

**CS 5263: Wireless Multimedia Networking
Technologies and Applications**

Scalable Video Coding

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Motivation

- **Receivers of video stream are heterogeneous**
 - **Connection bandwidth**
 - **Display resolution**
 - **Processing power**
 - **Battery level**
- **Dynamic conditions**
 - **Even for the same receiver**
 - **Internet bandwidth is changing**
 - **Wireless conditions and mobility**
- **➔ Need stream adaptation methods**

Stream Adaptation

■ Transcoding

- Transform the encoded stream to different format/
bitrate/resolution
- Simple approach: decode then encode again with
different parameters
- There are more sophisticated transcoding schemes, e.g.,
work in the compressed domain
- **Disadvantages?**
 - Computational cost

Stream Adaptation

- **Simulcasting (or Stream Switching)**
 - Encode a video stream multiple times
 - E.g., high, medium, low quality
 - Or high and low resolutions
 - Switch among streams during the session
 - Advantages: simple
 - **Disadvantages?**
 - Managing multiple versions of same video
 - Larger storage requirements
 - Switching streams is not easy: need to synchronize at I-frames

Stream Adaptation

- **Muti-Description Coding (MDC)**
 - Encode each stream into multiple descriptions
 - Each description improves the received quality
 - Any subset of descriptions can be decoded
 - **Advantages:**
 - Very flexible
 - **Disadvantages?**
 - **Coding inefficiency:** the aggregate bit rate of MDCs is much higher than single-layer (non-scalable stream) at the same quality

Stream Adaptation

■ Scalable Video Coding (SVC)

- **Goal:** Each stream is encoded once, but can be decoded/adapted in many different ways
- **Idea:** each stream has multiple **layers**, and subsets of layers can be decoded (some restrictions on layers)

■ Started early on

- H.262/MPEG-2, H.263, MPEG-4 Visual, ...
- But was not widely deployed:
 - Coding/decoding complexity and
 - Coding inefficiency, e.g., **2-5 dB** gap is common for MPEG-4 FGS (fine-grained scalability) streams when compared against MPEG-4 streams

H.264/SVC

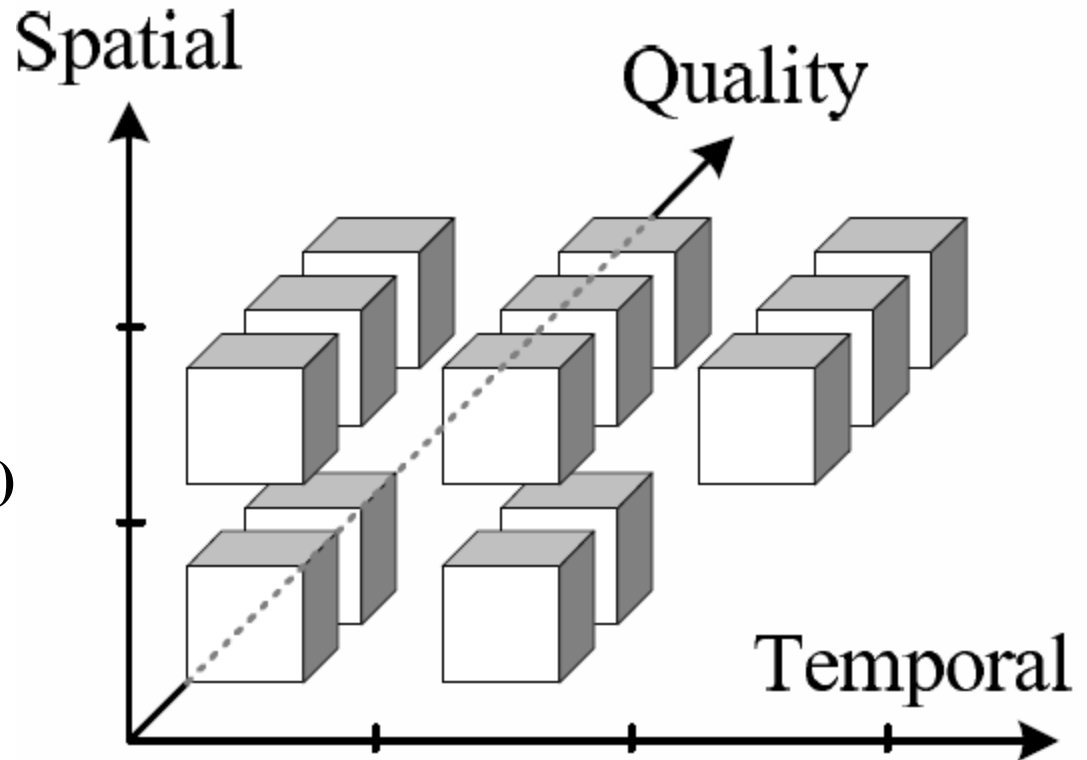
- **Most recent: H.264/SVC**
 - Tries to avoid previous problems
 - Gaining momentum (some companies already used it)
- **Our discussion is mostly focused on H.264/SVC**
- **Read: Schwarz et al.,**
Overview of the Scalable Video Coding Extension of the H.264/AVC Standard, IEEE Trans. on Circuits and Systems for Video Technology, 17(9), 2007

H.264/SVC

- **SVC tries to achieve (scalability wish list)**
 - Similar coding efficiency to single-layer coding (10% bit rate increase at most)
 - Support for temporal, spatial, quality scalability
 - Backward compatibility of the base layer
 - Support for simple bitstream adaptations after encoding
 - Little increase in decoding complexity (arguably failed)
- **SVC has many potential applications**
 - Support heterogeneous receivers (wired and wireless)
 - Unequal error protection
 - Archiving in surveillance applications (store base quality)
 -

H.264/SVC: 3-D Scalability

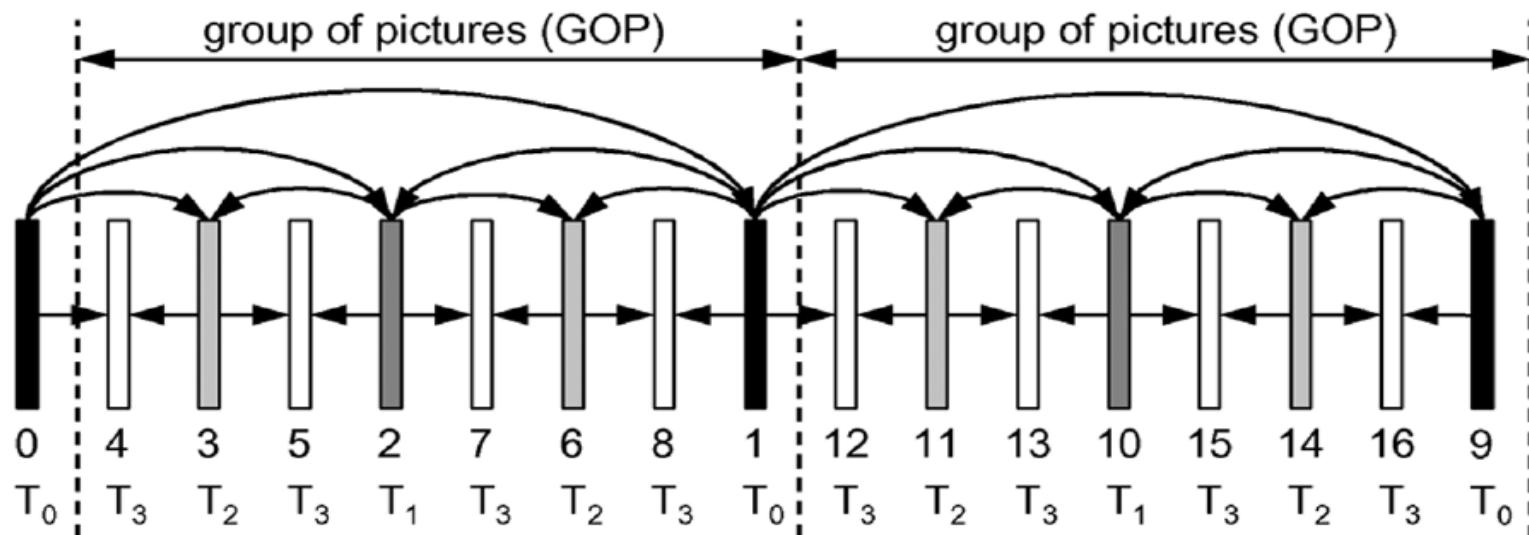
- **Temporal scalability**
 - Frame rate
- **Spatial scalability**
 - Resolution (picture size)
- **Quality scalability**
 - (Fidelity or SNR)
- **SVC → Very flexible adaptation**



Temporal Scalability

- **Divide sequence into temporal layers**
 - Restrict motion-compensated prediction
- **→ Hierarchical prediction structure**
 - Already provided by H.264/AVC

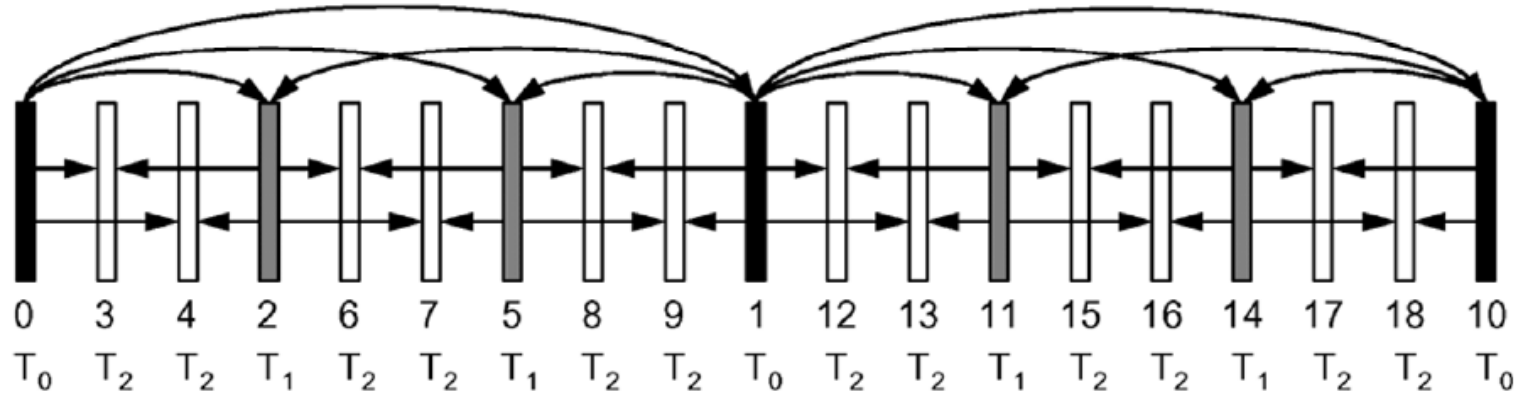
Temporal Scalability: Example



■ 4 temporal layers: T₀, ..., T₃

- T₀ = 1 frames per GoP
- T₁ = T₀ + 1 = 2 frames per GoP
- T₂ = T₁ + 2 = 4 frames per GoP
- Numbers below frames indicate decoding order
- Arrows show prediction dependency
- Dyadic (power of 2) temporal enhancement layers

Temporal Scalability: Example 2



- **Non-dyadic structure is also possible**
 - $T_0 = 1/9$ of full frame rate
 - $T_1 = 1/3$ of full frame rate
 - $T_2 =$ full frame rate

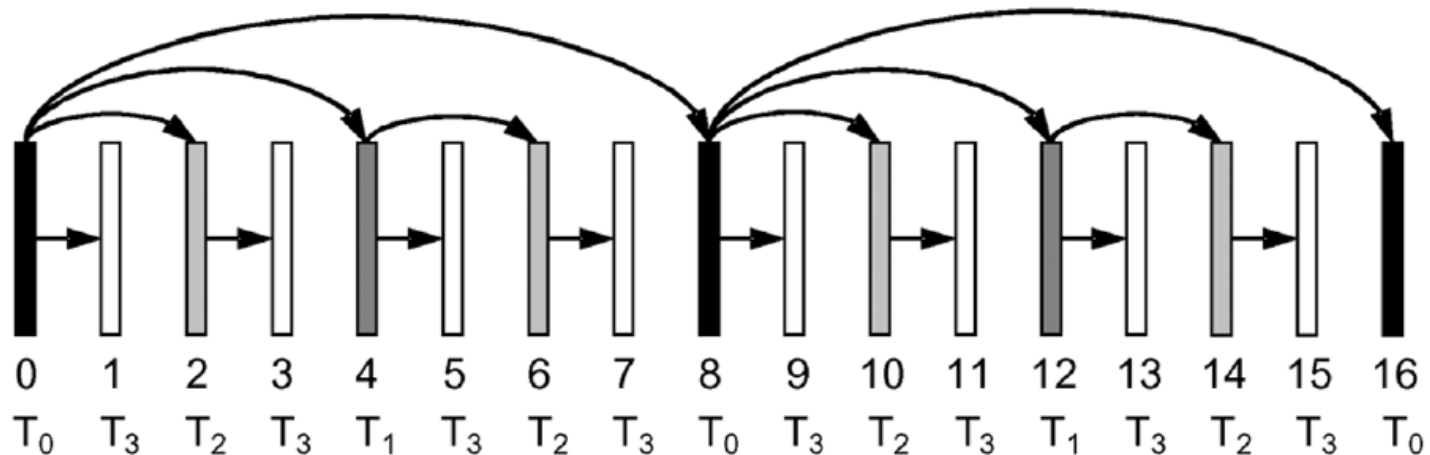
Temporal Scalability

- **SVC also supports**

- **Changing the hierarchical prediction structure over time**
- **Having the reference frame in the same temporal layer as the target frame**
- **Having multiple reference frames (as in H.264/AVC)**

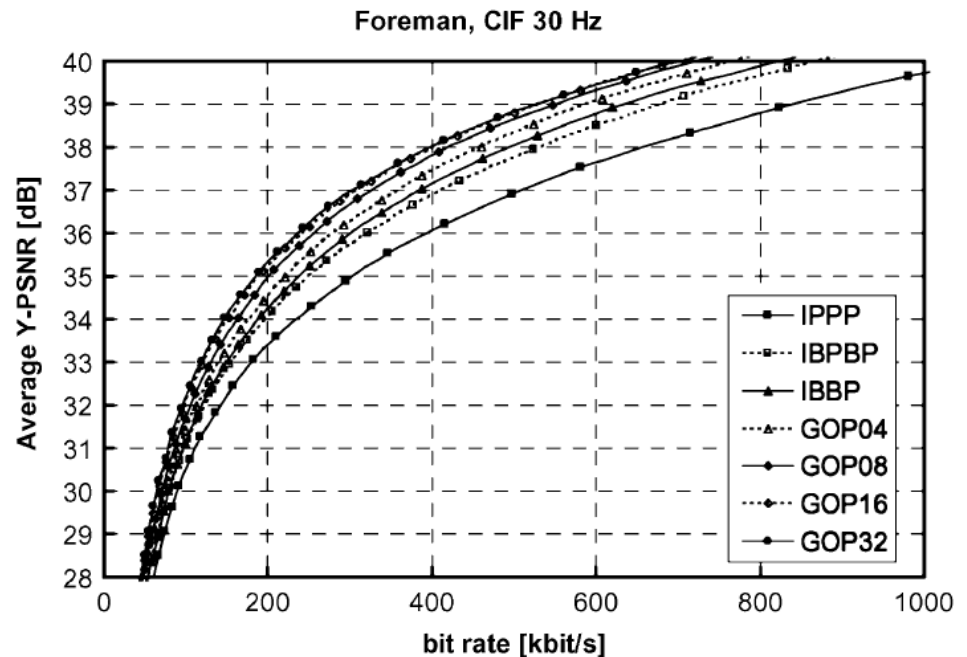
Temporal Scalability: Delay

- **Hierarchical structure could increase decoding delay**
 - Some frames cannot be decoded until receiving future frames
 - Not desired in interactive multimedia applications (e.g., video conf)
- **SVC can limit predictions to preceding frames only**
 - **Cost?**
 - Decreased coding efficiency

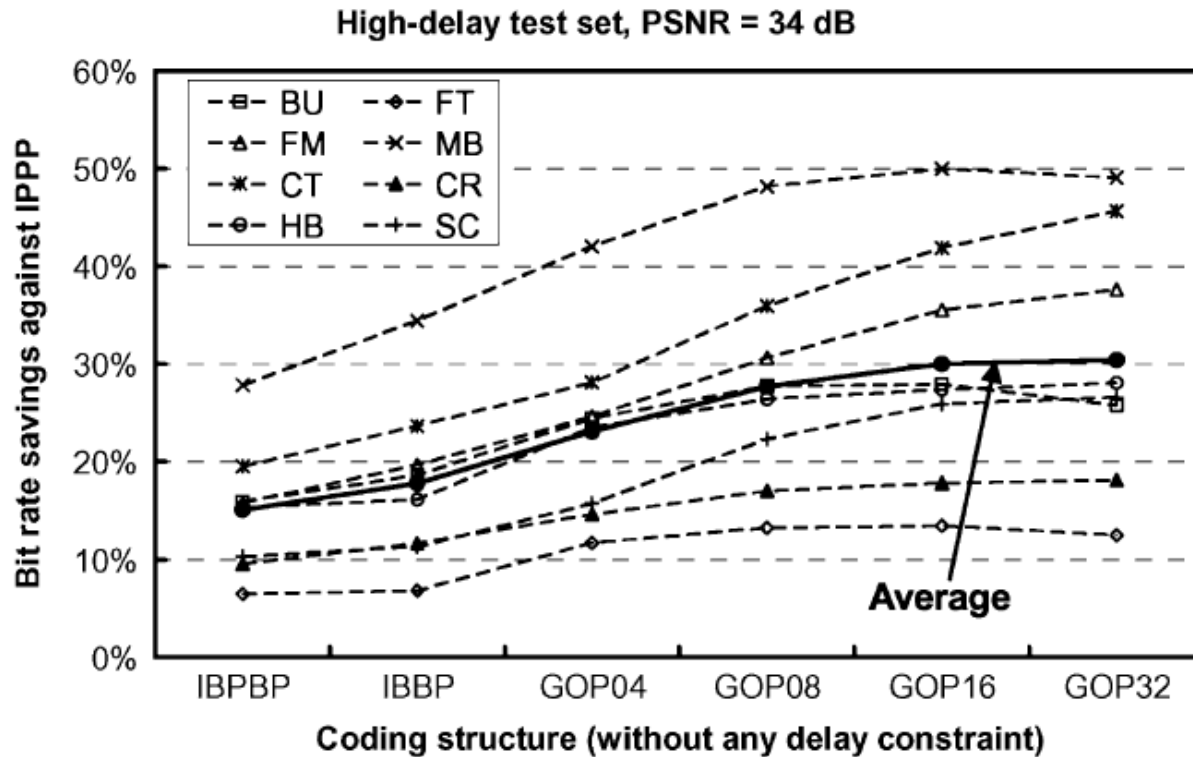


Temporal Scalability: Coding Efficiency

- Comparing dyadic hierarchical B-pictures (no decoding delay constraint) vs IPPP, IBPBP, and IBBP
- Hierarchical B-pictures achieve PSNR gain ≥ 1 dB compared to the widely used IBBP coding structure
- Gain is higher for large GoP sizes

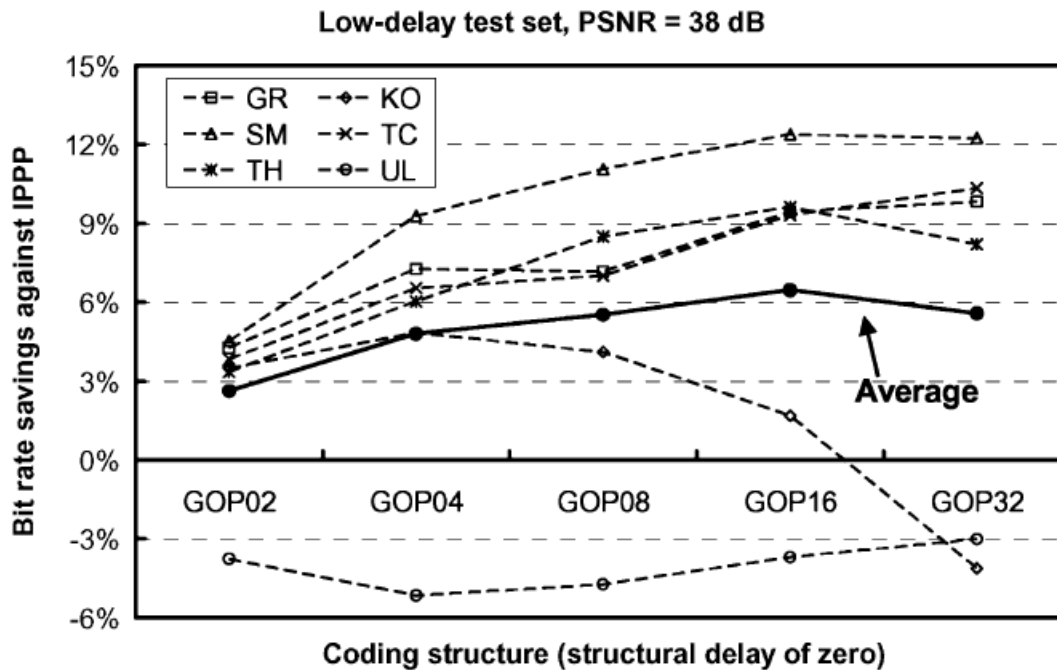


Temporal Scalability: Coding Efficiency



- Using high-delay test set (non-conversational sequences), CIF 30Hz, 34dB, compared to IPPP
- → significant saving in bitrate

Temporal Scalability: Coding Efficiency



- Using low-delay (delay = 0) test set (conversational sequences), 365x288, 25-30Hz, 38 dB vs IPPP
 - Still some gain but not as high as before

Temporal Scalability: Summary

- **Achieved using hierarchical temporal structures**
- **Typically no negative impact on coding efficiency**
 - **Significant improvement, especially when higher delays are tolerable**
 - **Minor losses in coding efficiency are possible when low delay is required**

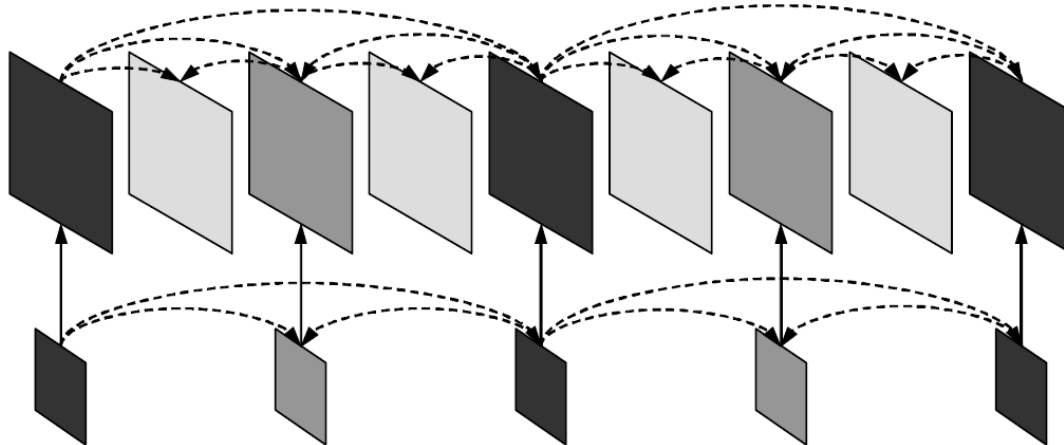
Spatial Scalability

- **Basic Idea:**

- Multiple layers with different resolutions
- Each layer is treated as if it were single-layer coding:
 - i.e., uses motion-compensated prediction and intra-prediction
- All layers share the same encoding order ← for low complexity
- Inter-layer prediction is also possible

- **Notice temporal and spatial scalabilities can exist**

- Inter-layer prediction is only performed at access units



Spatial Scalability: Inter-Layer Prediction

■ Inter-layer prediction

- Up-sample lower layer signal (reconstructed samples) and perform prediction ← early standards only support this
- Perform temporal prediction **inside** higher-resolution layer (in the enhancement layer)
- You can either use the first prediction and/or the second
 - Averaging in case of using both

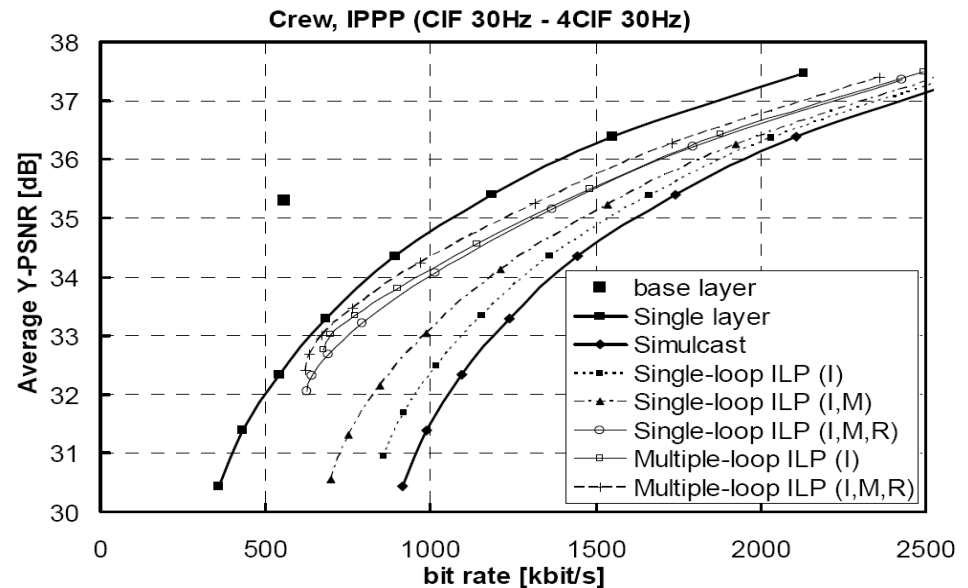
■ **Note: same-layer temporal prediction can provide better compression in case of low motion videos with detailed resolution**

Spatial Scalability: Improving Efficiency

- **To improve the coding efficiency of inter-layer prediction, two coding tools were added**
 - **Prediction of macroblock modes and associated motion parameters**
 - **Prediction of the residual signal**
- **A new macroblock type is defined**
 - **Transmits a residue signal**
 - **No intra-prediction mode nor motion parameters**
 - **If the corresponding macroblock in the reference layer is**
 - **Intra-coded** → **intra prediction: upsample reference layer**
 - **Inter-coded** → **motion prediction: motion vectors are scaled up**

Spatial Scalability: Coding Efficiency

- **Single-loop vs. multiple-loop decoding**
 - Reconstructing inter-coded reference layer or not...
- **Coding tools: Intra-layer prediction (I), motion prediction (M), residual prediction (R)**
- **Take-Away**
 - I, M, R are beneficial
 - But multiple-loop leads to minor enhancements, while incurring high decoding overhead



Quality Scalability

- **Basic Idea:**

- Multiple layers created with **same resolution** but **different fidelity** (picture quality)
- Different qualities can be achieved by controlling quantization step

- **H.264/SVC quality scalability models**

- **Coarse-Grained Scalability (CGS)**
 - Few layers
- **Medium-Grained Scalability (MGS)**
 - More flexible

Quality Scalability: CGS

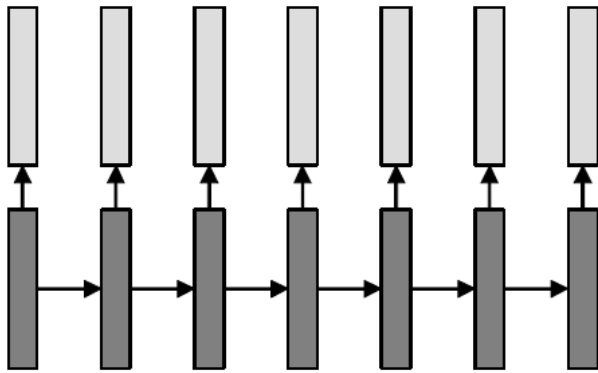
- **Similar to spatial scalability, but with same resolution**
- **Use different quality parameters in different layers**
- **Supports a few (typically 3 to 6) different bit-rates/ layers**
- **Too many layers → high overhead → low coding efficiency**

Quality Scalability: MGS

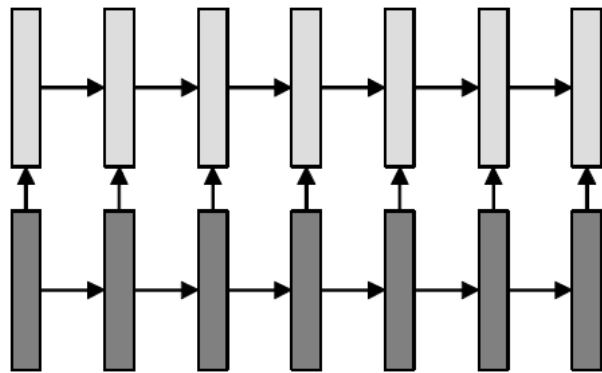
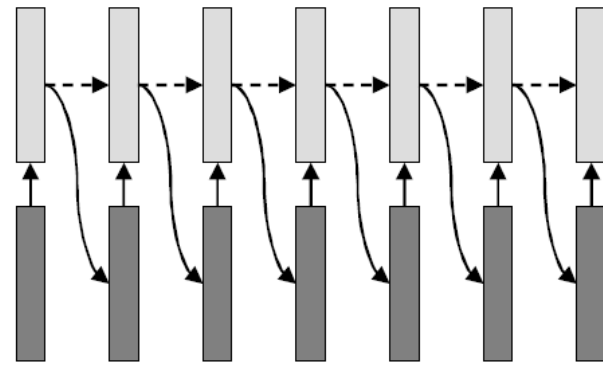
- **Medium-Grained Scalability (MGS) improves:**
 - **Flexibility of the stream**
 - Packet-level quality scalability
 - **Error robustness**
 - Controlling drift propagation
 - **Coding efficiency**
 - Use of more information for temporal prediction

Quality Scalability: MGS Prediction Structure

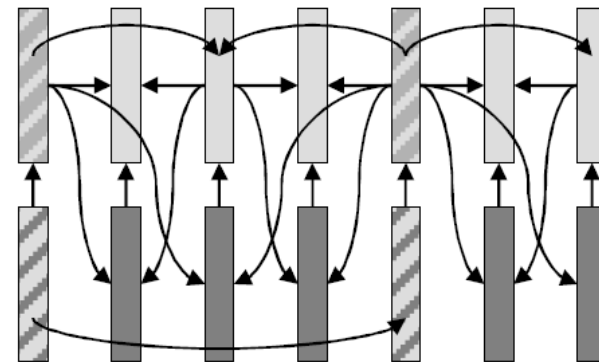
MPEG-4 FGS



MPEG-2 Quality Scalable



MPEG-2 Spatial Scalable



H.264/SVC MGS

Quality Scalability: MGS Key Frames

- **Video frames of coarsest temporal layer are called key frames**
- **Key frames only use base-layer frames for predictions ← robustness**
- **Non-key frames can only highest possible layers for prediction ← coding efficiency**

Quality Scalability: MGS

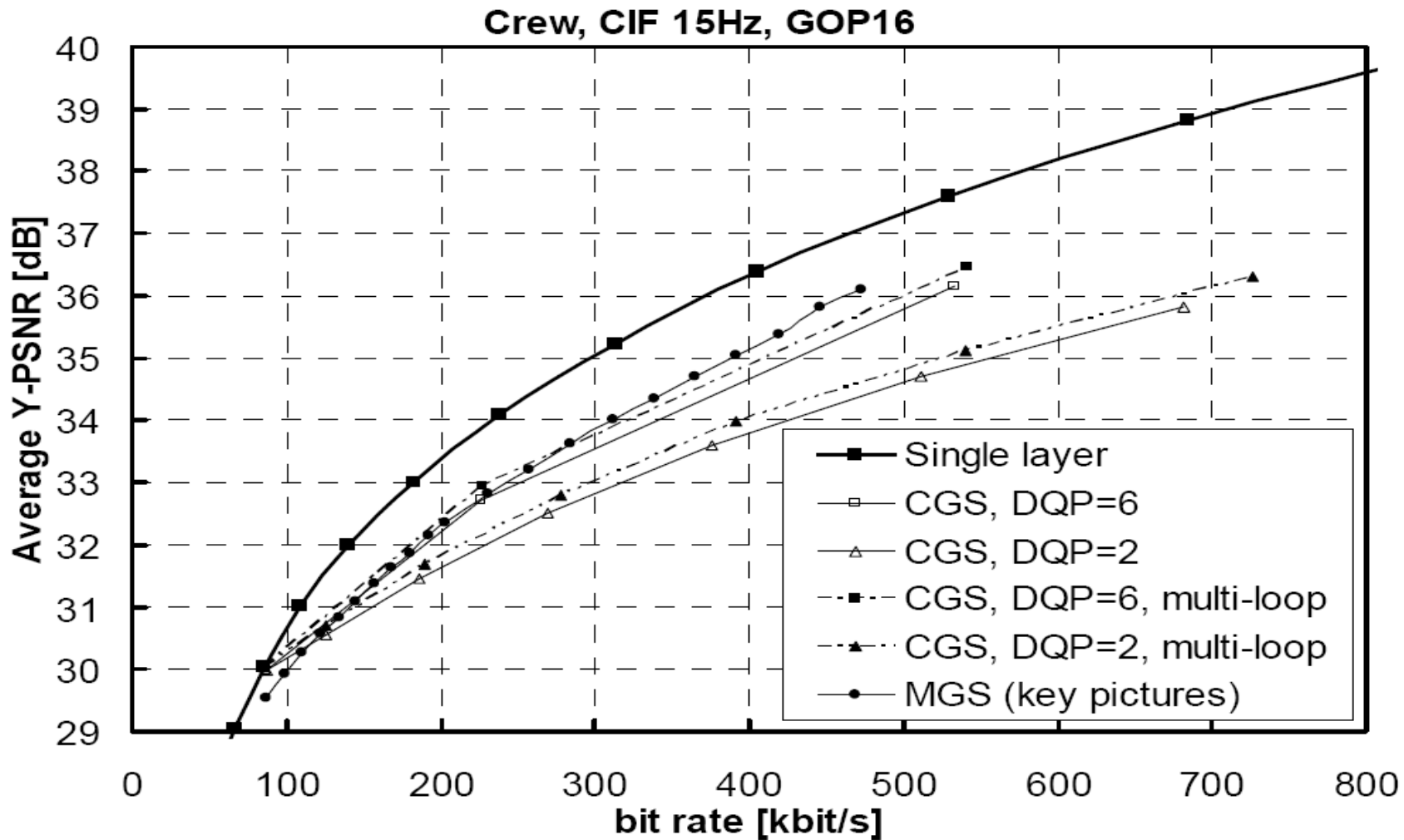
- **MGS: flexibility of the stream**

- **Enhancement layer transform coefficients can be distributed among several slices**

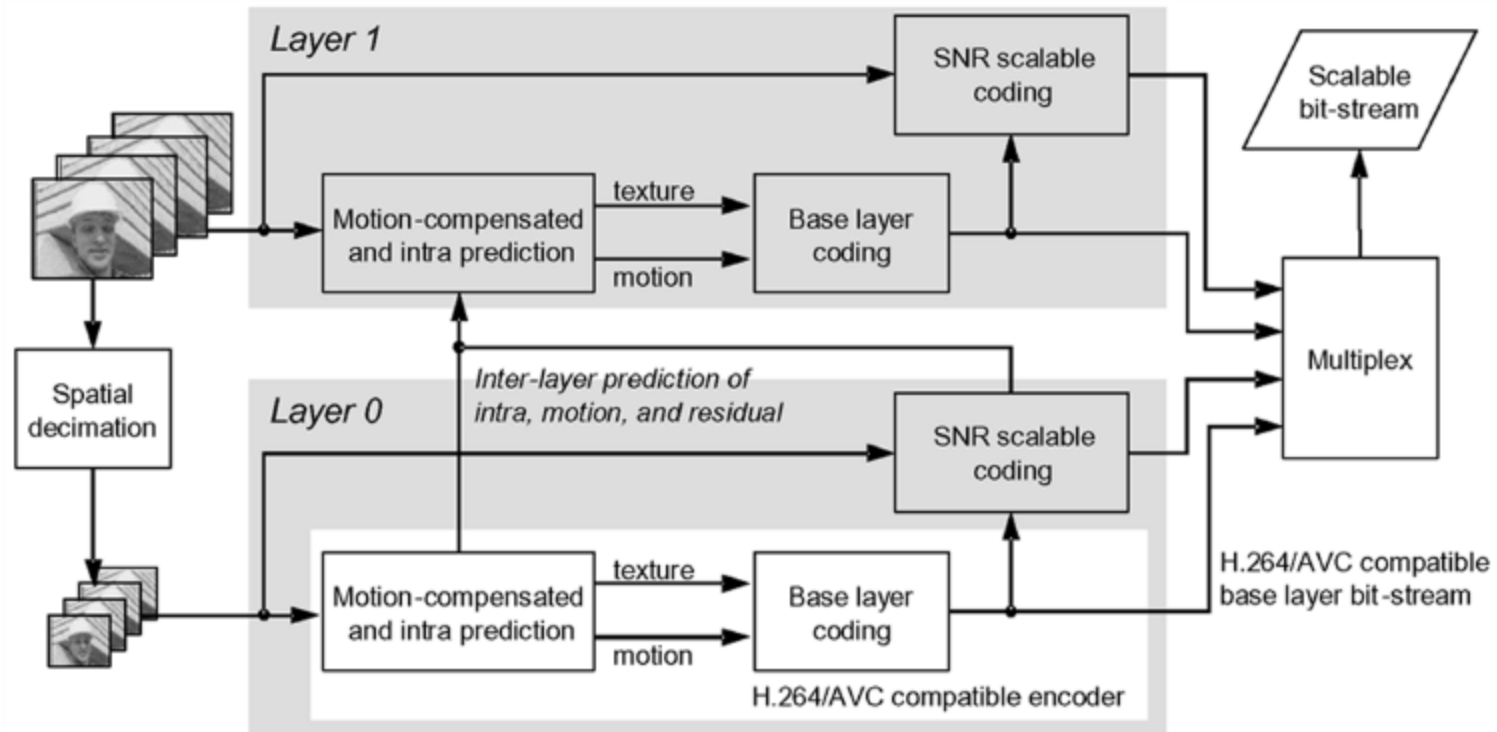
1	1	2	3
2	2	3	4
2	3	3	4
3	3	4	4

- **Packet-level quality scalability**

Quality Scalability: MGS vs. CGS



SVC Encoder Structure



- Simple example for 2 spatial layers

Summary

- **Different models of scalability**
 - **Simulcast, MDC, SVC**
- **SVC**
 - **Temporal**
 - **Spatial**
 - **Quality**
- **H.264/SVC tried to improve coding efficiency while reducing complexity**
 - **It achieves the former goal: gap between H.264/SVC and MPEG-4 is reported to be as low as 10%**
 - **It arguably fails the later goal: very few SVC chip designs are out there, mostly due to memory limitation**

Compiling JSVM (and other ref. sw)

- **Create working folder:** `mkdir JSVM; cd JSVM`
- **CVS login:** `cvs -d :pserver:jvtuser:jvt.Amd.2@garcon.ient.rwth-aachen.de:/cvs/jvt login`
- **CVS checkout:** `cvs -d :pserver:jvtuser@garcon.ient.rwth-aachen.de:/cvs/jvt checkout jsvm`
- **Get into the build directory (using Linux as example):**
`cd jsvm/JSVM/H264Extension/build/linux`
- **Compile:** `make`
- The resulting binary files are under `JSVM/jsvm/bin`

JSVM Utilities

- *H264AVCEncoderLibTestStatic*: reference encoder
- *H264AVCDecoderLibTestStatic* : reference decoder
- *BitStreamExtractorStatic* : extract a substream from the global scalable stream
- *PSNRStatic, YUVCompareStatic* : compare two yuv files for PSNR
- *FixedQPEncoderStatic*: binary search algorithm for rate control (there is no rate control algorithms in JSVM)
- *H264AVCVideoIoLibStatic*: library for read and write NAL units ← useful for your term projects

Encoding a Two Layer CGS Stream (1/5)

- **Prepare the configure files**
 - **One main configuration file: main.cfg**
 - **One layer configuration file for each layer: layer0.cfg and layer1.cfg**
- **Download the YUV files**
 - wget http://nsl.cs.sfu.ca/video/library/YUV/4CIF/CREW_704x576_30_orig_01.yuv
 - wget http://nsl.cs.sfu.ca/video/library/YUV/4CIF/CREW_352x288_30_orig_01.yuv

Encoding a Two Layer CGS Stream (2/5)

■ main.cfg

```
# JSVM Main Configuration File
```

```
OutputFile           CS5262.264    # Bitstream file
FrameRate            30.0          # Maximum frame rate [Hz]
FramesToBeEncoded    150          # Number of frames (at input frame
rate)
GOPSize              16           # GOP Size (at maximum frame rate)
BaseLayerMode        2           # Base layer mode (0,1: AVC
compatible,
                                #
                                #           2: AVC w
subseq SEI)
SearchMode           4           # Search mode (0:BlockSearch,
4:FastSearch)
SearchRange          32          # Search range (Full Pel)
NumLayers            2           # Number of layers
LayerCfg             layer0.cfg   # Layer configuration file
LayerCfg             layer1.cfg   # Layer configuration file
```

Encoding a Two Layer CGS Stream (3/5)

■ layer0.cfg

JSVM Layer Configuration File

```
InputFile          CREW_352x288_30_orig_01.yuv # Input  file
SourceWidth        352                # Input  frame width
SourceHeight       288                # Input  frame height
FrameRateIn        30                 # Input  frame rate [Hz]
FrameRateOut       30                 # Output frame rate [Hz]
```

Encoding a Two Layer CGS Stream (4/5)

- **Encode the video**

- `../bin/H264AVCEncoderLibTestStatic -pf main.cfg
-lqp 0 30 -lqp 1 32`

- **Decode at the full quality**

- `../bin/H264AVCDecoderLibTestStatic CS5262.264
full.yuv`

- **Playout the reconstructed yuv file**

- `mplayer -demuxer rawvideo -rawvideo
fps=10:w=704:h=576:format=i420 -loop 0 full.yuv`

Encoding a Two Layer CGS Stream (5/5)

- **Extract a lower resolution stream**

- `../bin/BitStreamExtractorStatic CS5262.264
CS5262_LoFi.264 -l 0`

- **Decode the video**

- `../bin/H264AVCDecoderLibTestStatic
CS5262_LoFi.264 LoFi.yuv`

- **Play the low resolution reconstructed video**

- `mplayer -demuxer rawvideo -rawvideo
fps=10:w=352:h=288:format=i420 -loop 0 LoFi.yuv`

Compute PSNR

- `../bin/PSNRStatic 704 576`
`CREW_704x576_30_orig_01.yuv full.yuv`

0	38,9117	43,1924	43,8809
1	34,3800	39,0224	39,2633
2	37,0061	42,5263	42,8077
3	36,7575	42,3130	42,4146
.....			
147	33,8073	39,1530	39,1838
148	35,4138	39,7400	39,5863
149	34,3667	39,4859	39,0969
total	35,1929	40,6697	40,6936

Compile and Use OpenSVC

- **Download the source code from Sourceforge**
 - <http://sourceforge.net/projects/opensvcdecoder/>
- **unzip the source code**
- **cd to Mplayer/ folder**
- **Configure:**
 - `CPPFLAGS="-I/opt/local/include/" LDFLAGS="-L/opt/local/lib" CC=gcc-4.2 ./configure --enable-svc`
- **make**
- **Decode the 4CIF version**
 - `./mplayer -fps 30 -loop 0 ../../jsvm/CS5262/CS5262.264`
- **Decode the CIF version**
 - `./mplayer -fps 30 -setlayer 0 -loop 0 ../../jsvm/CS5262/CS5262.264`
- **OpenSVC supports switching among layers, but it doesn't work on our 264 file, why? How can we fix it? ← homework assignment?**