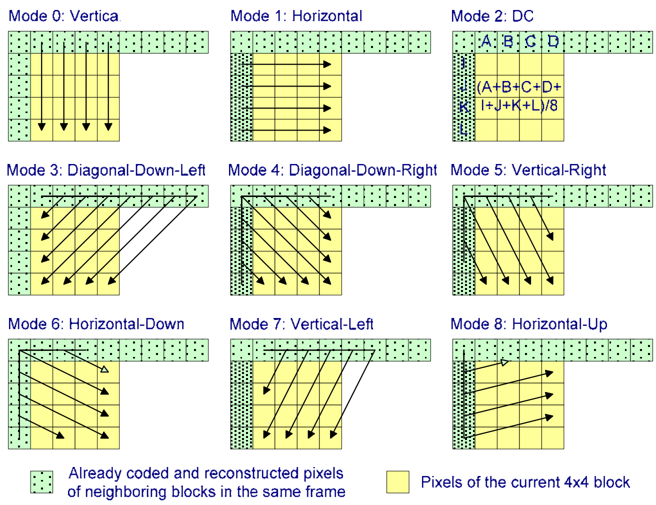


Foreman Test sequence, coded with four standard video codecs [Wiegand et al].

Features that make H.264 attractive

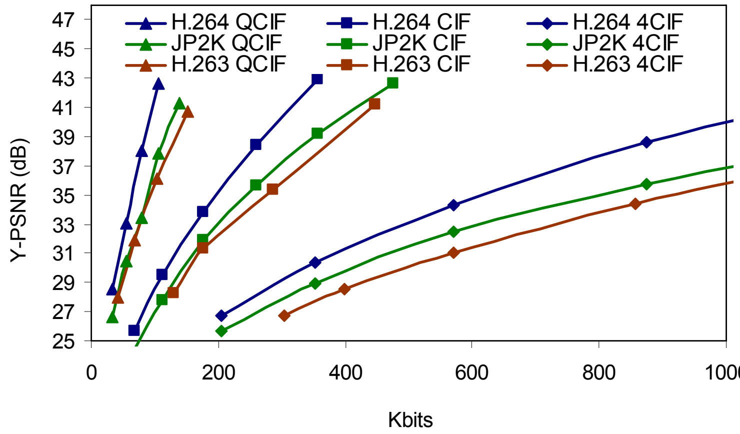
- 4x4 integer transformation
- Advanced **intra** prediction modes
- Context based adaptive binary arithmetic coding
- In-loop deblocking filter
- Advanced **inter** prediction modes
- Quarter sample motion vectors
- Multiple reference selection

Intra mode selection (4×4 intrapolation mode)

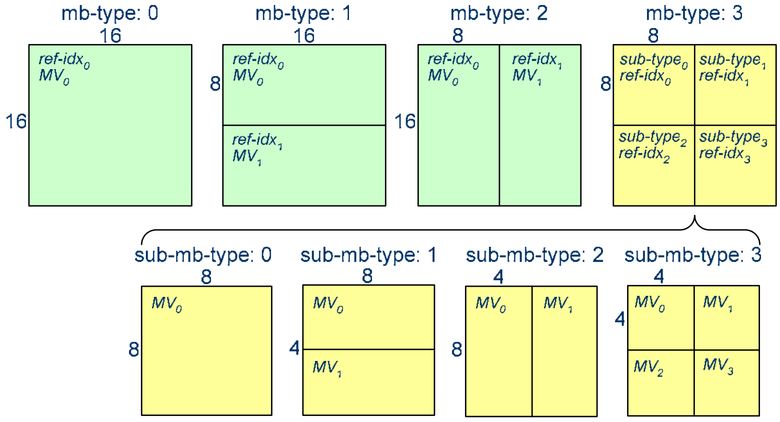


Inrta JVC/JPEG2000

(the intra frame prediction is even more powerful than the wavelet based image coding, used in JPEG2000)



Inter prediction Mode



Compression Performance

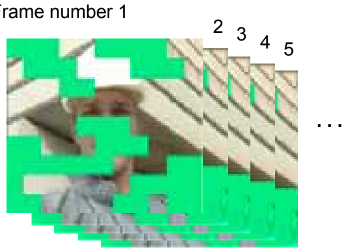
H.264 versus H.263 which has a similar performance to Frame-based MPEG-4

H.263, 30 K-Bits/Sec H.264, 30 K-Bits/Sec

Sensitivity to Errors

- Compressed video is very sensitive to errors.
  - A single error, will spread both spatially and temporally damaging all the successive frames.
  - The higher the Compression, the more sensitive is the compressed video to errors.

Frame number 1



CHALLENGES
Noise

- There are several methods to decrease the impact of noise/errors on the compressed video:
  - Error resilient Source Coding
  - Channel Coding
  - Error Concealment
  - etc

Error Resilience

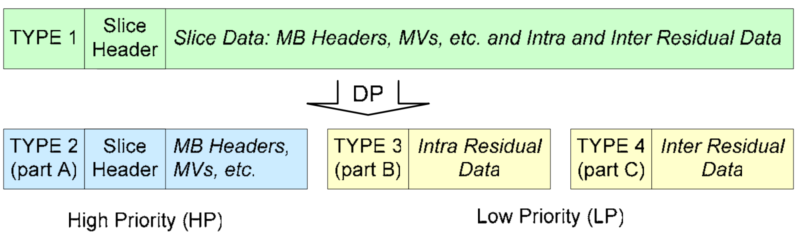
- Several techniques have been tailored in the standard to make the bitstream robust to the errors:
  - Resynchronization (slice) headers
  - Data Partitioning (DP)
  - Flexible Macroblock Ordering (FMO)
  - Redundant slices
  - Intra refresh
  - Multiple reference selection

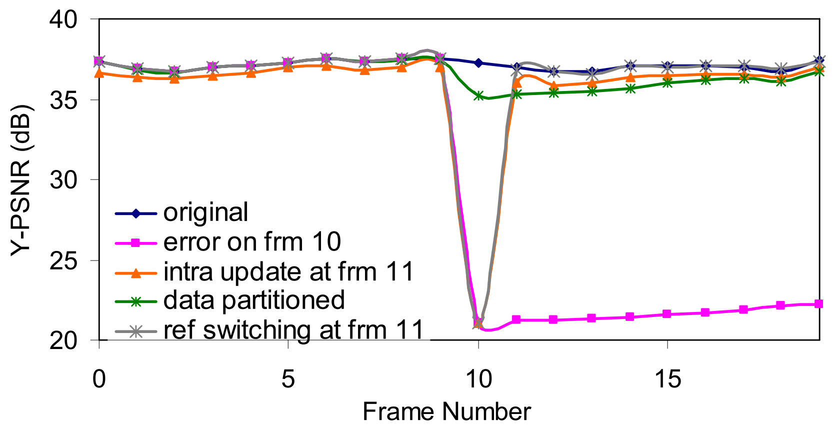
Layered coding

- Intra-Refresh and Multiple-Reference are effective, but need a back channel.
- In non-feedback video transmission, layered coding with transport prioritization is a very effective error resilience scheme.
- To improve the transmission efficiency, higher error protections are applied to the more important units of the coded data.

Data Partitioning

- The only frame layering technique currently supported by H.264 is Data Partitioning (DP).
- In DP a slice is divided into three units according to the importance of the data.





(A) Loss at Frame 10
(B) Loss at Frame 10, updated at Frame 15
(C) DP: Loss at frame 10, and not corrected

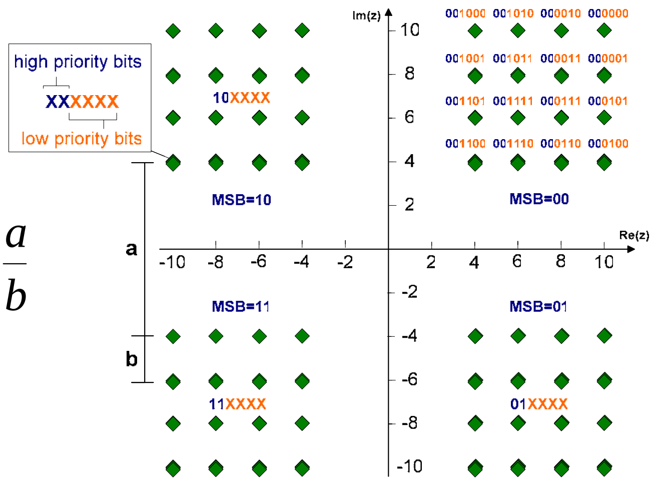
Unequal Error Protection (UEP)

- Higher priority (HP) bits should be better protected than the lower priority (LP) bits.
- This can be done with two methods:
  - Turbo code: HP bits use stronger Forward Error Correcting (FEC) code than the LP bits.
  - Modulation: HP bits use stronger SNR than the LP bits → **Hierarchical QAM**

In **Hierarchical QAM HP** symbols are further apart from each other than the LP symbols.

(Example: HP/LP = 2/4 in a 64-HQAM)

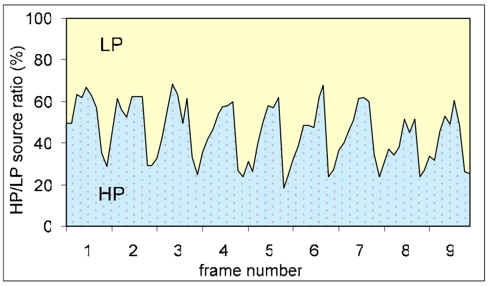
$$\alpha = \frac{a}{b}$$



Problem in UEP

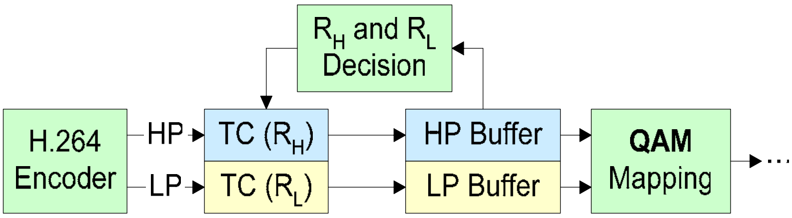
- In HQAM the ratio of HP to LP symbols is constant. (e.g. HP/LP = 2/4 in a 64-HQAM)
- In DP, the ratio of HP to LP bits is not constant.
- For practical implementation this conflict must be resolved.

Foreman@
100 kb/s



UEP With Channel Coding (Turbo code)

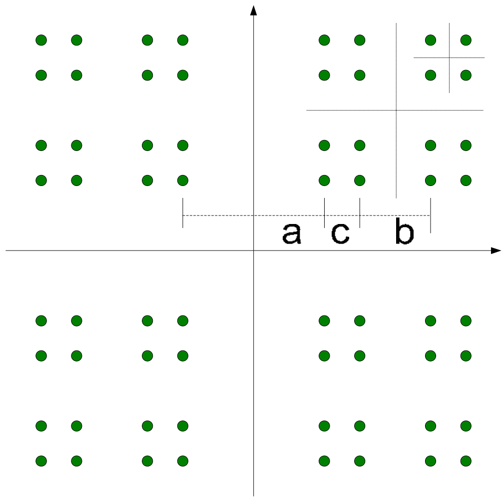
- The higher priority (HP) data should be protected by more redundancy (parity) bits than the lower priority (LP) parts.
- Since the HP/LP source bits ratio is variable, their Turbo coded rates, R_H and R_L , should vary accordingly.



With Multilevel HQAM, the distances between the symbols can vary to accommodate the HP/LP changes

$$\alpha = \frac{a}{b}$$

$$\beta = \frac{b}{c}$$

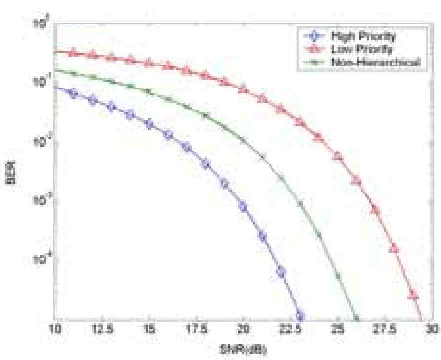


With Multilevel HQAM, *α* and *β* are adaptively adjusted according to the size of HP and LP .

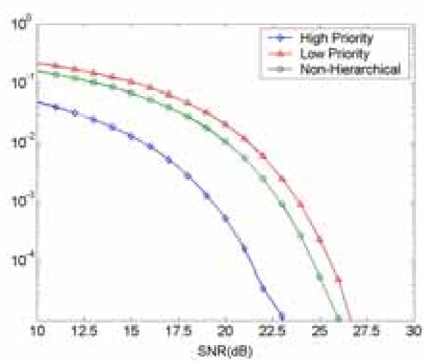
Mode	*α*	*β*	Relative Capacity	
			High Priority	Low Priority
1. Non-hierarchical	**1**	**1**	**6 bits (100%)**	
2. Hierarchical two-priorities	**1**	**>1**	4 bits (66%)	**2 bits (33%)**
3. Hierarchical two-priorities	**>1**	**1**	2 bits (33%)	**4 bits (66%)**

Multilevel HQAM: **BER vs. channel SNR**

Mode-2 (α=1, β=2) and Mode-1



Mode-3 (α:1.5, β:1) and Mode-1



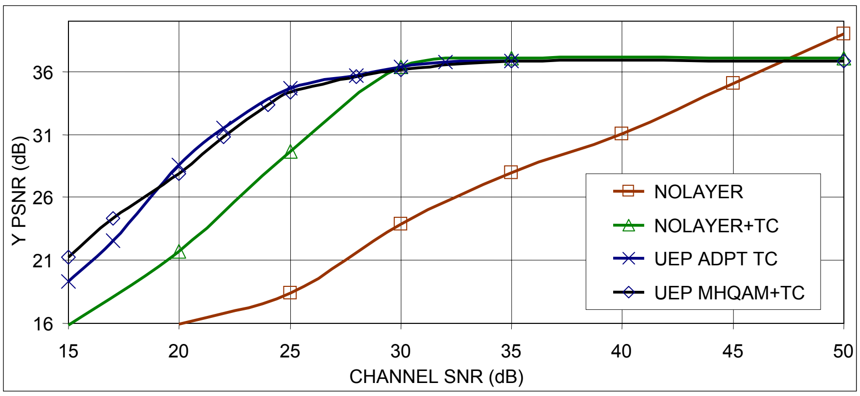
UEP comparison between MHQAM/Turbo Code

NOLAYER: QAM

NOLAYER+TC: QAM + Turbo code for extra protection of entire data

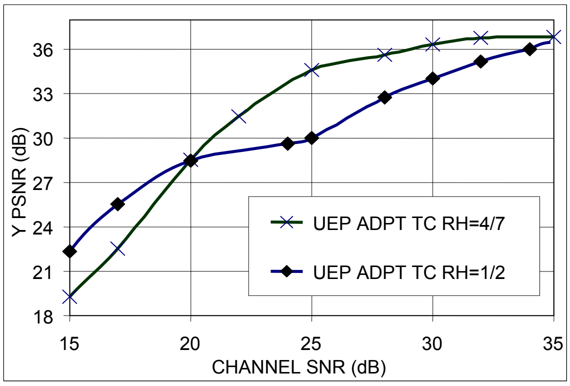
UEP ADPTTC: DP partitioned + adapting the parity bits in Turbo code + QAM

UEP MHQAM+TC: DP partitioned + Multilevel HQAM in HP and LP + Turbo Code on entire data



Simulation Results

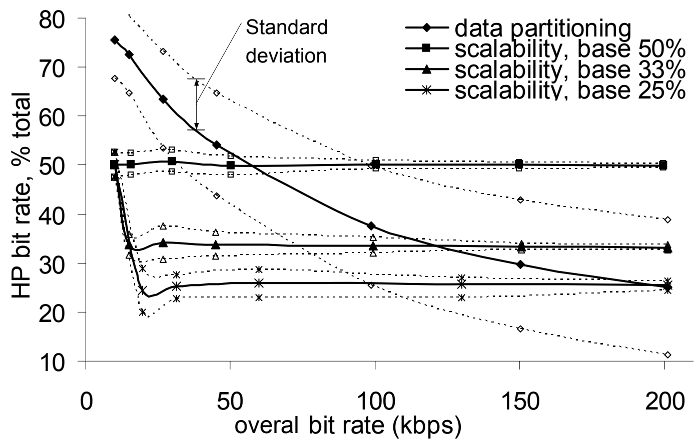
Increasing HP protection (e.g. 1/2 vs 4/7), will improve the performance at lower SNRs at the cost of lower performance at higher SNRs.



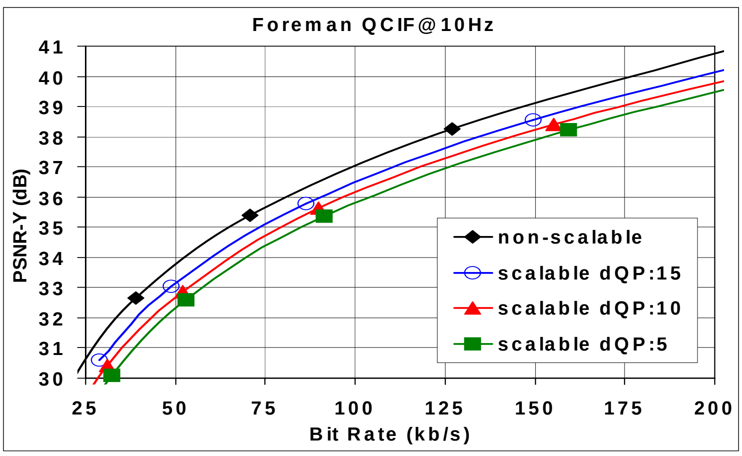
Scalability

- Another way of solving UEP problem of DP is scalable coding.
- Scalability is to partition a bitstream into layers such that the base layer gives a low quality video and the enhancement layer improves the quality.
  - e.g. Quality (SNR), Spatial or Temporal resolutions.
- Although the first version of H.264 does not support scalability, it is listed on the work plan as an important tool that should be supported by the standard.

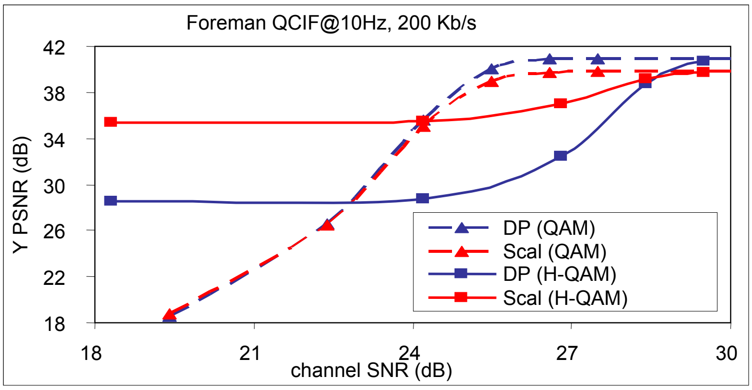
HP/LP changes in Scalability/DP



R-D performance of the non-scalable and the scalable coders for three values of dQP (= QPB-QPE).



PSNR vs. channel SNR, scalable and data-partitioned with equal error protection (QAM) and unequal error protection using hierarchical QAM α: 4 (H-QAM)



Loss concealment

- If despite all these errors are still present, then they can be concealed (hidden).
- There are several ways to hide the error
  - Copy from the adjacent pixels (intraframe)
  - Copy from the previous frame (Interframe)
  - Copy from motion compensated pixels, by an estimated motion vector
    - Top or bottom MV
    - Average of all MV
    - Median of MV
    - MV that gives the best continuity

CHALLENGES
Noise

- Examples of some Error Concealment Methods;

A Corrupted Sequence | Concealed using simple copy | Concealed using an advanced method

CONCLUSIONS

- In the very early days of 21st century, video transmission over the mobile handsets has become a reality!
- With continuing advances in video coding and reducing the transmission cost, usage of mobile video will become even more popular.