Scalable Video Coding

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About the Lecturer

- Research Leader, Media Systems and Transport
- Interests
  - Scalable, error-resilient and multi-view video coding
  - Real-time multimedia transport (RTP, H.324, MPEG-2 Systems)
  - Multimedia file formats (especially derivates of ISO base media file format)
  - Multimedia communication systems
  - Subjective quality of audio-visual services
  - Multimedia applications and APIs for handheld devices
- Standardization:
  - H.263++, H.264/AVC, Scalable Video Coding (SVC), Multiview Video Coding (MVC)
  - IETF RTP payload formats for H.264/AVC and SVC
  - ISO base media file format, 3GP file format, DVB file format
  - 3GPP multimedia specifications, DLNA RTP profile, DVB IP data casting
- Read more: http://research.nokia.com/people/miska_hannuksela/

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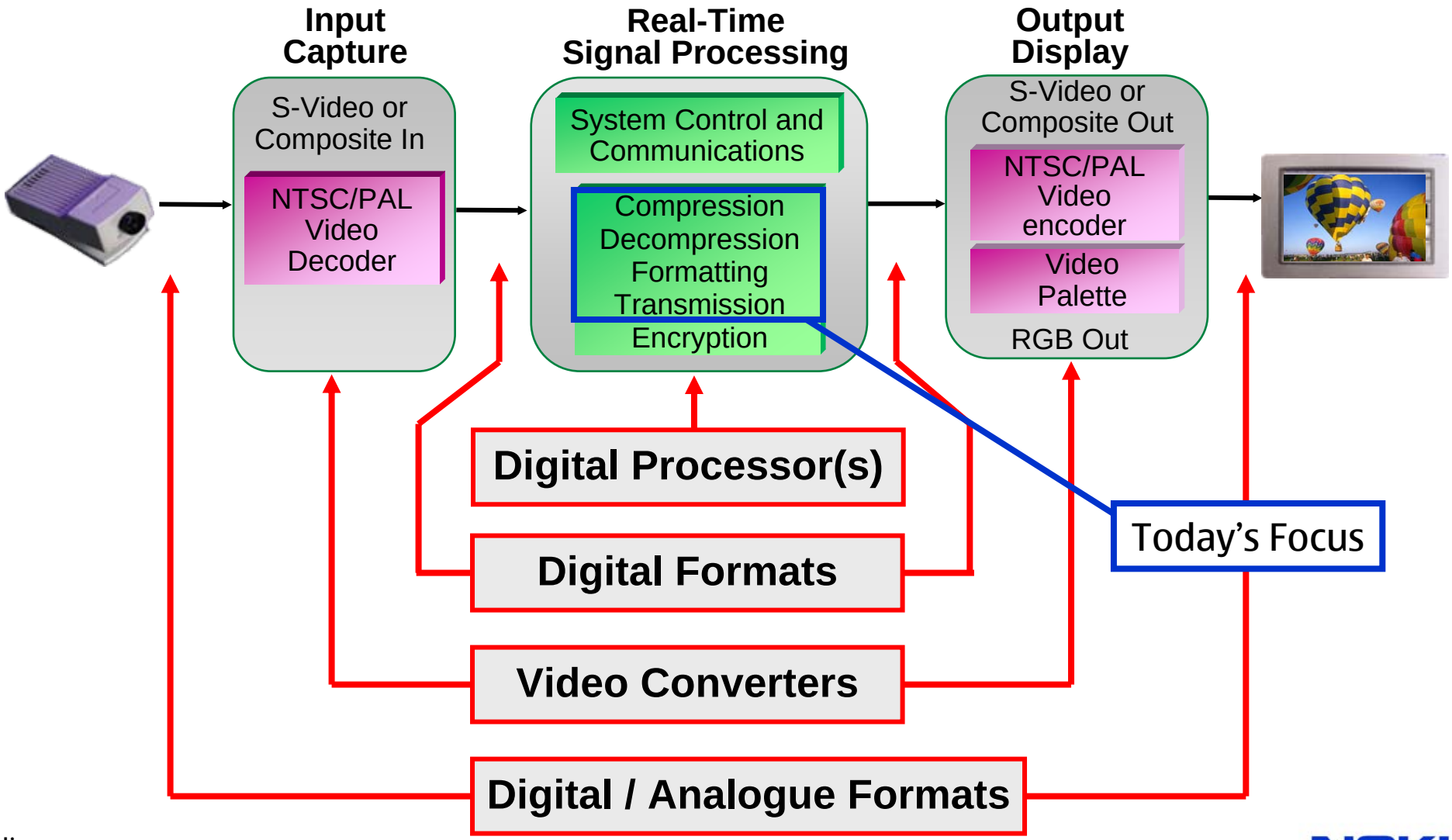
Outline

1. Scalable video coding:
basics, history, and motivation

2. Features of
the Scalable Video Coding (SVC) standard

3. Integration of SVC into services

Typical Digital Video System



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Scalable Video Coding

- Video is compressed once and played back at the optimal picture size for a display or optimal bit rate for a network
- Unified video content and services for mobile and wired use; anything from mobile to high-definition television

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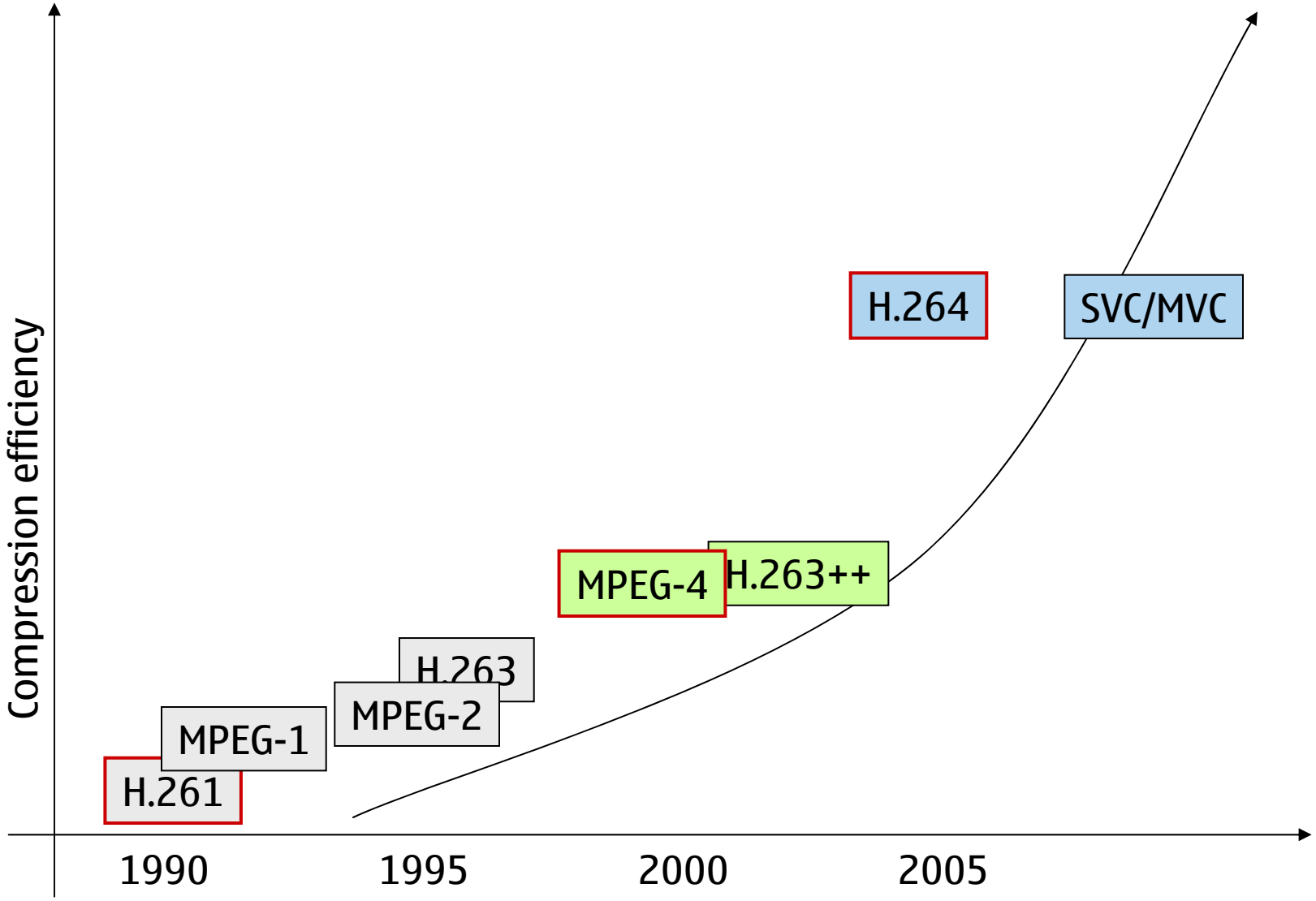
Types of Scalability

- Temporal Scalability
- Spatial Scalability
- Quality Scalability

Brief History of Video Coding Standards



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Applications of H.264/AVC

- High Definition Video
  - Blu-Ray Discs
  - HD Broadcasting
- Internet Video
  - YouTube high quality videos
- Mobile Multimedia
  - Mandatory or recommended in 3GPP and DVB-H
  - iPod Video

History of Scalable Video Coding Standards

- Temporal, spatial, and quality scalability have been included in all codecs since MPEG-2
- Only temporal scalability is used commonly
  - Improves compression efficiency
  - Fast forward and rewind functionality
- Spatial and quality scalability before SVC not used
  - Higher computational complexity and lower compression efficiency than in non-scalable codecs
- SVC has better chances to become widely used
  - The same compression efficiency as H.264/AVC with 10% bit rate increase (source: MPEG verification tests)
  - Single-loop decoding – moderate computational complexity increase in decoding
  - Built on top of H.264/AVC
  - Being adopted in all DVB services and ATSC M/H mobile television

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Why Scalable Video?

Internet and mobile transmission are
best-effort/shared-resource and
becoming primary distribution mechanisms
→ Need for graceful degradation, bitrate adaptation

Lot of mobile video applications
→ Need for power adaptation

Variety of terminals and display sizes: QCIF, QVGA, VGA, SD, HD
→ Need for resolution adaptation

Alternatives to Scalable Video Coding

- In unicast streaming
  - Multiple streams encoded for different bit rates
  - Switching between the streams according to network throughput and/or 3GPP PSS rate adaptation signaling
- In multicast/broadcast streaming
  - Simulcast = simultaneous transmission of multiple independent streams
- In few other services, such as multiparty conferencing
  - Transcoding = (partial) decoding and re-encoding

Benefits of Scalability – One Video Fits All

- A single scalable service can cover wide range of devices and networks
  - Today's widely deployed AVC decoders can always decode the base layer
  - No need to tailor services specifically for mobile use
  - Scalable video is a key enabler for Internet services suitable for both wireline and mobile use

- A single video fits all devices and environments
  - Same content can be played and shared among low-end and high-end devices
  - Playback is optimized for the available display resolution
  - Allows low-power playback in battery-constrained cases

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Benefits of Scalability – Improved User Experience

- When the same content is broadcast using multiple picture sizes, SVC brings considerable bit rate saving
  - E.g. 17% bit rate saving compared to H.264/AVC simulcast of QVGA and VGA [MPEG verification tests]
- Improved service continuity and resiliency against transmission errors
  - Unequal error protection in broadcasting
  - Unequal error protection in video conferencing
  - Resiliency against unexpected network throughput drops in point-to-point streaming [Schierl et al., ICIP 2005]
- Lower end-to-end delay in multiparty video conferencing
  - >100 msec one-way delay reduction [Eleftheriadis et al., 2006]
- Better picture quality in many services, as no transcoding required

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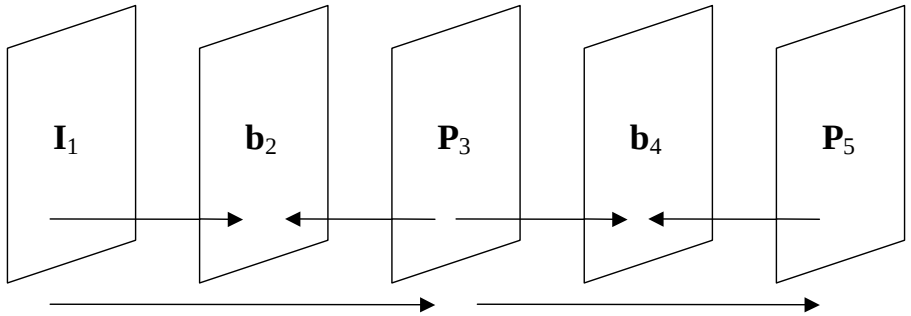
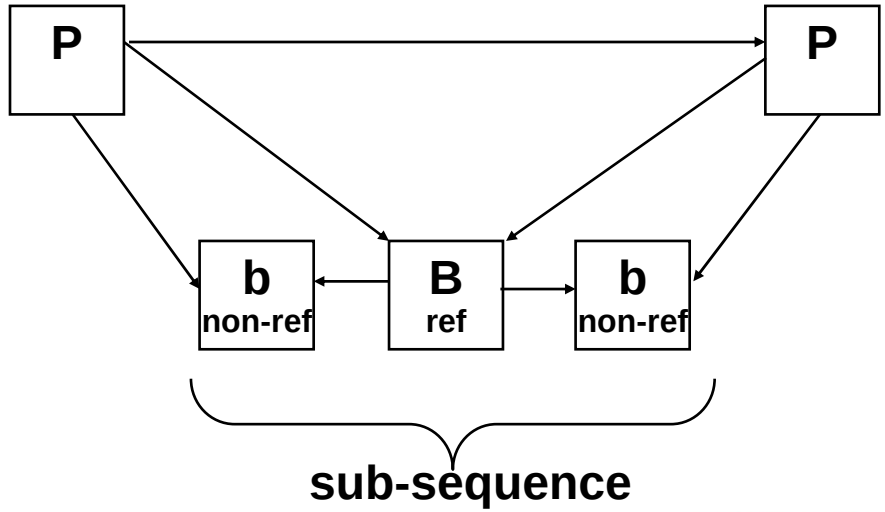
Temporal Scalability

1. Non-reference pictures



2. Hierarchical temporal scalability / disposable sub-sequences



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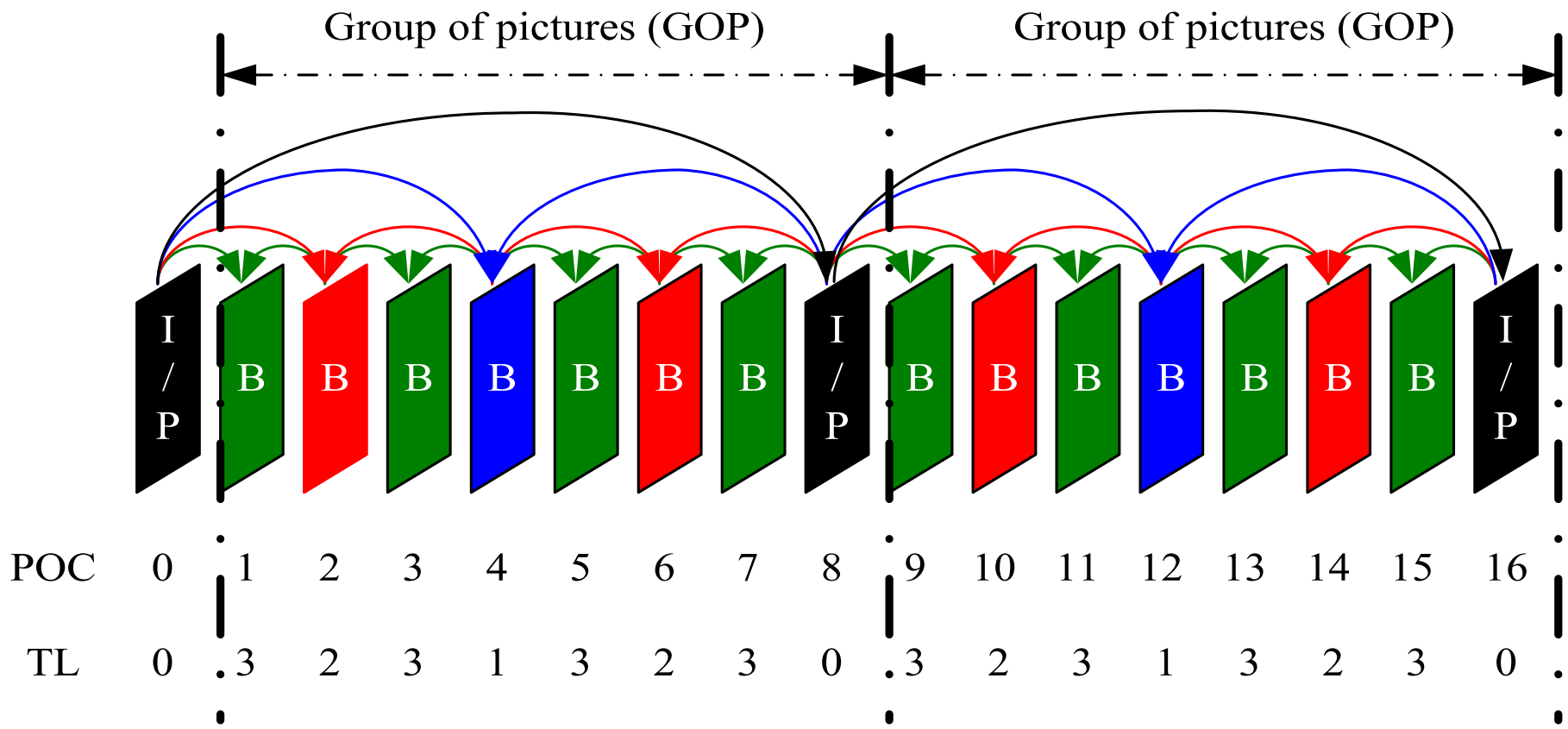
Temporal Scalability



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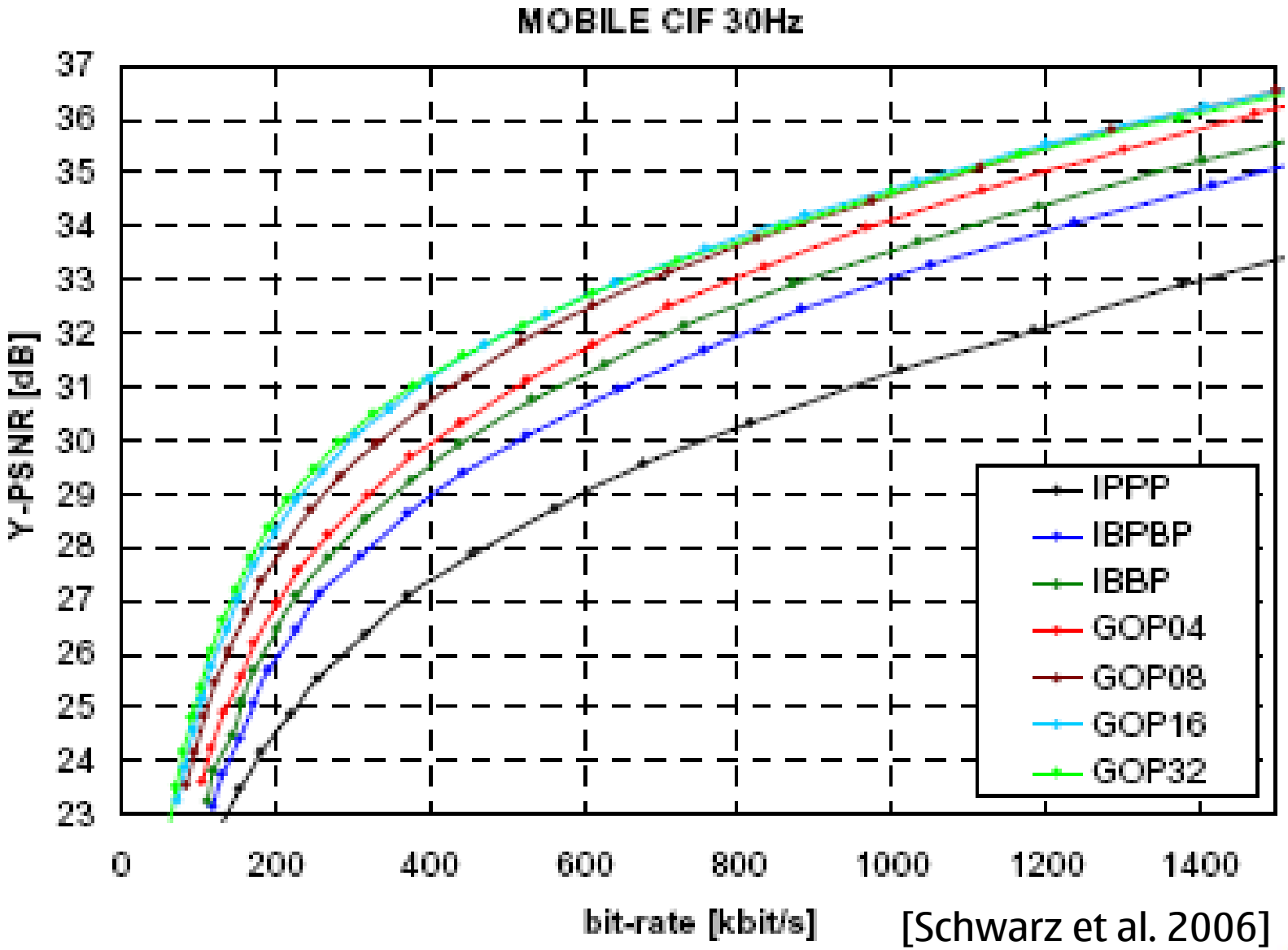
Compression Efficiency of Temporal Scalability



[Schwarz et al. 2006]

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Compression Efficiency of Temporal Scalability
(B pictures not in use)

Sequence	Compared to IPPP	
	PSNR Gain	***Bit-rate saving***
container	***1.388***	***7.19%***
foreman	***1.306***	***19.75%***
irene	***1.184***	***19.97%***
mobile	***3.163***	***42.95%***
news	***1.18***	***22.58%***
paris	***2.2***	***28.61%***
silent	***2.141***	***29.71%***
tempete	***2.128***	***34.14%***
Average	***1.836***	***25.61%***

[Wen et al., submitted to ISCAS 09]

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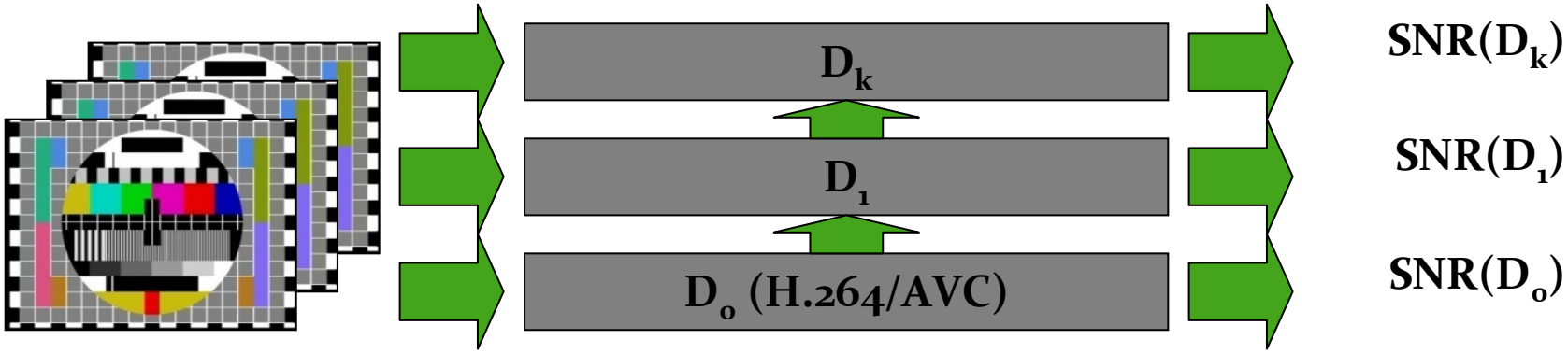
Spatial scalability

Quality Scalability

- Coding tools the same as in spatial scalability
- Two types:
  - Coarse Grain Scalability (CGS)
    - Switching between layers at IDR pictures
  - Medium Grain Scalability (MGS)
    - Finer quantization step deltas
    - Switching between layers at any position → controlled drift with base representation



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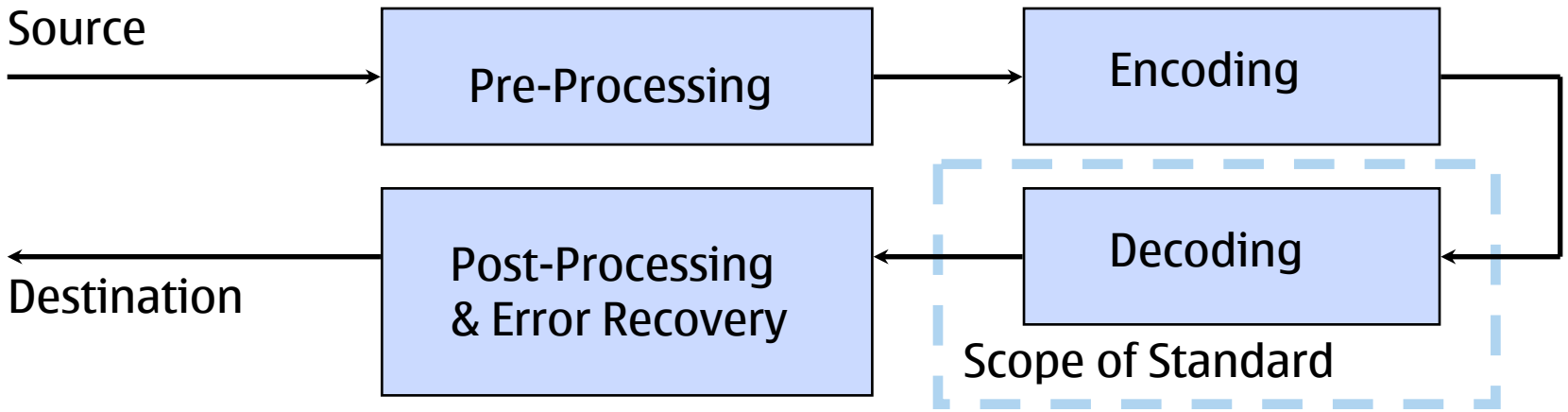
The Scope of Video Coding Standardization

Only restrictions on the bitstream, bitstream syntax, and decoder operation are standardized:

- Permits optimization beyond the obvious
- Permits complexity vs. compression efficiency trade-offs in encoders
- Provides no guarantees of quality



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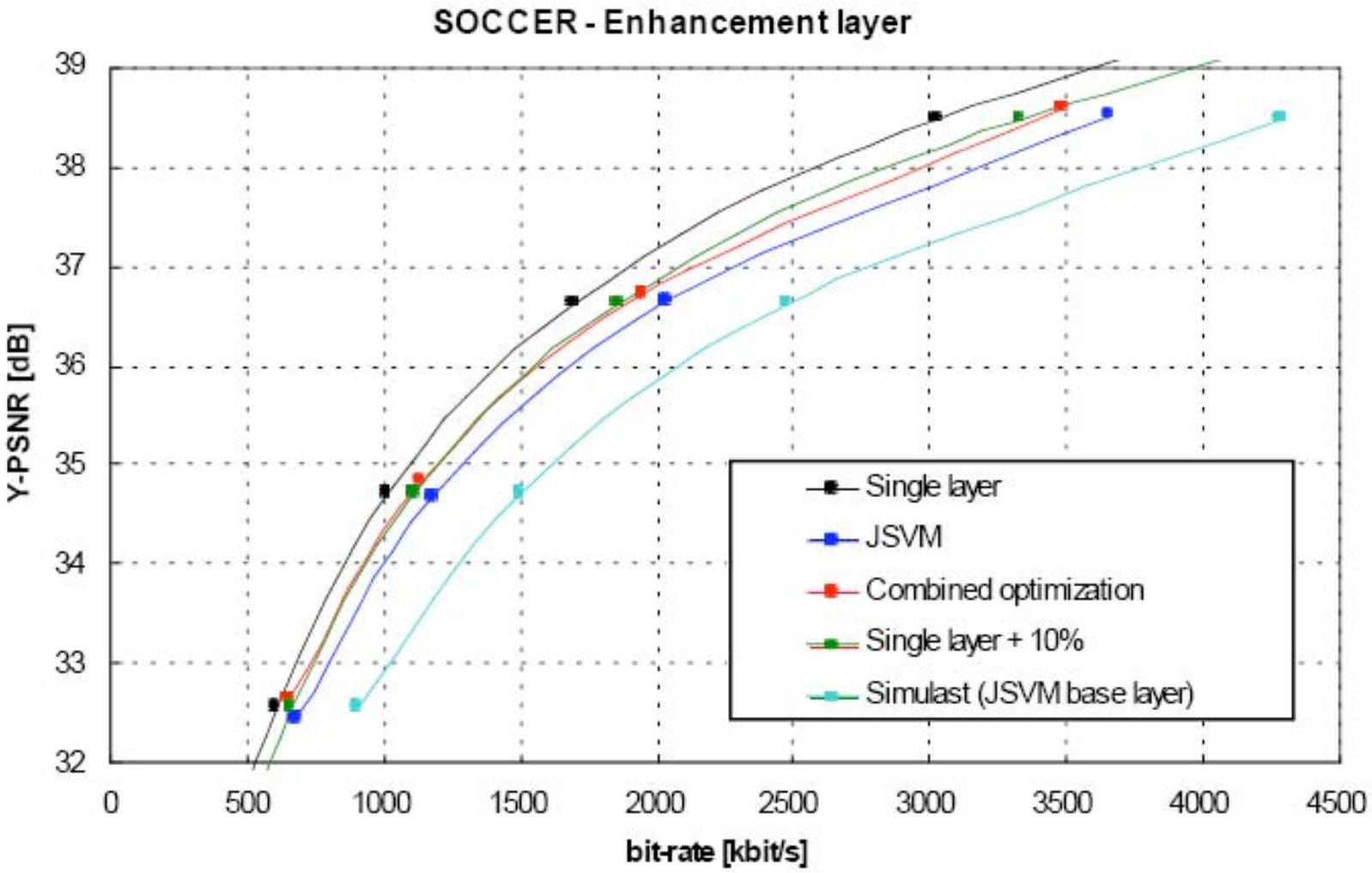
Joint Optimization Results: Spatial: CIF30Hz/4CIF30Hz



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Video Coding Standards - Profiles and Levels

- Profile
  - A subset of algorithmic features of the coding standard and constraints on the features
  - Decoders conforming to a profile shall be capable of supporting the entire subset of the algorithmic features of that profile
  - Encoders are not required to use a particular subset of a profile
  - A typically profile is targeted for a set of applications that share a similar trade-off between memory, processing, latency, and error resiliency requirements
- Level
  - A set of limits mainly on memory and computation performance parameters
  - Gives minimum limits for decoders
- Profile and level
  - Indicate characteristics of bitstreams. Can be used in session/stream description.
  - Indicate capabilities of decoders. Can be used in capability exchange process.

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SVC Profiles

- Scalable Baseline Profile
  - Resolution ratios of 1.5 and 2 between successive spatial layers in both horizontal and vertical direction and macroblock-aligned cropping
  - Progressive sources
  - Enhancement layers: B slices, weighted prediction, CABAC, 8x8 luma transform
  - Base layer conforms to the H.264/AVC constrained baseline profile
- Scalable High Profile
  - Restrictions of Scalable Baseline Profile are removed
  - Base layer conforms to the H.264/AVC high profile
- Scalable High Intra Profile
  - Professional applications
  - Only IDR pictures (for all layers)
  - Scalable High Profile is supported

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Accompanying Specifications

- SVC file format
  - Specifies how SVC streams are stored in MP4, 3GP, DVB, and other similar file formats
  - File metadata helping in adapting the stream
- SVC transport over MPEG-2 transport stream
  - For most digital television systems
- RTP payload format for SVC
  - For real-time SVC transport over IP networks
  - Technically stable, last call to be issued soon

Summary

- Types of scalability
  - Temporal
  - Spatial
  - Quality
- Benefits of scalability
  - One video fits all
  - Improved user experience
- SVC Performance
  - Temporal scalability improves compression efficiency significantly
  - Spatial and quality scalability: The same compression efficiency as H.264/AVC with 10% additional bitrate
  - ~15% bitrate saving for dyadic spatial scalability compared to simulcast
  - Cross-layer-optimized encoder needed for achieving the best compression gain
  - Single-loop decoding keeps decoding complexity reasonable