Content-Adaptive Macroblock Partitioning Scheme for Error Concealment of H.264/AVC Coded Video

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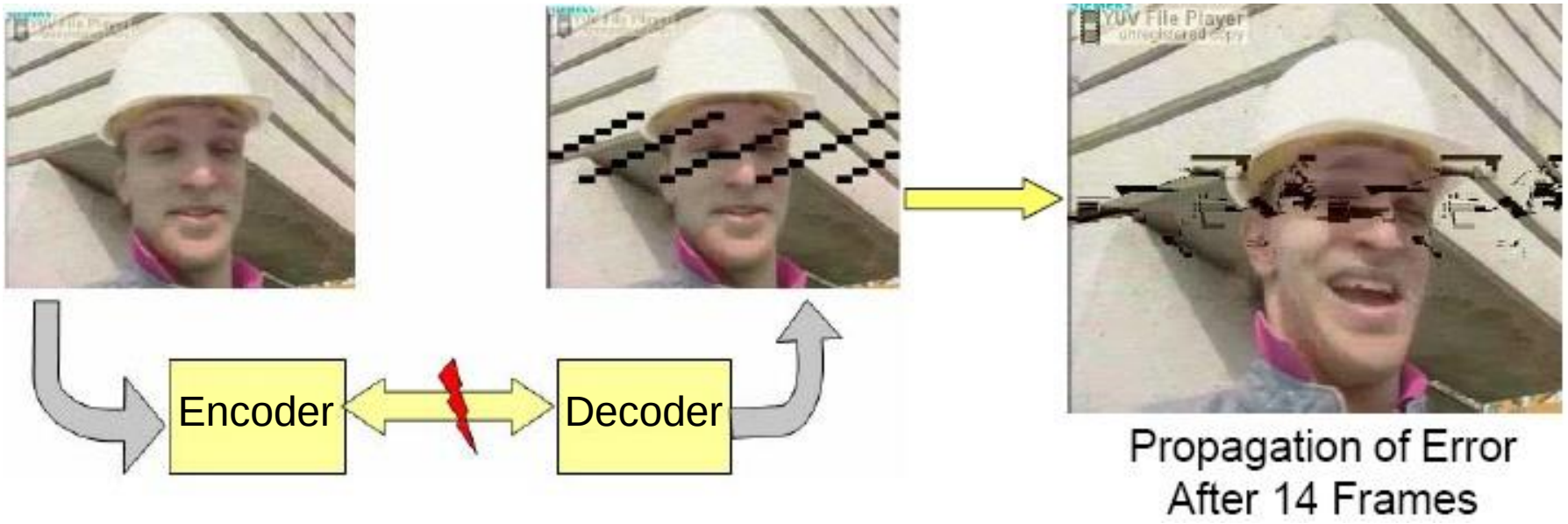
Error Propagation



Transmission errors may result in loss of information, propagating over several frames of video sequence.

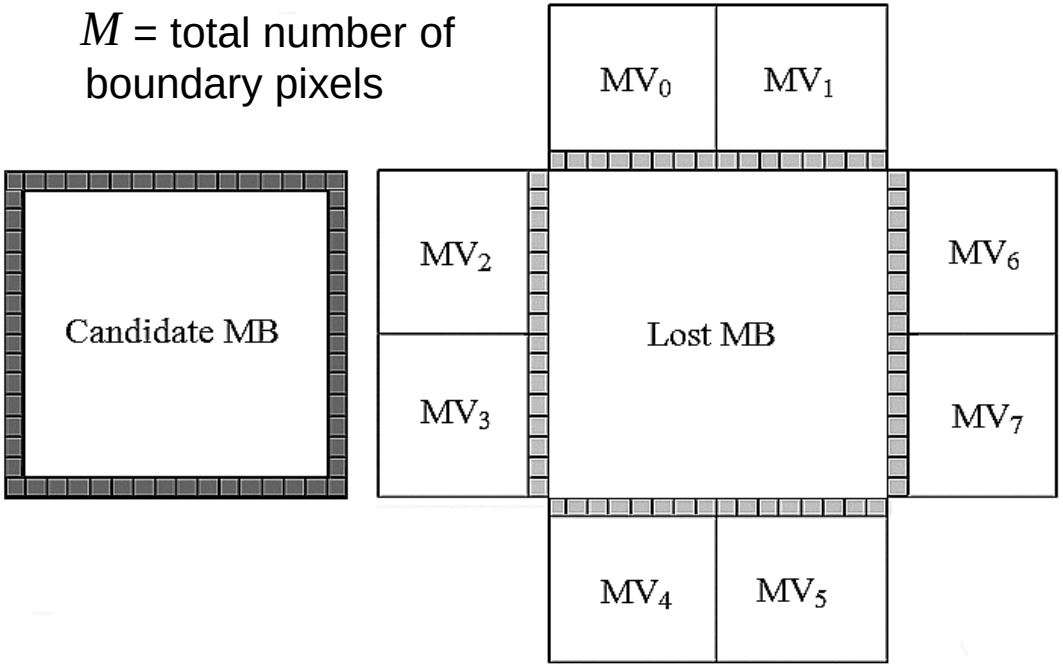
Goal: Estimate the lost information with some form of spatial interpolation in order to conceal the fact that an error has occurred

Error Concealment in H.264/AVC

- Boundary Matching Algorithm (BMA)
- Motion vector (MV) yielding least distortion is selected for best candidate MB

$$D_{n\_BMA} = \frac{1}{M}\left|\sum_{\forall i \in I} N_i - \sum_{\forall j \in J} C_j\right|$$

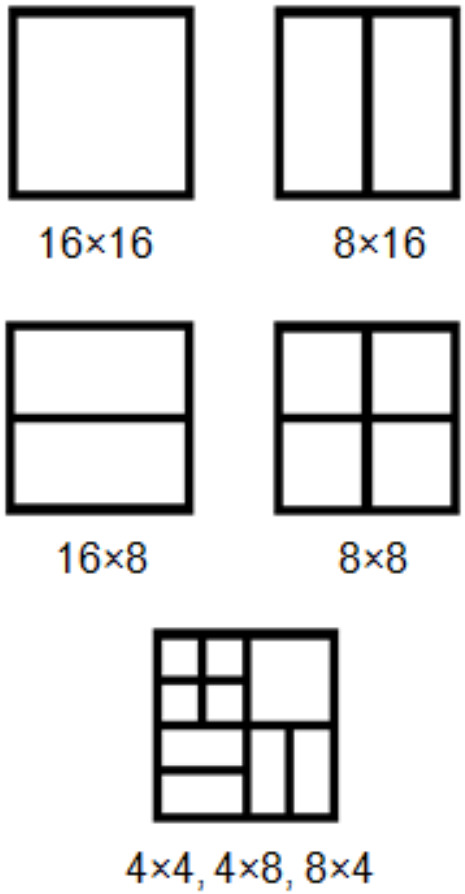
M = total number of boundary pixels



Inaccurate estimation of motion vectors

Temporal Error Concealment

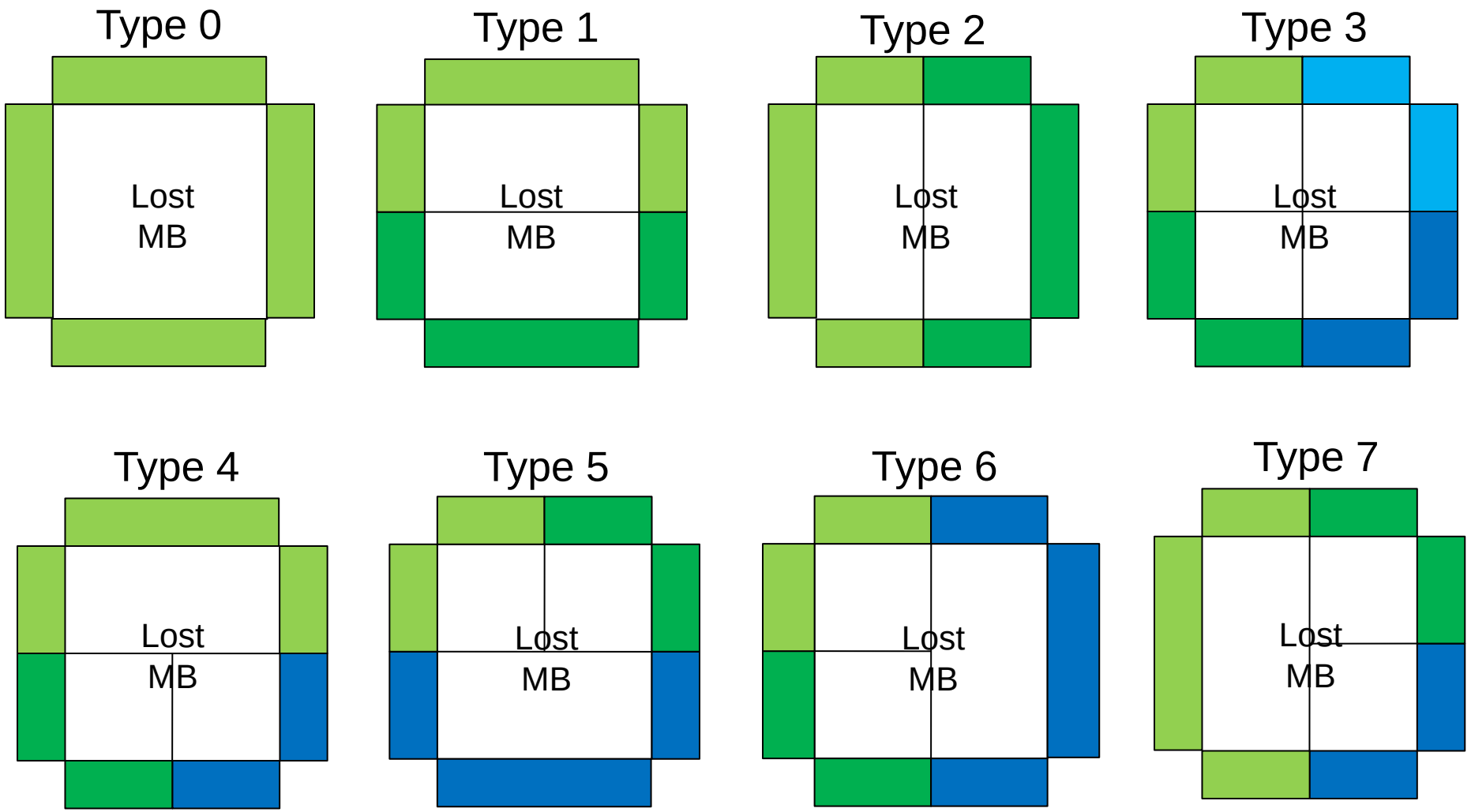
H.264/AVC uses tree-structured motion compensation with variable block sizes



Proposed Temporal Algorithm: CAMP (Content-Adaptive Macroblock Partitioning)

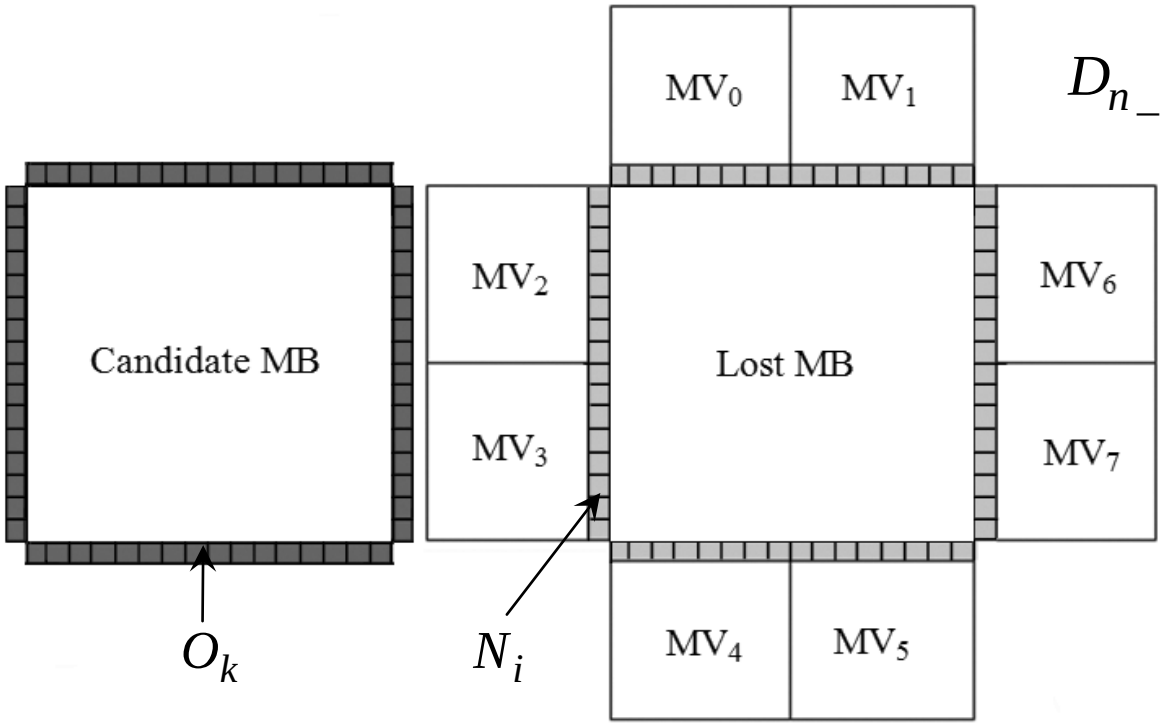
- In the proposed **content-adaptive macroblock partitioning** (CAMP) algorithm, the lost MB is partitioned adaptively into different block sizes (16x16, 16x8, 8x16, 8x8)
- Using the mode information of the neighboring MBs, the lost MB is suitably partitioned into one out of eight possible types
- Each partition is concealed with different candidate set of motion vectors
- Results in smoother concealment and avoids the blocking artifacts

Macroblock Partition Types



CAMP Distortion Computation

- Outer Boundary Matching Algorithm (OBMA) is used for distortion computation to perform the initial temporal concealment
- Better performance than BMA at the same level of complexity



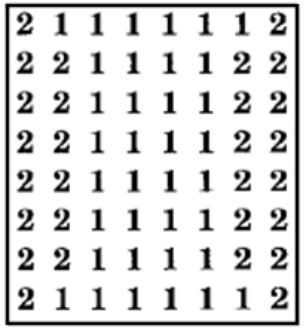
$$D_{n\_OBMA} = \frac{1}{M}\left|\sum_{\forall i \in I} N_i - \sum_{\forall k \in K} O_k\right|$$

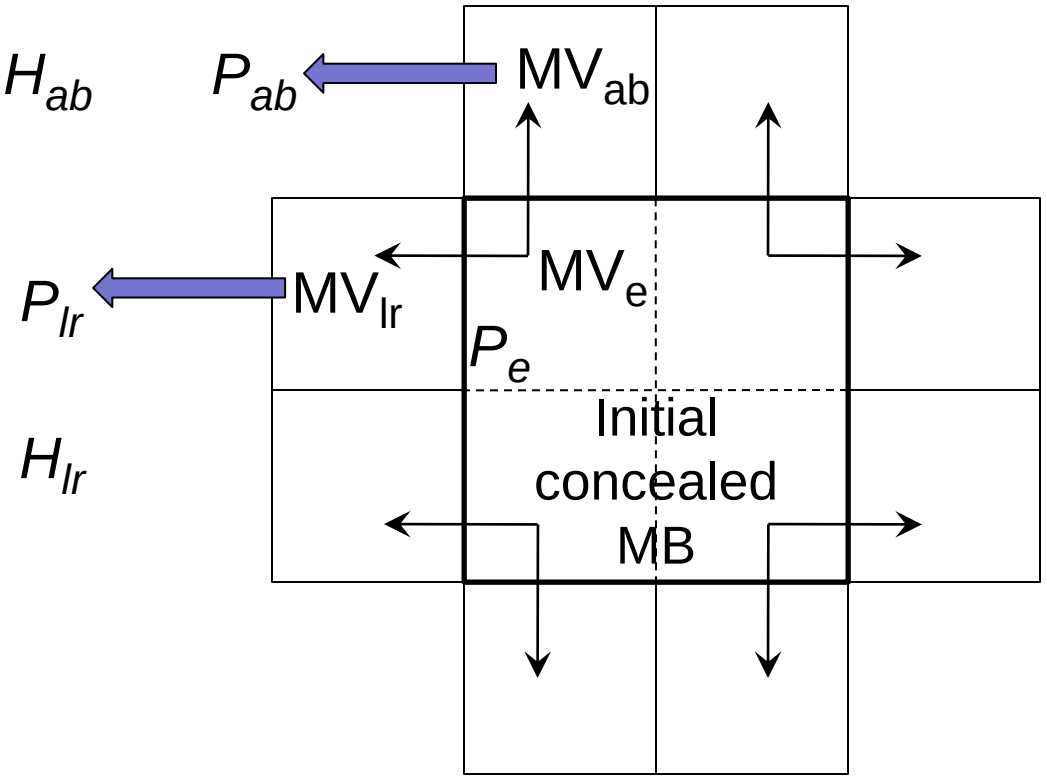
M = total number of relevant boundary pixels

CAMP concepts

- Overlapped Block Motion Compensation (OBMC) is used to post-process the initial concealed MB
- Avoids spatial discontinuities between the concealed MB and its neighbors
- Split the initial concealed MB into four 8×8 blocks
- For each 8×8 block, the pixels are modified by a weighted sum of prediction values using the OBMC weighting matrices
- The MVs of the neighboring blocks spatially adjacent to the concerned 8×8 block are used for prediction

Spatial Smoothing by OBMC





$$P(i, j) = [P_e(i, j)H_e(i, j) + P_{ab}(i, j)H_{ab}(i, j) + P_{lr}(i, j)H_{lr}(i, j) + 4] >> 3$$

$\forall(i, j)$ 8×8 block of initial concealed MB

CAMP Results

Stefan CIF Inter frame @ 10% loss rate

Concealed with ABS
PSNR = 26.35 dB, Q = 0.8726

Concealed with CAMP
PSNR = 27.63 dB, Q = 0.9432

(Q: Video Quality Index [0, 1], computed using Structural Similarity Index)

CAMP Results: PSNR

Test Sequence	Error-free PSNR (dB)	Loss Rate	$PSNR_{JM}$ (dB)	$\Delta PSNR_{ABS}$ (dB)		$\Delta PSNR_{CAMP}$ (dB)	
				Mean	σ	Mean	σ
Table-tennis	35.6771	5%	29.1297	0.8655	0.1895	1.3271	0.1421
		10%	26.2604	1.0737	0.1353	1.8491	0.1831
		20%	24.0365	**1.3527**	0.0925	**2.3538**	0.1460
Carphone	37.9892	5%	33.4334	0.8395	0.1402	1.8679	0.1466
		10%	31.1764	**1.1601**	0.2142	**2.2666**	0.2622
		20%	28.9781	1.5535	0.0676	2.4958	0.1401
Mother-Daughter	35.8685	5%	34.1248	0.6723	0.1498	1.4815	0.0998
		10%	33.5477	1.4567	0.0661	1.9337	0.0952
		20%	30.3227	1.8879	0.1167	2.5468	0.0989
Stefan	36.4337	5%	26.5314	1.3733	0.1025	2.1388	0.0954
		10%	24.4016	1.6537	0.0896	2.3575	0.0377
		20%	21.4639	2.0741	0.0985	2.5721	0.1145
Foreman	36.4593	5%	30.9586	**0.8137**	0.0568	**1.8959**	0.0715
		10%	28.9998	1.3994	0.0920	2.2281	0.0914
		20%	26.2685	2.0122	0.1761	2.5608	0.0881

Max. Improvement: 1.1 dB relative to ABS and 2.5 dB relative to JM

CAMP Results: Video quality index Q

Test Sequence	Error-free Q	Loss Rate	Q_{JM}	ΔQ_{ABS}		ΔQ_{CAMP}	
				Mean	σ	Mean	σ
Table-tennis	0.8863	5%	0.7471	0.0902	0.0033	0.1271	0.0072
		10%	0.7255	0.1053	0.0022	0.1423	0.0054
		20%	0.6806	**0.1212**	0.0180	**0.2002**	0.0035
Carphone	0.9651	5%	0.8733	0.0252	0.0030	0.0832	0.0053
		10%	0.7677	0.0857	0.0032	0.1841	0.0034
		20%	0.7082	0.1327	0.0047	0.2378	0.0047
Mother-Daughter	0.9531	5%	0.8921	0.0135	0.0014	0.0528	0.0034
		10%	0.8353	**0.0356**	0.0062	**0.1048**	0.0032
		20%	0.7565	0.0891	0.0071	0.1921	0.0027
Stefan	0.9751	5%	0.8474	0.0432	0.0028	0.1156	0.0065
		10%	0.7862	0.0931	0.0034	0.1779	0.0048
		20%	0.7141	0.1401	0.0029	0.2362	0.0072
Foreman	0.9333	5%	0.8191	**0.0452**	0.0032	**0.1057**	0.0054
		10%	0.7649	0.0742	0.0034	0.1565	0.0063
		20%	0.7234	0.1192	0.0029	0.2034	0.0041

Max. Improvement: 0.1 relative to ABS and 0.2 relative to JM