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Partie 10: Codage visuel avancé

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives or www.iec.ch/members_experts/refdocs)

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 29, *Coding of audio, picture, multimedia and hypermedia information*, in collaboration with ITU-T (as ITU-T H.264).

This eleventh edition cancels and replaces the tenth edition (ISO/IEC 14496-10:2022), which has been technically revised.

The main changes are as follows:

— the addition of support for neural-network post-filter characteristics, neural-network post-filter activation, phase indication SEI messages specified in Rec. ITU-T H.274 | ISO/IEC 23002-7, and additional colour type identifiers.

A list of all parts in the ISO/IEC 14496 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

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Introduction

0.1 Prologue

As the costs for both processing power and memory have reduced, network support for coded video data has diversified, and advances in video coding technology have progressed, the need has arisen for an industry standard for compressed video representation with substantially increased coding efficiency and enhanced robustness to network environments. Toward these ends the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG) formed a Joint Video Team (JVT) in 2001 for development of a new Recommendation | International Standard. The standard has since been maintained and enhanced jointly by VCEG and MPEG.

0.2 Purpose

This Recommendation | International Standard was developed in response to the growing need for higher compression of moving pictures for various applications such as videoconferencing, digital storage media, television broadcasting, internet streaming, and communication. It is also designed to enable the use of the coded video representation in a flexible manner for a wide variety of network environments. The use of this Recommendation | International Standard allows motion video to be manipulated as a form of computer data and to be stored on various storage media, transmitted and received over existing and future networks and distributed on existing and future broadcasting channels.

0.3 Applications

This Recommendation | International Standard is designed to cover a broad range of applications for video content including but not limited to the following:

- CATV: cable TV on optical networks, copper, etc.
- DBS: direct broadcast satellite video services.
- DSL: digital subscriber line video services.
- DTTB: digital terrestrial television broadcasting.
- ISM: interactive storage media (optical disks, etc.).
- MMM: multimedia mailing.
- MSPN: multimedia services over packet networks.
- RTC: real-time conversational services (videoconferencing, videophone, etc.).
- RVS: remote video surveillance.
- SSM: serial storage media (digital VTR, etc.).

0.4 Publication and versions of this document

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 1 refers to the first approved version of this Recommendation | International Standard.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 2 refers to the integrated text containing the corrections specified in the first technical corrigendum.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 3 refers to the integrated text containing both the first technical corrigendum (2004) and the first amendment, which is referred to as the "Fidelity range extensions".

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ITU-T Rec. H.264 | ISO/IEC 14496-10 version 4 refers to the integrated text containing the first technical corrigendum (2004), the first amendment (the "Fidelity range extensions"), and an additional technical corrigendum (2005).

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 5 refers to the integrated version 4 text with its specification of the High 4:4:4 profile removed.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 6 refers to the integrated version 5 text after its amendment to support additional colour space indicators.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 7 refers to the integrated version 6 text after its amendment to define five new profiles intended primarily for professional applications (the High 10 Intra, High 4:2:2 Intra, High 4:4:4 Intra, CAVLC 4:4:4 Intra, and High 4:4:4 Predictive profiles) and two new types of supplemental enhancement information (SEI) messages (the post-filter hint SEI message and the tone mapping information SEI message).

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 8 refers to the integrated version 7 text after its amendment to specify scalable video coding in three profiles (Scalable Baseline, Scalable High, and Scalable High Intra profiles).

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 9 refers to the integrated version 8 text after applying the corrections specified in a third technical corrigendum.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 10 refers to the integrated version 9 text after its amendment to specify a profile for multiview video coding (the Multiview High profile) and to define additional SEI messages.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 11 refers to the integrated version 10 text after its amendment to define a new profile (the Constrained Baseline profile) intended primarily to enable implementation of decoders supporting only the common subset of capabilities supported in various previously-specified profiles.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 12 refers to the integrated version 11 text after its amendment to define a new profile (the Stereo High profile) for two-view video coding with support of interlaced coding tools and to specify an additional SEI message specified as the frame packing arrangement SEI message. The changes for versions 11 and 12 were processed as a single amendment in the ISO/IEC approval process.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 13 refers to the integrated version 12 text with various minor corrections and clarifications as specified in a fourth technical corrigendum.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 14 refers to the integrated version 13 text after its amendment to define a new level (Level 5.2) supporting higher processing rates in terms of maximum macroblocks per second and a new profile (the Progressive High profile) to enable implementation of decoders supporting only the frame coding tools of the previously-specified High profile.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 15 refers to the integrated version 14 text with miscellaneous corrections and clarifications as specified in a fifth technical corrigendum.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 16 refers to the integrated version 15 text after its amendment to define three new profiles intended primarily for communication applications (the Constrained High, Scalable Constrained Baseline, and Scalable Constrained High profiles).

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 17 refers to the integrated version 16 text after its amendment to define additional supplemental enhancement information (SEI) message data, including the multiview view position SEI message, the display orientation SEI message, and two additional frame packing arrangement type indication values for the frame packing arrangement SEI message (the 2D content and tiled arrangement type indication values).

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ITU-T Rec. H.264 | ISO/IEC 14496-10 version 18 refers to the integrated version 17 text after its amendment to specify the coding of depth signals, including the specification of an additional profile, the Multiview Depth High profile.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 19 refers to the integrated version 18 text after incorporating a correction to the sub-bitstream extraction process for multiview video coding.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 20 refers to the integrated version 19 text after its amendment to specify the combined coding of video view and depth enhancement, including the specification of an additional profile, the Enhanced Multiview Depth High profile.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 21 refers to the integrated version 20 text after its amendment to specify additional colorimetry identifiers and an additional model type in the tone mapping information SEI message.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 22 refers to the integrated version 21 text after its amendment to specify multi-resolution frame-compatible (MFC) enhancement for stereoscopic video coding, including the specification of an additional profile, the MFC High profile.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 23 refers to the integrated version 22 text after its amendment to specify multi-resolution frame-compatible (MFC) stereoscopic video with depth maps, including the specification of an additional profile, the MFC Depth High profile, and the mastering display colour volume SEI message, additional colour-related video usability information codepoint identifiers, and miscellaneous minor corrections and clarifications.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 24 refers to the integrated version 23 text after its amendment to specify additional levels of decoder capability supporting larger picture sizes (Levels 6, 6.1, and 6.2), the green metadata SEI message, the alternative depth information SEI message, additional colour-related video usability information codepoint identifiers, and miscellaneous minor corrections and clarifications.

Rec. ITU-T H.264 | ISO/IEC 14496-10 version 25 refers to the integrated version 24 text after its amendment to specify the Progressive High 10 profile; support for additional colour-related indicators, including the hybrid log-gamma transfer characteristics indication, the alternative transfer characteristics SEI message, the IC_TC_P colour matrix transformation, chromaticity-derived constant luminance and non-constant luminance colour matrix coefficients, the colour remapping information SEI message, and miscellaneous minor corrections and clarifications.

Rec. ITU-T H.264 | ISO/IEC 14496-10 version 26 refers to the integrated version 25 text after its amendment to specify additional SEI messages for ambient viewing environment, content light level information, content colour volume, equirectangular projection, cubemap projection, sphere rotation, region-wise packing, omnidirectional viewport, SEI manifest, and SEI prefix indication, and miscellaneous minor corrections and clarifications.

Rec. ITU-T H.264 | ISO/IEC 14496-10 version 27 refers to the integrated version 26 text after its amendment to specify additional SEI messages for annotated regions (through referencing to Rec. ITU-T H.274 | ISO/IEC 23002-7) and shutter interval information, and miscellaneous minor corrections and clarifications.

Rec. ITU-T H.264 | ISO/IEC 14496-10 version 28 (the current document) refers to the integrated version 27 text after its amendment to specify additional SEI messages for neural-network post-filter characteristics, neural-network post-filter activation, and phase indication (through referencing to Rec. ITU-T H.274 | ISO/IEC 23002-7), additional colour type identifiers, and miscellaneous minor corrections and clarifications.

This edition corresponds in technical content to the fifteenth edition in ITU-T (approved in August 2024).

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0.5 Profiles and levels

This document is designed to be generic in the sense that it serves a wide range of applications, bit rates, resolutions, qualities, and services. Applications should cover, among other things, digital storage media, television broadcasting and real-time communications. In the course of creating this document, various requirements from typical applications have been considered, necessary algorithmic elements have been developed, and these have been integrated into a single syntax. Hence, this document will facilitate video data interchange among different applications.

Considering the practicality of implementing the full syntax of this document, however, a limited number of subsets of the syntax are also stipulated by means of "profiles" and "levels". These and other related terms are formally defined in Clause 3.

A "profile" is a subset of the entire bitstream syntax that is specified by this document. Within the bounds imposed by the syntax of a given profile it is still possible to require a very large variation in the performance of encoders and decoders depending upon the values taken by syntax elements in the bitstream such as the specified size of the decoded pictures. In many applications, it is currently neither practical nor economic to implement a decoder capable of dealing with all hypothetical uses of the syntax within a particular profile.

In order to deal with this problem, "levels" are specified within each profile. A level is a specified set of constraints imposed on values of the syntax elements in the bitstream. These constraints may be simple limits on values. Alternatively they may take the form of constraints on arithmetic combinations of values (e.g., picture width multiplied by picture height multiplied by number of pictures decoded per second).

Coded video content conforming to this document uses a common syntax. In order to achieve a subset of the complete syntax, flags, parameters, and other syntax elements are included in the bitstream that signal the presence or absence of syntactic elements that occur later in the bitstream.

0.6 Overview of the design characteristics

0.6.1 General

The coded representation specified in the syntax is designed to enable a high compression capability for a desired image quality. With the exception of the transform bypass mode of operation for lossless coding in the High 4:4:4 Intra, CAVLC 4:4:4 Intra, and High 4:4:4 Predictive profiles, and the I_PCM mode of operation in all profiles, the algorithm is typically not lossless, as the exact source sample values are typically not preserved through the encoding and decoding processes. A number of techniques may be used to achieve highly efficient compression. Encoding algorithms (not specified in this document) may select between inter and intra coding for block-shaped regions of each picture. Inter coding uses motion vectors for block-based inter prediction to exploit temporal statistical dependencies between different pictures. Intra coding uses various spatial prediction modes to exploit spatial statistical dependencies in the source signal for a single picture. Motion vectors and intra prediction modes may be specified for a variety of block sizes in the picture. The prediction residual is then further compressed using a transform to remove spatial correlation inside the transform block before it is quantized, producing an irreversible process that typically discards less important visual information while forming a close approximation to the source samples. Finally, the motion vectors or intra prediction modes are combined with the quantized transform coefficient information and encoded using either variable length coding or arithmetic coding.

Scalable video coding is specified in Annex F allowing the construction of bitstreams that contain sub-bitstreams that conform to this document. For temporal bitstream scalability, i.e., the presence of a sub-bitstream with a smaller temporal sampling rate than the bitstream, complete access units are removed from the bitstream when deriving the sub-bitstream. In this case, high-level syntax and inter prediction reference pictures in the bitstream are constructed accordingly. For spatial and quality bitstream scalability, i.e., the presence of a sub-bitstream with lower spatial resolution or quality than the

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bitstream, NAL units are removed from the bitstream when deriving the sub-bitstream. In this case, inter-layer prediction, i.e., the prediction of the higher spatial resolution or quality signal by data of the lower spatial resolution or quality signal, is typically used for efficient coding. Otherwise, the coding algorithm as described in the previous paragraph is used.

Multiview video coding is specified in Annex G allowing the construction of bitstreams that represent multiple views. Similar to scalable video coding, bitstreams that represent multiple views may also contain sub-bitstreams that conform to this document. For temporal bitstream scalability, i.e., the presence of a sub-bitstream with a smaller temporal sampling rate than the bitstream, complete access units are removed from the bitstream when deriving the sub-bitstream. In this case, high-level syntax and inter prediction reference pictures in the bitstream are constructed accordingly. For view bitstream scalability, i.e., the presence of a sub-bitstream with fewer views than the bitstream, NAL units are removed from the bitstream when deriving the sub-bitstream. In this case, inter-view prediction, i.e., the prediction of one view signal by data of another view signal, is typically used for efficient coding. Otherwise, the coding algorithm as described in the previous paragraph is used.

An extension of multiview video coding that additionally supports the inclusion of depth maps is specified in Annex H, allowing the construction of bitstreams that represent multiple views with corresponding depth views. In a similar manner as with the multiview video coding specified in Annex G, bitstreams encoded as specified in Annex H may also contain sub-bitstreams that conform to this document.

A multiview video coding extension with depth information is specified in Annex I. Sub-bitstreams consisting of a texture base view conform to this document, sub-bitstreams consisting of multiple texture views may also conform to Annex G of this document, and sub-bitstreams consisting of one or more texture views and one or more depth views may also conform to Annex H of this document. Enhanced texture view coding that utilizes the associated depth views and decoding processes for depth views are specified for this extension.

Rec. ITU-T H.274 | ISO/IEC 23002-7 specifies the syntax and semantics of supplemental enhancement information (SEI) messages that do not affect the conformance specifications in Annex C and subclauses F.8, G.8, H.8, and I.8. Among these SEI messages, those for which the syntax and semantics are not specified in this document may be used together with this document. SEI messages for which the syntax and semantics are specified in this document may always be used together with this document. To enable being used together with this document, the SEI payload type value of an SEI message specified in Rec. ITU-T H.274 | ISO/IEC 23002-7 needs to be specified in this document. For example, the SEI payload type value 202 (for the annotated regions SEI message) is specified in subclause D.1.1, while the syntax and semantics of that SEI message are specified in Rec. ITU-T H.274 | ISO/IEC 23002-7.

0.6.2 Predictive coding

Because of the conflicting requirements of random access and highly efficient compression, two main coding types are specified. Intra coding is done without reference to other pictures. Intra coding may provide access points to the coded sequence where decoding can begin and continue correctly, but typically also shows only moderate compression efficiency. Inter coding (predictive or bi-predictive) is more efficient using inter prediction of each block of sample values from some previously decoded picture selected by the encoder. In contrast to some other video coding standards, pictures coded using bi-predictive inter prediction may also be used as references for inter coding of other pictures.

The application of the three coding types to pictures in a sequence is flexible, and the order of the decoding process is generally not the same as the order of the source picture capture process in the encoder or the output order from the decoder for display. The choice is left to the encoder and will depend on the requirements of the application. The decoding order is specified such that the decoding of pictures that use inter-picture prediction follows later in decoding order than other pictures that are referenced in the decoding process.

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0.6.3 Coding of progressive and interlaced video

This document specifies a syntax and decoding process for video that originated in either progressive-scan or interlaced-scan form, which may be mixed together in the same sequence. The two fields of an interlaced frame are separated in capture time while the two fields of a progressive frame share the same capture time. Each field may be coded separately or the two fields may be coded together as a frame. Progressive frames are typically coded as a frame. For interlaced video, the encoder can choose between frame coding and field coding. Frame coding or field coding can be adaptively selected on a picture-by-picture basis and also on a more localized basis within a coded frame. Frame coding is typically preferred when the video scene contains significant detail with limited motion. Field coding typically works better when there is fast picture-to-picture motion.

0.6.4 Picture partitioning into macroblocks and smaller partitions

As in previous video coding Recommendations and International Standards, a macroblock, consisting of a 16x16 block of luma samples and two corresponding blocks of chroma samples, is used as the basic processing unit of the video decoding process.

A macroblock can be further partitioned for inter prediction. The selection of the size of inter prediction partitions is a result of a trade-off between the coding gain provided by using motion compensation with smaller blocks and the quantity of data needed to represent the data for motion compensation. In this document the inter prediction process can form segmentations for motion representation as small as 4x4 luma samples in size, using motion vector accuracy of one-quarter of the luma sample grid spacing displacement. The process for inter prediction of a sample block can also involve the selection of the picture to be used as the reference picture from a number of stored previously-decoded pictures. Motion vectors are encoded differentially with respect to predicted values formed from nearby encoded motion vectors.

Typically, the encoder calculates appropriate motion vectors and other data elements represented in the video data stream. This motion estimation process in the encoder and the selection of whether to use inter prediction for the representation of each region of the video content is not specified in this document.

0.6.5 Spatial redundancy reduction

Both source pictures and prediction residuals have high spatial redundancy. This document is based on the use of a block-based transform method for spatial redundancy removal. After inter prediction from previously-decoded samples in other pictures or spatial-based prediction from previously-decoded samples within the current picture, the resulting prediction residual is split into 4x4 blocks. These are converted into the transform domain where they are quantized. After quantization many of the transform coefficients are zero or have low amplitude and can thus be represented with a small amount of encoded data. The processes of transformation and quantization in the encoder are not specified in this document.

0.7 How to read this document

It is suggested that the reader starts with Clause 1 (Scope) and moves on to Clause 3 (Terms and Terms and definitions). Clause 6 should be read for the geometrical relationship of the source, input, and output of the decoder. Clause 7 (Syntax and semantics) specifies the order to parse syntax elements from the bitstream. See subclauses 7.1 to 7.3 for syntactical order and see subclause 7.4 for semantics; i.e., the scope, restrictions, and conditions that are imposed on the syntax elements. The actual parsing for most syntax elements is specified in Clause 9 (Parsing process). Finally, Clause 8 (Decoding process) specifies how the syntax elements are mapped into decoded samples. Throughout reading this document, the reader should refer to Clauses 2 (Normative references), 4 (Abbreviated terms), and 5 (Conventions) as needed. Annexes A through I also form an integral part of this document.

Annex A specifies fourteen profiles (Baseline, Constrained Baseline, Main, Extended, High, Progressive High, Constrained High, High 10, High 4:2:2, High 4:4:4 Predictive, High 10 Intra,

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High 4:2:2 Intra, High 4:4:4 Intra, and CAVLC 4:4:4 Intra), each being tailored to certain application domains, and defines the so-called levels of the profiles. Annex B specifies syntax and semantics of a byte stream format for delivery of coded video as an ordered stream of bytes. Annex C specifies the hypothetical reference decoder and its use to check bitstream and decoder conformance. Annex D specifies syntax and semantics for supplemental enhancement information message payloads. Annex E specifies syntax and semantics of the video usability information parameters of the sequence parameter set.

Annex F specifies scalable video coding (SVC). The reader is referred to Annex F for the entire decoding process for SVC, which is specified there with references being made to Clauses 2 to 9 and Annexes A to E. Subclause F.10 specifies five profiles for SVC (Scalable Baseline, Scalable Constrained Baseline, Scalable High, Scalable Constrained High, and Scalable High Intra).

Annex G specifies multiview video coding (MVC) and multi-resolution frame compatible stereo coding (MFC). The reader is referred to Annex G for the entire decoding process for MVC and MFC, which is specified there with references being made to Clauses 2 to 9 and Annexes A to F. Subclause G.10 specifies two profiles for MVC (Multiview High and Stereo High) and one profile for MFC (MFC High).

Annex H specifies MVC extensions for inclusion of depth maps, referred to as multiview video coding with depth (MVCD). The reader is referred to Annex H for the entire decoding process for MVCD, which is specified there with references being made to Clauses 2 to 9 and Annexes A to G. Subclause H.10 specifies two profiles for MVCD (Multiview Depth High and MFC Depth High).

Annex I specifies a multiview video coding extension with depth information (3D-AVC). The reader is referred to Annex I for the entire decoding process for 3D-AVC, which is specified there with references being made to Clauses 2 to 9 and Annexes A to E, G, and H. Subclause I.10 specifies one profile for 3D-AVC.

Rec. ITU-T H.274 | ISO/IEC 23002-7 specifies the syntax and semantics of some video usability information (VUI) parameters and supplemental enhancement information (SEI) messages that do not affect the conformance specifications in Annex C and subclauses F.8, G.8, H.8, and I.8. Among these SEI messages, those for which the syntax and semantics are not specified in this document may be used together with this document.

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Information technology — Coding of audio-visual objects —

Part 10: Advanced video coding

1 Scope

This document specifies advanced video coding for coding of audio-visual objects.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Rec. ITU-T H.274 | ISO/IEC 23002-7, *Versatile supplemental enhancement information messages for coded video bitstreams*

Rec. ITU-T T.35, *Procedure for the allocation of ITU-T defined codes for non-standard facilities*

ISO/IEC 11578:1996, *Information technology — Open Systems Interconnection — Remote Procedure Call (RPC)*

ISO 11664-1, *Colorimetry — Part 1: CIE standard colorimetric observers*

ISO 12232, *Photography – Digital still cameras – Determination of exposure index, ISO speed ratings, standard output sensitivity, and recommended exposure index*

ISO/IEC 23001-11, *Information technology — MPEG systems technologies — Part 11: Energy-efficient media consumption (green metadata)*

IETF RFC 3986, *Uniform Resource Identifiers (URI): Generic Syntax*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

—ISO Online browsing platform: available at https://www.iso.org/obp

—IEC Electropedia: available at https://www.electropedia.org/

3.1 General terms related to advanced video coding

3.1.1
access unit
<general advanced video coding> set of *NAL units* that are consecutive in *decoding order* and contain exactly one *primary coded picture*

Note 1 to entry: In addition to the primary coded picture, an access unit can also contain one or more redundant coded pictures, one auxiliary coded picture, or other NAL units not containing slices or slice data partitions of a coded picture. The decoding of an access unit always results in a decoded picture.

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