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Foreword

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ISO/IEC 15444-11 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. The identical text is published as ITU-T Rec. T.810.

ISO/IEC 15444 consists of the following parts, under the general title *Information technology — JPEG 2000 image coding system*:

- *Part 1: Core coding system*
- *Part 2: Extensions*
- *Part 3: Motion JPEG 2000*
- *Part 4: Conformance testing*
- *Part 5: Reference software*
- *Part 6: Compound image file format*
- *Part 8: Secure JPEG 2000*
- *Part 9: Interactivity tools, APIs and protocols*
- *Part 10: Extensions for three-dimensional data*
- *Part 11: Wireless*
- *Part 12: ISO base media file format*
- *Part 13: An entry level JPEG 2000 encoder*

INTERNATIONAL STANDARD
ITU-T RECOMMENDATION

Information technology – JPEG 2000 image coding system: Wireless

1 Scope

This Recommendation | International Standard defines, in an extensible manner, syntaxes and methods for the protection against errors that may occur during the transmission of JPEG 2000 codestreams compliant with ITU-T Rec. T.800 | ISO/IEC 15444-1.

In this Recommendation | International Standard, these are referred to as Wireless JPEG 2000, "JPWL", and applications using JPWL are referred to as a "JPWL system".

JPWL specifies a set of tools consisting of additional data structures to JPEG 2000 codestreams and error protection techniques, necessary for error correction and signalling. This Recommendation | International Standard includes definitions of the semantics, and suggests how these may be used.

2 Normative references

The following Recommendations and International Standards contain provisions which, through reference in this text, constitute provisions of this Recommendation | International Standard. At the time of publication, the editions indicated were valid. All Recommendations and Standards are subject to revision, and parties to agreements based on this Recommendation | International Standard are encouraged to investigate the possibility of applying the most recent edition of the Recommendations and Standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards. The Telecommunication Standardization Bureau of the ITU maintains a list of currently valid ITU-T Recommendations.

– ITU-T Recommendation T.800 (2002) | ISO/IEC 15444-1:2004, *Information technology – JPEG 2000 image coding system: Core coding system*.

3 Terms and definitions

For the purposes of this Recommendation | International Standard, the following terms and definitions apply. The definitions defined in ITU-T Rec. T.800 | ISO/IEC 15444-1 clause 3 apply to this Recommendation | International Standard.

3.1 backward compatible: Includes all techniques that produce a bitstream that will lead the Part-1 decoder to decode/display according to JPEG 2000 Part 4 (ITU-T Rec. T.803 | ISO/IEC 15444-4) specifications in case of error-free environment.

3.2 backward compatible with extensions: Includes all techniques that produce a bitstream that will not lead the Part-1 decoder to crash in case of error-free environment. A JPWL decoder is required to correctly decode/display images.

3.3 big endian: The bits of a value representation occur in order from most significant to least significant.

3.4 bitstream: The sequence of bits resulting from the coding of a sequence of symbols. It does not include the markers or marker segments in the main and tile-part headers or the EOC marker. It does include any packet headers and in stream markers and marker segments not found within the main or tile-part headers.

3.5 Bit Error Rate (BER): The BER is defined as the statistical expected value of the ratio between the number of erroneous bits in the received data and the size of the received data themselves.

3.6 code-block: A rectangular grouping of coefficients from the same subband of a tile-component.

3.7 codestream: A collection of one or more bit streams and the main header, tile-part headers, and the EOC required for their decoding and expansion into image data. This is the image data in a compressed form with all of the signalling needed to decode.

3.8 **data partitioning**: Data partitioning is a modification of the organization of the codestream, with a separation of the compressed data in different parts.

3.9 **decoder**: An embodiment of a decoding process, and optionally a colour transformation process.

3.10 **decoding process**: A process which takes as its input all or part of a codestream and outputs all or part of a reconstructed image.

3.11 **encoder**: An embodiment of an encoding process.

3.12 **encoding process**: A process that takes as its input all or part of a source image data and outputs a codestream.

3.13 **Forward Error Correction (FEC)**: The FEC consists of any techniques aiming at providing error detection and/or correction capability by adding redundancy to the codestream.

3.14 **interleaving**: Interleaving is a modification of the data ordering of a codestream.

3.15 **JPWL Registration Authority**: An organization that is in charge of delivering a unique ID to reference a JPWL tool and storing the parameter list of its description.

3.16 **layer**: A collection of compressed image data from coding passes of one, or more, code-blocks of a tile-component. Layers have an order for encoding and decoding that must be preserved.

3.17 **little endian**: The bits of a value representation occur in order from least significant to most significant.

3.18 **marker**: A two-byte code in which the first byte is hexadecimal FF (0xFF) and the second byte is a value between 1 (0x01) and hexadecimal FE (0xFE).

3.19 **marker segment**: A marker and associated (not empty) set of parameters.

3.20 **non-backward compatible**: Includes all techniques that produce a bitstream that may lead the JPEG 2000 Part 1 decoder to crash also in case of error-free environment. This kind of technique is outside of the scope of this Recommendation | International Standard.

3.21 **packet**: A part of the bitstream comprising a packet header and the compressed image data from one layer of oneprecinct of one resolution level of one tile-component.

3.22 **packet header**: Portion of the packet that contains signalling necessary for decoding that packet.

3.23 **Packet Loss Rate (PLR)**: The PLR is defined as the statistical expected value of the ratio between the number of packets discarded during the transmission, and the number of packets sent during the transmission. Within this definition, it is intended that a packet is considered at transmission level, and not as a basic entity of a JPEG 2000 codestream.

3.24 **pointer markers and pointer marker segments**: Markers and marker segments that offer information about the location of structures in the codestream.

3.25 **precinct**: A rectangular region of a transformed tile-component, within each resolution level, used for limiting the size of packets.

3.26 **precision**: Number of bits allocated to a particular sample, coefficient, or other binary numerical representation.

3.27 **systematic codes**: A systematic code is one that produces a given number of redundancy symbols in addition to the original input data symbols.

3.28 **tile**: A rectangular array of points on the reference grid, registered with and offset from the reference grid origin and defined by a width and height. The tiles which overlap are used to define tile-components.

3.29 **tile-component**: All the samples of a given component in a tile.

3.30 **tile index**: The index of the current tile ranging from zero to the number of tiles minus one.

3.31 **tile-part**: A portion of the codestream with compressed image data for some, or all, of a tile. The tile-part includes at least one, and up to all, of the packets that make up the coded tile.

3.32 **tile-part header**: A group of markers and marker segments at the beginning of each tile-part in the codestream that describe the tile-part coding parameters.

3.33 **transcoder**: An embodiment of a transcoding process.

3.34 transcoding process: A process which takes as its input all or part of a codestream and outputs all or parts of it, together with the possible addition of other data.

3.35 Unequal Error Protection (UEP): UEP refers to the act of assigning different degrees of error protection to different parts of a codestream.

4 Symbols and abbreviated terms

4.1 Abbreviations

For the purposes of this Recommendation | International Standard, the following abbreviations apply.

ITU	International Telecommunication Union
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector (formerly the CCITT)
JPEG	Joint Photographic Experts Group – The joint ISO/IEC/ITU committee responsible for developing standards for continuous-tone still picture coding. It also refers to the standards produced by this committee: ISO/IEC 10918 and their corresponding ITU-T Recommendations.
JPEG 2000	Joint Photographic Experts Group – The joint ISO/IEC/ITU committee responsible for developing standards for continuous-tone still picture coding. It also refers to the standards produced by this committee: ISO/IEC 15444 and their corresponding ITU-T Recommendations.
JPEG 2000 Part 1	Refers to Part 1 of JPEG 2000, ITU-T Rec. T.800 | ISO/IEC 15444-1.
JPEG 2000 Part 11	Refers to this Recommendation | International Standard.
JPWL	Refers to this Recommendation | International Standard.
RA	Registration Authority

4.2 Symbols

For the purposes of this Recommendation | International Standard, the following symbols apply.

0x----	Denotes a hexadecimal number.
\nnn	A three-digit number preceded by a backslash indicates the value of a single byte within a character string, where the three digits specify the octal value of that byte.
ε_b	Exponent of the error sensitivity value defined in ESD
μ_b	Mantissa of the error sensitivity value defined in ESD
BCH	Bose-Chaudhuri-Hocquenghem
COC	Coding style component marker
COD	Coding style default marker
COM	Comment marker
CRC	Cyclic Redundancy Check
CRG	Component Registration Marker
EOC	End of Codestream marker
EPB	Error Protection Block marker
EPC	Error Protection Capability marker
EPH	End of Packet Header marker
ESD	Error Sensitivity Descriptor marker
FEC	Forward Error Correction

PLM Packet Length, Main header marker

PLT Packet Length, Tile-part header marker

POC Progression Order Change marker

PPM Packed Packet headers, Main header marker

PPT Packed Packet headers, Tile-part header marker

QCC Quantization Component marker

QCD Quantization Default marker

RED Residual Error Descriptor marker

RGN Region of interest marker

RS Reed Solomon

SIZ Image and tile size marker

SOC Start of Codestream marker

SOD Start of Data marker

SOP Start of Packet marker

SOT Start of Tile-part marker

TLM Tile-part Lengths Marker

UEP Unequal Error Protection

5 JPWL general description

5.1 Introduction

This Recommendation | International Standard defines a set of tools and methods to achieve the efficient transmission of JPEG 2000 Part 1 imagery over an error-prone transmission/storage environment. The main target of this Recommendation | International Standard is wireless applications, although the same tools can be employed in other types of applications, which are prone to errors.

Wireless networks are characterized by the frequent occurrence of transmission errors, henceforth putting strong constraints on the transmission of digital images. Since JPEG 2000 provides high compression efficiency, it is a good candidate for wireless multimedia applications. Moreover, due to its high scalability, JPEG 2000 enables a wide range of quality of service strategies for network operators. However, to be suitable for wireless multimedia applications, JPEG 2000 has to be robust to transmission errors.

ITU-T Rec. T.800 | ISO/IEC 15444-1 defines error-resilience tools to improve performances over noisy channels. However, these tools can only detect occurrences of errors in the bitstream, conceal the erroneous data, and resynchronize the decoder. More specifically, they do not correct transmission errors. Furthermore, these tools do not apply to the main and tile-part headers which are the most important parts of the codestream. For these reasons, they are not sufficient in the context of wireless transmissions.

For the purpose of efficient transmission over error-prone transmission/storage environments, this Recommendation | International Standard defines additional mechanisms for error protection and correction. These mechanisms extend the elements in the core coding system described in ITU-T Rec. T.800 | ISO/IEC 15444-1. These extensions are backward compatible or backward compatible with extensions, as specified in clause 3.

This Recommendation | International Standard is not linked to a specific network or transport protocol, but provides a general solution for the robust transmission of JPEG 2000 imagery over error-prone channels and networks. JPWL would normally act at the application level. However, if appropriate, the JPWL tools can be used for direct transmission of images on the channel physical layer.

5.2 JPWL system description

The main functionalities of the JPWL system are to protect the codestream against transmission errors, to describe the degree of sensitivity to transmission errors of different parts of the codestream, and to describe the locations of residual errors in the codestream.

The JPWL system can either be applied to an input source image or to a Part 1 codestream, as is illustrated in Figures 1 and 2 respectively. In Figure 1, at the transmission side, a JPWL encoder consists of three modules running concurrently: a JPEG 2000 Part 1 encoder compressing the input image, a generator of the error sensitivity description, and a processor applying the error protection tool. The result is a JPEG 2000 Part 11 codestream robust to transmission errors. At the receiving side, a JPWL decoder is also composed of three modules: a processor to correct errors, a generator of the residual errors description and a JPEG 2000 Part 1 decoder. Alternatively, in Figure 2 at the transmission side a JPWL transcoder processes a JPEG 2000 Part 1 codestream, generating the error sensitivity description and applying error protection tools. At the receiving side, a JPWL transcoder corrects the transmission errors and generate the residual errors description, producing a Part 1 codestream which can be sent to a Part 1 decoder, along with residual errors information.

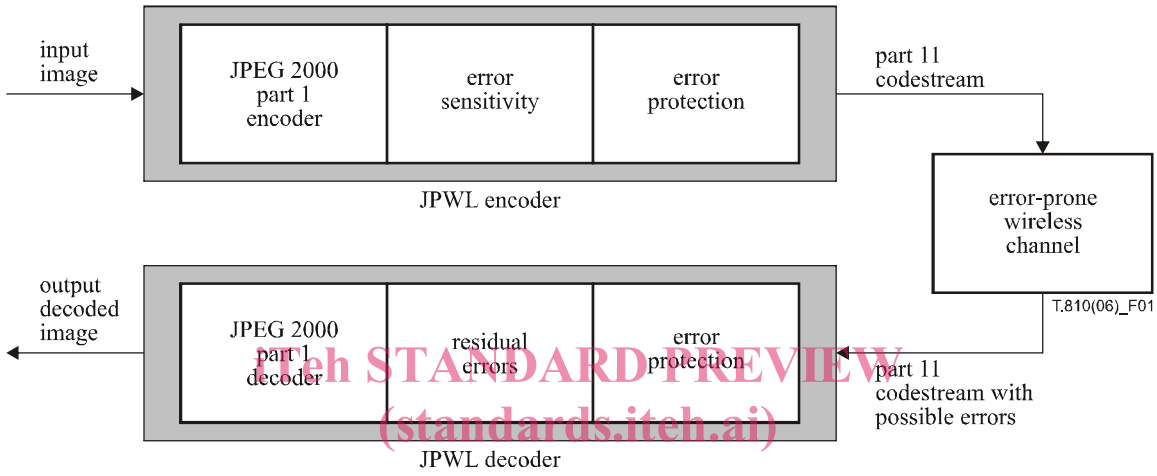

Figure 1 – JPWL system description: JPWL encoder and decoder

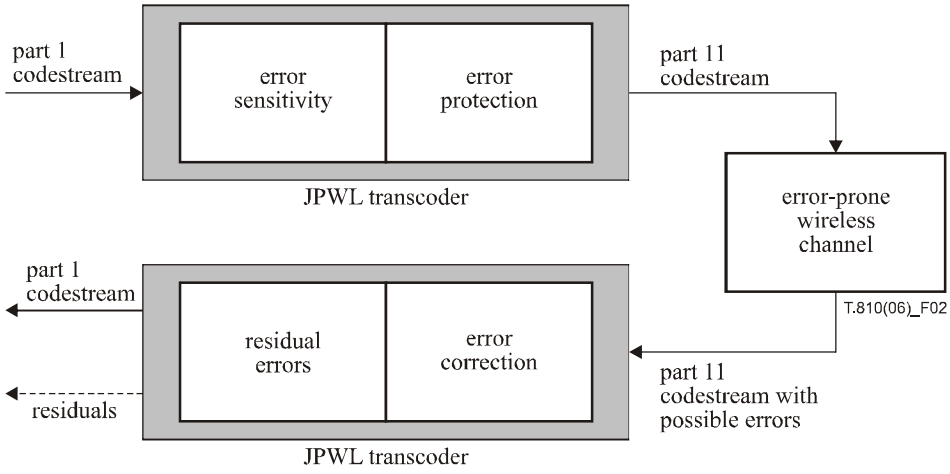

Figure 2 – JPWL system description: JPWL transcoder

Other similar configurations are also possible as illustrated in Figures 3 and 4. Whereas in Figures 1 and 2 the generation of the error sensitivity description and the application of the error protection tool are concurrent, in Figures 3 and 4 the two operations are performed successively. More precisely, in a first step, a JPWL encoder/transcoder produces a JPEG 2000 Part 11 codestream containing error sensitivity information. In a second step, a JPWL transcoder uses this information to optimize the error protection tool, generating a JPEG 2000 Part 11 codestream robust to transmission errors.

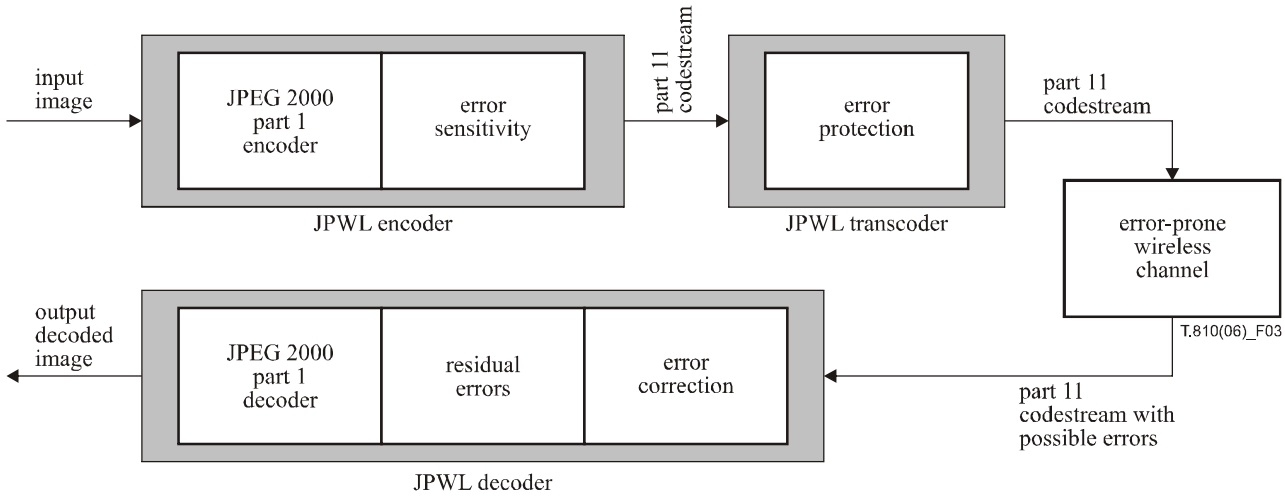

Figure 3 – JPWL system description: another configuration

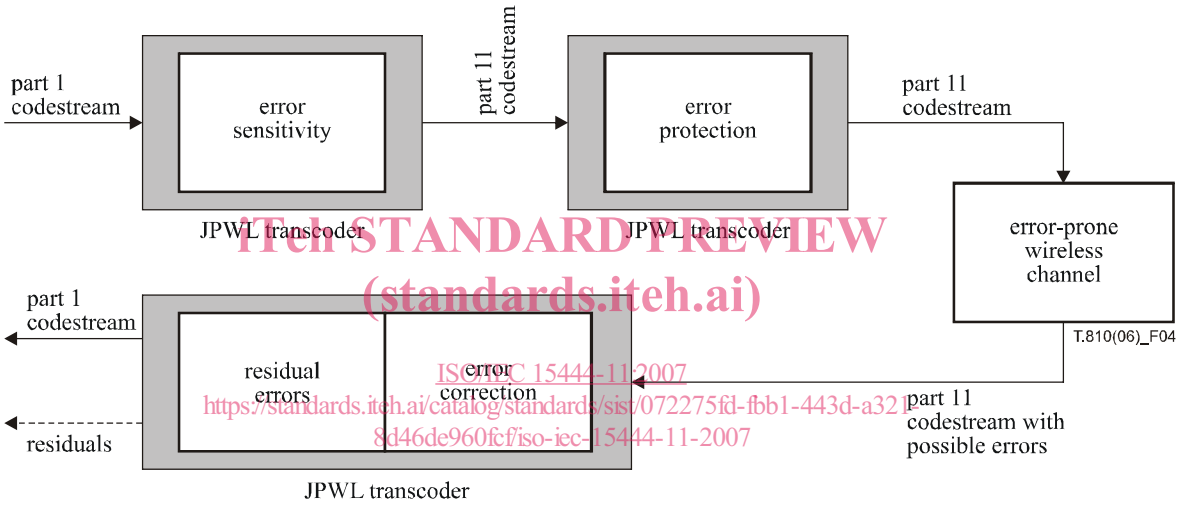

Figure 4 – JPWL system description: another configuration

The error protection process modifies the codestream to make it more resilient to errors, e.g., by adding redundancy or by partitioning and interleaving the data. The error correction process detects the occurrence of errors and corrects them whenever possible. Techniques to protect the codestream include Forward Error Correcting (FEC) codes, data partitioning and interleaving, robust entropy coding, and unequal error protection.

The error sensitivity descriptor describes the degree of sensitivity of different parts of the codestream to transmission errors. This information is typically generated when the image is encoded using a JPEG 2000 Part 1 encoder (e.g., Figures 1 and 3), but it can also be directly derived from a Part 1 codestream (e.g., Figures 2 and 4). This information can subsequently be used when protecting the image. More specifically, sensitive parts of the codestream can be more strongly protected than less sensitive parts (unequal error protection).

The residual errors descriptor specifies the locations of residual errors in the codestream. The residual errors are the errors which cannot be corrected by the error protection tool. This information is typically generated during the error correction process. This information can subsequently be used in the JPEG 2000 Part 1 decoder to prevent decoding of corrupted parts of the stream.

The above figures, describing the JPWL system, are examples and different configurations are possible.

JPWL system has provision for future techniques, in addition to those described in this Recommendation | International Standard. The process of adding new techniques is managed by the Registration Authority as described in Annex K.

6 JPWL normative parts

An encoding process converts source image data to compressed image data. All encoding processes are specified informatively.

An encoder is an embodiment of the encoding process. In order to conform to this Recommendation | International Standard, an encoder shall convert source image data to compressed image data that conform to the codestream syntax specified in Annex A.

A decoding process converts compressed image data to reconstructed image data. Some parts of a decoding process are normative, and namely those related to extracting information contained in the JPEG 2000 Part 11 specific marker segments, as well as those that refer to the decoding of JPEG 2000 Part 1 features. All other aspects of the decoding process, for instance the procedure that the decoder shall follow in order to cope with the possible presence of errors and the actions it shall take to minimize their effect, are not specified as part of this Recommendation | International Standard; guidelines are however specified in Annex G.

A decoder is an embodiment of the decoding process. In order to conform to this Recommendation | International Standard, a decoder shall convert all, or specific parts of, any compressed image data that conform to the codestream syntax specified in Annex A to a reconstructed image.

There is no normative or required implementation for the encoder or decoder. In some cases, the descriptions use particular implementation techniques for illustrative purposes only.

Annex A describes the syntax that defines the coded representation of compressed image data for exchange between application environments. Any compressed image data shall comply with the syntax and code assignments appropriate for the coding processes defined in this Recommendation | International Standard.

The remainder of this clause outlines the normative parts of this Recommendation | International Standard and refers to the respective annexes for detailed description:

- Codestream syntax (Annex A): Definition of the codestream syntax every JPWL codestream must conform to.
- Error protection block (Annex B): Tool to protect the image header (main header, tile/tile-part header) and to correct the possible presence of transmission errors using FEC codes.
- Error protection capability descriptor (Annex C): Description of the tools which have been used to protect the codestream and to correct the possible presence of transmission errors. This descriptor relies on a registration authority as to the informative error protection techniques.
- Error sensitivity descriptor (Annex D): Description of the degree of sensitivity of different parts of the codestream to transmission errors. This information is typically generated when encoding the image. It can subsequently be used to apply Unequal Error Protection (UEP) techniques which take into account the error sensitivity.
- Residual errors descriptor (Annex E): Description of the locations of residual errors in the codestream. The residual errors are the errors which cannot be corrected by the tools used to protect the image. This information is typically generated when decoding the codestream.
- Registration authority (Annex K): Specification of the Registration Authority (RA).

7 JPWL informative parts

This clause outlines informative parts of this Recommendation | International Standard and refers to the respective annexes for detailed description:

- Encoding guidelines (Annex F): Guidelines for error-resilient coding at the encoder side in the context of error prone environments.
- Decoding guidelines (Annex G): Guidelines for error handling behaviour at the decoder side.
- Error-resilient entropy coding (Annex H): Tools to protect the codestream and to detect and correct the possible errors based on error-resilient entropy coding.
- Unequal error protection (Annex I): Tools to protect differently parts of the codestream based upon the error sensitivity of the respective parts.
- Interoperability with ISO/IEC 15444 (Annex J): Guidelines for interoperability with other specifications in the JPEG 2000 family.
- Patents (Annex L): Received intellectual property rights statements that apply to this Recommendation | International Standard.

Annex A

Codestream syntax

(This annex forms an integral part of this Recommendation | International Standard)

A.1 Definitions of markers and marker segments

This Recommendation | International Standard relies on the use of marker segments to delimit and signal the characteristics of the codestream in order to protect it against errors. For backward compatibility, the JPWL markers and marker segments must be included in JPEG 2000 Part 1 codestream headers, which can be of two types only:

1) the main header, found at the beginning of the codestream;
2) the tile-part headers, found at the beginning of each tile-part.

Main and tile-part headers are collections of markers and marker segments.

As for every other standard marker defined in JPEG 2000 Part 1, each marker defined in this proposal is two bytes long, and its first byte value is 0xFF. The second byte specifies the marker use and can take any value in the range 0x01 to 0xFE, apart from those already used by ITU-T Rec. T.81 | ISO/IEC 10918-1 and ITU-T Rec. T.84 | ISO/IEC 10918-3 (recalled in Table A.1).

A marker segment includes a marker and associated parameters, called marker parameters. By definition, the first two bytes of any marker segment immediately after the marker must correspond to an unsigned big endian integer value that denotes the length in bytes of the marker parameters (including two bytes of this length parameter but not including the two bytes of the marker itself). When the decoder finds a marker segment that is not specified in this Recommendation | International Standard, it shall use the length parameter to discard the marker segment.

A.2 Marker code range defined in this Recommendation | International Standard

Following the syntax used for each marker and marker segment defined in ITU-T Rec. T.81 | ISO/IEC 10918-1, this Recommendation | International Standard reserves some markers for signalling, as specified in Table A.1. Table A.1 recalls the various values of already existing or reserved markers.

Table A.1 – Marker definitions

Marker value range	Standard definition
0xFF00, 0xFF01, 0xFFFE, 0xFFC0 – 0xFFDF	Defined in ITU-T Rec. T.81 | ISO/IEC 10918-1
0xFFF0 – 0xFFF6	Defined in ITU-T Rec. T.84 | ISO/IEC 10918-3
0xFFF7 – 0xFFF8	Defined in ITU-T Rec. T.87 | ISO/IEC 14495-1
0xFF4F – 0xFF65, 0xFF6A – 0xFF6F, 0xFF90 – 0xFF93	ITU-T Rec. T.800 | ISO/IEC 15444-1
0xFF66 – 0xFF69	Defined in this Recommendation | International Standard
0xFF30 – 0xFF3F	Reserved for definition as markers only (no marker segments)
	All other values reserved.

A.3 Marker and marker segment and codestream rules

Marker segments, described in this Recommendation | International Standard, are respecting the rules given in A.1.3/JPEG 2000 Part 1.

A.4 Information in the marker segments

As standardized in JPEG 2000 Part 1, marker segments, and therefore the main and tile-parts headers, are a multiple of 8 bits (one byte).

All markers and marker segments in a tile-part header or a start of packet header apply only to the tile or the packet to which it belongs.

If truncation, alteration, or editing of the codestream has been done, the impacted marker segments (like TLM/PLT or JPWL marker segments) shall be updated accordingly. Note that several JPWL marker segments contain codestream indexing information (e.g., byte ranges); this information must be updated upon insertion or cancellation of a marker segment.

Table A.2 lists the markers specified in this Recommendation | International Standard and Table A.3 lists the information provided by the syntax and indicates the marker segment containing that information.

Table A.2 – List of marker segments

	Name	Code	Main header (Note)	Tile-part header (Note)
Error Protection Block	EPB	0xFF66	Optional	Optional
Error Sensitivity Descriptor	ESD	0xFF67	Optional	Optional
Error Protection Capability	EPC	0xFF68	Required	Optional
Residual Errors Descriptor	RED	0xFF69	Optional	Optional
NOTE – Required means the marker segment shall be in this header, optional means it may be used.				

If the EPC, ESD or RED marker segments appear both in the main header and tile-part header, the marker present in the tile-part header is overriding the one present in the main header for the current tile-part. The EPC and RED marker segments are allowed to appear at most once per header (main or tile-part header). Multiple ESD in one single header are allowed.

A.5 Construction of the codestream

The construction of the codestream of this Recommendation | International Standard complies with the codestream construction defined in A.3/JPEG 2000 Part 1. The EPB marker segment(s) are required to be in a specific location, as specified in Annex B.

Table A.3 – Information in the marker segments

Information	Marker segment
Signals the presence of JPWL protected data in the header. It includes: – Set of error protection parameters used in the codestream. – Error protection data generated from a systematic code.	EPB
Indicates the methods used in the current codestream to protect it against transmission errors. Its presence signals the fact that the codestream complies with this Recommendation | International Standard.	EPC
Describes the sensitivity to errors of the current codestream	ESD
Describes the index of the residual errors of the current codestream	RED

A.6 JPWL marker segments

A.6.1 Error Protection Block (EPB)

The EPB marker segment contains information about the error protection parameters and data used to protect the codestream against errors. The primary function of EPB is to protect the main and tile-part header (see Annex B). However, it can also be used to protect the bitstream (see Annex I). There can be one or more EPB marker segments in the main header and/or tile-part headers. The first EPB marker segment in a main header is required to be placed immediately after the SIZ marker segment. The first EPB marker segment in a tile-part header is required to be placed immediately after the SOT marker.

Function: The EPB marker segment contains necessary error correction data for the header where it is located. See Annex B and Annex I for more information on how to use EPB marker segments.

Usage: Main header and tile-part headers. The first EPB marker segment of the codestream must be placed after the SIZ marker segment. The first EPB marker segment of a tile-part header must be placed after the SOT marker segment.

Length: Variable depending on the parameters used to protect the headers and the length of the headers to be protected. Figure A.1 describes the syntax of the EPB marker segment.