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Information technology — JPEG 2000 image coding system: Core coding system

AMENDMENT 4: Guidelines for digital cinema applications

Technologies de l'information — Système de codage d'images JPEG 2000: Système de codage de noyau

AMENDEMENT 4: Lignes directrices pour les applications de cinéma numérique

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Foreword

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Guidelines for digital cinema applications

1) Modification to Annex J

Add the following new clause J.16 at the end of Annex J (i.e., immediately following J.15.3):

J.16 Guidelines for digital cinema applications

This clause is intended as guidelines for the usage of JPEG 2000 in the framework of digital cinema applications. It is split in four parts: the first is dedicated to multicast transmission; the second presents the recommended visual frequency weightings for digital cinema environment; the third deals with the use of JPEG 2000 for film archive applications, and finally the fourth gives guidelines for digital cinema distribution.

J.16.1 Reliable multicast transmission of JPEG 2000 codestreams

J.16.1.1 Introduction

Digital Cinema (D-Cinema) content may be delivered to the theatres by using several communication channels, and many of them can be wireless, such as, for example, DVB-T [50], DVB-S [51], and WiMAX [52]. The destination of the video contents, in this case, can also (at reduced resolution/quality) be a mobile user, such as, for instance, an audience located on a train or bus.

In addition to the file transfer approach, already used for digital cinema transfer to the theatres, the use of streaming would allow for applications such as live events exhibition and (Near) movie on demand (in this case, however, additional methods for the reduction of the bit rate must be adopted).

The delivery of JPEG 2000 compressed video is a well-known challenge for wireless IP networks. In the case of TCP, the variable delay is unacceptable for many types of real-time applications. D-Cinema will introduce even more stringent conditions, in terms of both the required bandwidth and the high quality demand.

As concerns the distribution, the requirements can be specified in the following terms:

- low required bandwidth occupancy, not only of the JPEG 2000 compressed content itself, but also considering some signalling overhead;
- reliable transmission of the contents, by use of forward error correction techniques (FEC) and/or selective retransmission of lost data (selective ARQ).

A possible solution can be that of adopting a multicast protocol, which can be adapted to the high bit rate and low packet loss rate necessary for the distribution of D-Cinema content. If using multicast transmission, a reliable protocol could be used, which guarantees the sender that every receiver has a copy equal to the original. NORM protocol [56] can be a viable solution for such needs: it uses a NACK-oriented reliable multicast, achieving reliability by means of negative ACKs that are sent back from the receivers to the sender. In addition, it is possible to specify even a small FEC layer, which reduces the retransmission rate at the expense of some added overhead.

Moreover, in case of multicast transmission of JPEG 2000 codestreams, there are some constraints in limited network bandwidth or capabilities of mobile devices.

New mechanisms are required to distribute D-cinema contents to local theatres, high-end mobile users via wireless networks under the constrained conditions.

In forwarding packets to a mobile user, an intermediate distributor may have such functions such as adjusting the image quality or resolution for network bandwidth, network convergence, or capability of mobile device purposes.

J.16.1.2 Distribution model

Figure J.17 shows a possible scenario for content distribution. Different users, with different quality requirements/capabilities may be foreseen. In this scenario, an intermediate distributor is required with the role of adaptation of resolution/quality for forwarding capabilities.

In Figure J.17, cinema contents are transmitted from the production site (for example, studio post-production house) to regional theatres through satellite links. After that, some resolution or quality level is extracted from the original content and is distributed to local theatres, high-end mobile users, home and low-end mobile users by wireless network such as DVB-T, WiMAX and WLAN (IEEE 802.11n) [54].

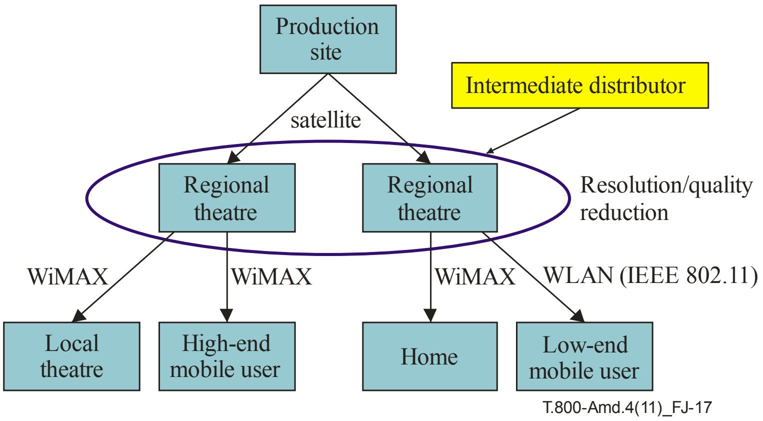

Figure J.17 – Distribution scenario for D-Cinema and live event

There are mainly three main problems in network delivery:

1) limited bandwidth;
2) convergence;
3) packet loss.

In forwarding a digital cinema stream to mobile users, an intermediate distributor such as a regional theatre might have functions of adjusting the image quality or resolution for network bandwidth, network convergence, or the capability of mobile device purposes.

J.16.1.3 Multicast protocol overview

NORM (NACK oriented reliable multicast) is a multicast protocol designed to provide end-to-end reliable multicast transfer. This protocol uses generic IP multicast capabilities, and on top of that tries to achieve reliable transfer using NACKs (negative acknowledgments). It can work both on reciprocal multicast network (i.e., wireless or wired LAN) or unidirectional link (such as a unidirectional satellite); in this way, it can satisfy all of the transmission needs for digital cinema distribution [53].

NORM repair capabilities are based on the use of negative acknowledgments (NACKs), sent from the receivers to the sender upon detection of an erroneous or missing packet. The sender transmits packets of data, segmented according to a precise strategy, each of which is identified by symbol numbers. As a receiver detects a missing packet, it initiates a repair request with a NACK message. Upon reception of NACKs, the sender prepares the appropriate repair messages, using FEC (forward error correction) blocks. Each receiver can reinitiate a repair procedure if it does not receive repair blocks.

Feedback suppression is applied, using a random back-off algorithm; each receiver, before sending a NACK for a certain packet, waits for a random-duration interval, during which it senses the medium and checks if other receivers requested a repair for the same packet: if so, it discards the NACK; otherwise, it sends it and waits for repair bits. When the sender receives the NACK, it enqueues repair bits (or the entire lost packet). Feedback suppression works efficiently in this protocol, and can achieve good results.

NACK packets can be sent both in multicast or unicast mode, using the sender's address. In the second case, feedback suppression can be achieved using multicast advertising messages, sent from each sender, which allow the receivers to know which packets have a pending repair request.

A NORM sender can even autonomously add FEC parity bits to each packet, thus enabling the receiver to correct errors and recover losses without starting a NACK procedure.

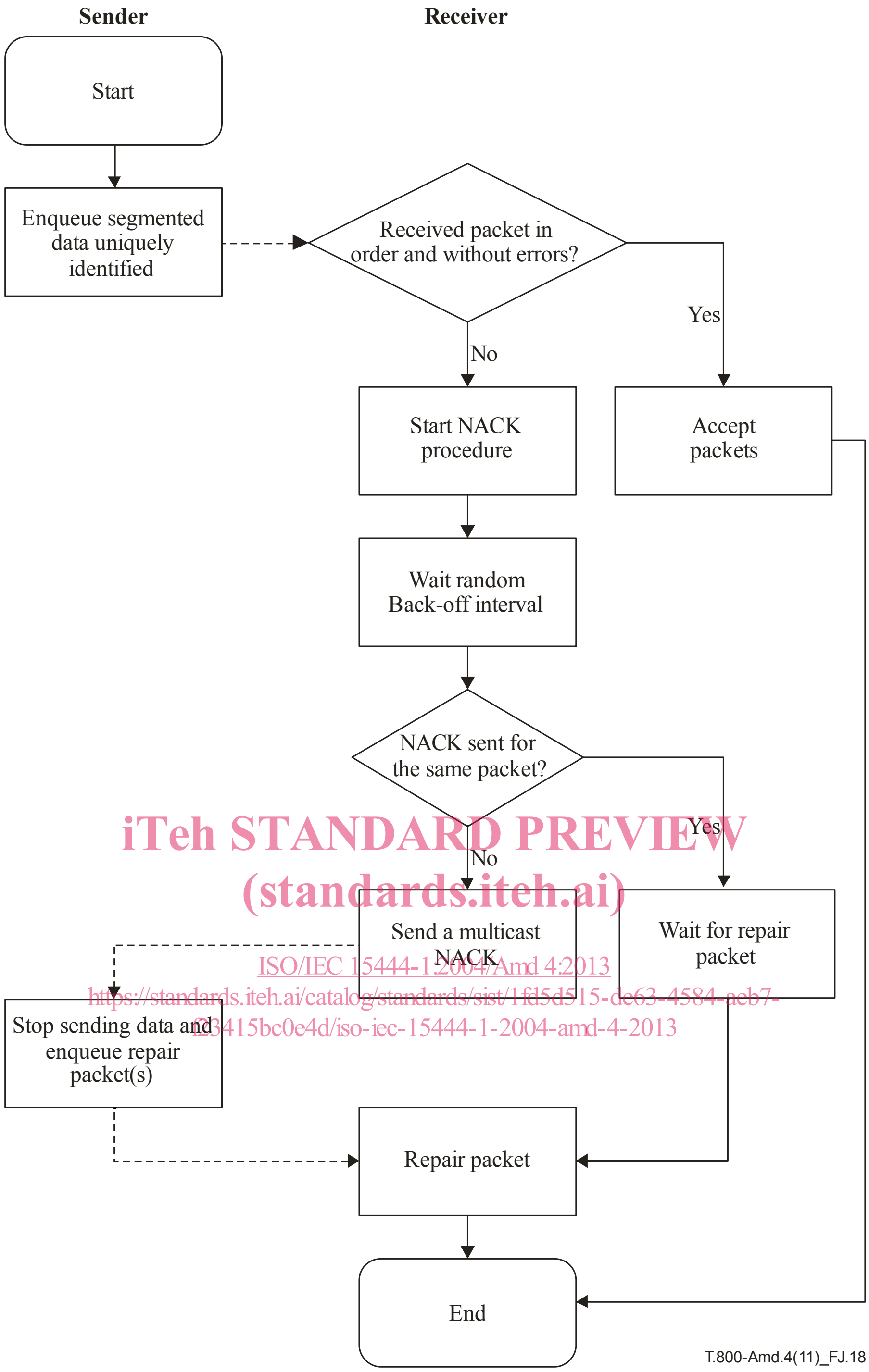

Figure J.18 – Sender and receiver sequence of operations

Figure J.18 shows a sequence of operations performed by a NORM sender and receiver during the normal transmission session. The sender node enqueues data packets, segmented according to parameters that can be changed by the user to accommodate for particular needs: in this case, JPEG 2000 codestreams are encapsulated and an additional header is included at the end of the NORM packet header. It also periodically enqueues control messages, such as round-trip collection and rate congestion control feedback.

Each receiver controls if the packet is in order and error-free: in this case, it accepts the packet and passes it to the destination application. Otherwise, it enters the NACK procedure: this consists in picking a random back-off delay, based on some parameters such as the greatest round-trip delay, usually supplied by the sender, and delaying NACK transmission until this interval is passed. In the meantime, if it receives a repair request for the same packet or the repair bits, the NACK is dropped; otherwise, it sends the NACK in multicast mode. Sending the NACK in multicast is useful for feedback suppression, as described previously.

When the sender receives the NACK, it stops usual data transmission and sends repair packets, in the form of a bit sequence derived from a Reed-Solomon (RS) code. With these repair bits, receivers are able to recover from transmission errors. If a receiver loses a repair packet too, it can resend a new NACK for the same packet after waiting for a new back-off interval.

J.16.1.4 Packetization strategy

To achieve a correct delivery of the DC content to all users, the JPEG 2000 video content must be carefully split into network packets that will be sent via the multicast protocol. To this purpose, three main procedures are needed:

1) preparation of the JPEG 2000 codestream (J2K);
2) splitting of codestreams into network packets;
3) adaptation of the multicast protocol packet header to J2K contest.

J.16.1.4.1 J2K codestream preparation

In the first stage, the J2K codestream is split into many pieces to be combined with the NORM header and UDP header as shown in Figure J.19. As a result, the network packet consists of the UDP header, the NORM header and one part of the J2K codestream.

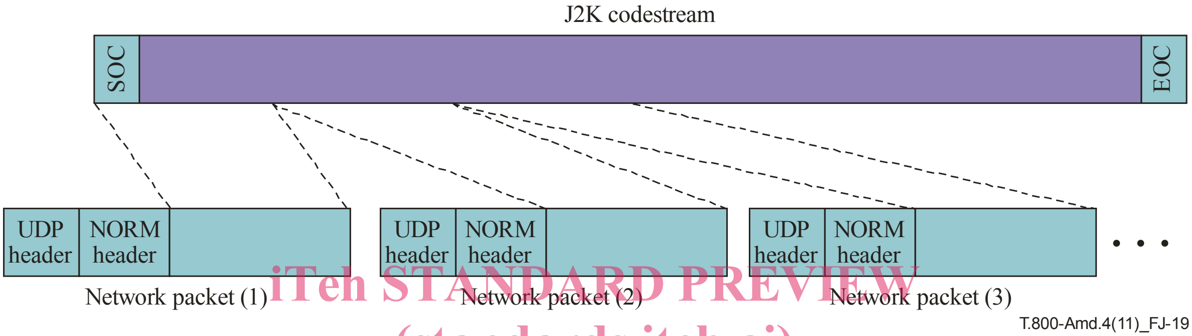

Figure J.19 – J2K codestream and network packets

In this case, the problem is that it is difficult to control the image quality because there is no information on what kinds of J2K packets are contained in network packets.

In order to solve the problem, a kind of J2K packet attribute information on the NORM J2K header is added to the following two cases.

– Case 1: An intermediate distributor that can easily control the image quality by discarding the network packets containing higher layers.
– Case 2: An intermediate distributor that can easily control the image resolution by discarding the network packets containing higher resolutions.

The "attribute" concept is provided to indicate the attribute of J2K packets, and it is similar to "Priority" in the JPEG 2000 RTP format. But "attribute" is simpler. "Attribute" is an incremental number classifying J2K packets by the same layer number and resolution level. Every J2K packet has an attribute number (> 0). The main header and tile-part header have a special attribute number (= 0).

There are two types of attribute numbering:

– "Layer-Resolution" attribute numbering
  • Applied to LRCP progression order.
– "Resolution-Layer" attribute numbering
  • Applied to RLCP, RPCL, PCRL or CPRL progression order.

J.16.1.4.1.1 <Type-1> "Layer-Resolution" attribute numbering

J2K packets are grouped by the layer and the resolution (Figure J.20).

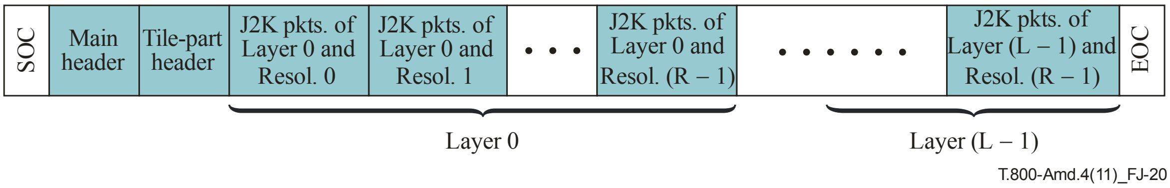

Figure J.20 – Attribute numbering (Layer-Resolution)

In "Layer-Resolution" attribute numbering, the attribute number is calculated as *(layer number)* * *(number of resolution levels)* + *(resolution level)* + 1.

The attribute numbering can be applied for J2K codestream (LRCP).

For example:

– The attribute number of J2K packets belonging to **"Layer 0 and Resolution 0"** is **1**.

– The attribute number of J2K packets belonging to **"Layer 0 and Resolution 1"** is **2**.

…

– The attribute number of J2K packets belonging to **"Layer l and Resolution r"** is "**l * R + r + 1**"

…

– The attribute number of J2K packets belonging to **"Layer (L – 1) and Resolution (R – 1)"** is "**L * R**"

J.16.1.4.1.2 <Type-2> "Resolution-Layer" attribute numbering

J2K packets are grouped by the resolution and the layer (Figure J.21).

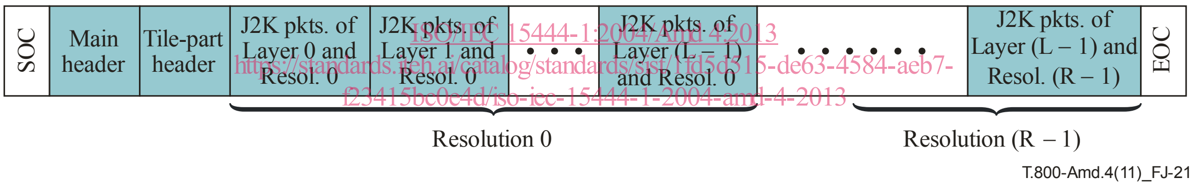

Figure J.21 – Attribute numbering (Resolution-Layer)

In "Resolution-Layer" attribute numbering, the attribute number is calculated as *"(resolution number)* * *(number of layers)* + *(layer number)* + 1*"*.

The attribute numbering can be applied for J2K codestreams (RLCP, RPCL, PCRL or CPRL).

For example:

– The attribute number of J2K packets belonging to **"Layer 0 and Resolution 0"** is **1**.

– The attribute number of J2K packets belonging to **"Layer 1 and Resolution 0"** is **2**.

…

– The attribute number of J2K packets belonging to **"Layer l and Resolution r"** is "**r * L + l + 1**"

…

– The attribute number of J2K packets belonging to **"Layer (L – 1) and Resolution (R – 1)"** is "**L * R**"

J.16.1.4.2 Network packet and attribute number

This clause explains the coordinating network packets (Figure J.19) to the J2K codestream. The J2K codestream in Figure J.22 is of the "Layer-Resolution" type, as shown in Figure J.20.

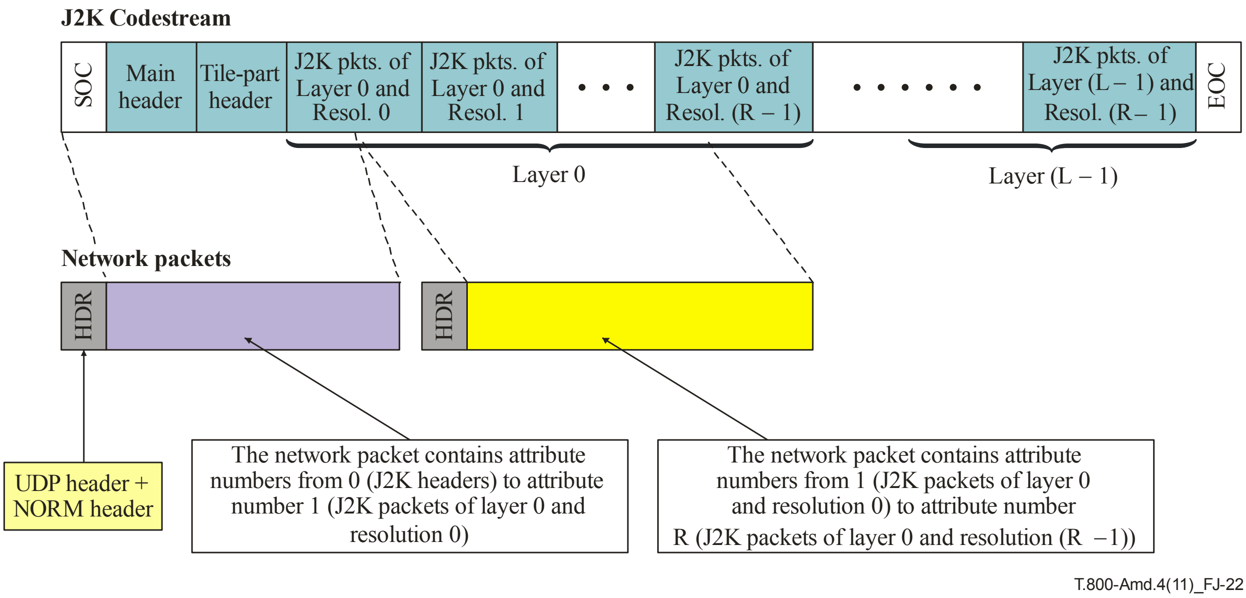

Figure J.22 – Network packet and attribute number

J.16.1.4.3 Multicast protocol header format

It is important that the sender and the receiver jointly minimize the probability of retransmissions; this can be done by making them aware of the underlying codestream-based file structure. A number of fields can be added to the base NORM protocol header, based on the fields utilized by the JPEG 2000 RTP streaming protocol.

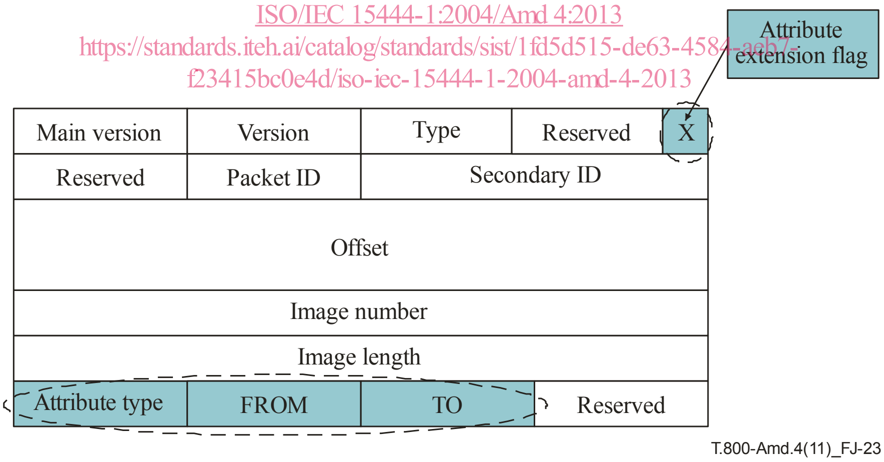

Figure J.23 – Format of the header used for JPEG 2000 packetization

A tabular view of the additional header fields is presented in Figure J.23; their meaning and aim are as follows:

– *main version* (8 bits): it is always set to 0xCB. If the received packet has a different value for this field, it is discarded.

– *version* (8 bits): minor version of the protocol, currently 1. Any packet with a different minor version is discarded from the receiver.

– *type* (8 bits): it indicates the kind of transfer; in particular, it is related to the format of the codestream-containing file. Currently, it can be set to 0xF1 when a set of .j2c files (raw codestreams) is sent or to 0xF6 if a single .mj2 video file (wrapped file format) is being transferred. Unrecognized types would result in packet discarding.

– *X* (1 bit): attribute extension flag, attribute extensions are valid only if X = 1.

– *packet ID* (8 bits): if a single codestream is fragmented at the sender, it indicates the progressive number of the transmission. This is especially useful when transmitting large codestreams, which can be divided into smaller portions at the data packet boundary. This is used for packet reordering upon receiving and checking missing packets.

– *secondary ID* (16 bits): it can be used to order different tracks inside a video file, or to differentiate among video, audio and synchronization data.

– *image number* (32 bits): progressive number of image (i.e., codestream) in a movie. This is used to reconstruct the video file in the correct order, and to check for the correct receiving of packets.

– *offset* (64 bits): it represents the offset of the first data in this packet, starting from the beginning of the file; it is directly expressed in bytes (since DC video content files can be as large as 250 GB, 8 bytes are necessary for seeking). The receiver uses the value carried by this file for correctly placing the received packet in the destination file.

– *image length* (32 bits): it denotes the total length of the codestream containing the image, expressed in bytes. It is used to check if the image has been completely received.

– *attribute type* (8 bits): 0 denotes "Layer-Resolution" attribute, 1 denotes "Resolution-Layer" attribute, other values are reserved.

– *FROM* (8 bits): attribute range, from.

– *TO* (8 bits): attribute range, to.

This header is added to each sent multicast packet for identification.

Figure J.24 is an example of the "attribute header value". In the first NORM J2K extension header, the attribute range is from "0" to "1", and in the second header, the attribute range is from "1" to "R".

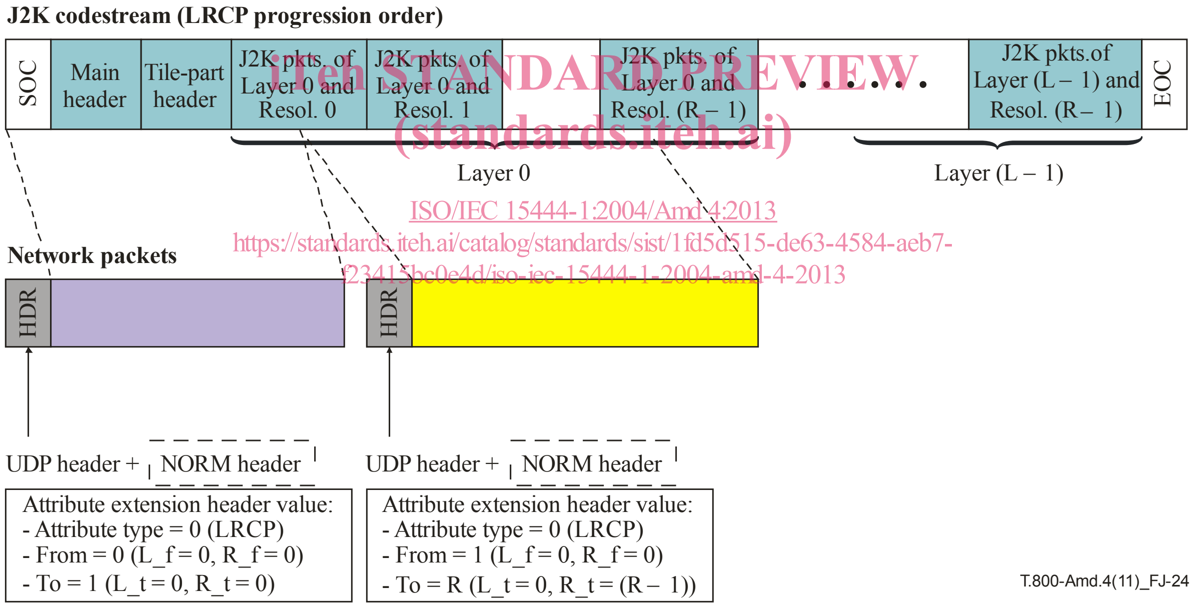

Figure J.24 – Attribute header value

J.16.1.5 Intermediate distributor function

This clause explains the function of the intermediate distributor. Full quality NORM packets ("L" layers and "R" resolutions) will be distributed from the production site to the intermediate distributor, as shown in Figure J.25.

The following workflow is an example of forwarding network packets to end users:

1) An intermediate distributor determines the number of layers and the number of resolution levels to be forwarded to the end user by judging from the network bandwidth or display.

2) After that, the distributor defines which network packets are to be forwarded, by using the attribute information of "FROM" and "TO", in the NORM J2K extension header.

3) Determination of the number of layers and resolution is out of scope in this Recommendation | International Standard. Instead, a method of how to forward network packets by checking the attribute extension is presented in the following examples.