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Information technology — Telecommunications and information exchange between systems — Local and metropolitan area networks — Specific requirements —

Part 1CB: Frame replication and elimination for reliability

AMENDMENT 2: Extend stream identification functions

Technologies de l'information — Télécommunications et échange d'information entre systèmes — Réseaux locaux et métropolitains — Exigences spécifiques —

Partie 1CB: Duplication de trame et son élimination pour la fiabilité

AMENDEMENT 2: Fonctions d'identification de flux étendu

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IEEE Std 802.1CBdb™-2021
(Amendment to IEEE Std 802.1CB™-2017
as amended by IEEE Std 802.1CBcv™-2021)

IEEE Standard for
Local and metropolitan area networks—

Frame Replication and Elimination for Reliability

Amendment 2: Extended Stream Identification Functions

Developed by the

LAN/MAN Standards Committee
of the
IEEE Computer Society

Approved 8 December 2021

IEEE SA Standards Board

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Abstract: This amendment specifies procedures, managed objects, and protocols for bridges and end systems that provide identification and replication of packets for redundant transmission, identification of duplicate packets, and elimination of duplicate packets. It is not concerned with the creation of the multiple paths over which the duplicates are transmitted.

Keywords: amendment, Bridged Local Area Networks, Bridges, Bridging, Extended Stream identification, Frame Elimination, Frame Replication, IEEE 802®, IEEE 802.1CB™, IEEE 802.1CBdb™, IEEE 802.1Q™, local area networks (LANs), MAC Bridges, Redundancy, Stream identification, Time-Sensitive Networking, TSN, Virtual Bridged Local Area Networks (virtual LANs)

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Introduction

This introduction is not part of IEEE Std 802.1CBdb-2021, IEEE Standard for Local and metropolitan area networks—Frame Replication and Elimination for Reliability—Amendment 2: Extended Stream Identification Functions.

This Standard defines Extended Stream identification functions.

This standard contains state-of-the-art material. The area covered by this standard is undergoing evolution. Revisions are anticipated within the next few years to clarify existing material, to correct possible errors, and to incorporate new related material. Information on the current revision state of this and other IEEE 802 standards can be obtained from

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IEEE Standard for
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Frame Replication and Elimination for Reliability

Amendment 2: Extended Stream Identification Functions

(This amendment is based on IEEE Std 802.1CB™-2017 as amended by IEEE Std 802.1CBcv™-2021.)

NOTE—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strikethrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Deletions and insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.[6]

[6] Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

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3. Definitions

Change the definition of "Internal Sublayer Service (ISS)" in Clause 3 as follows:

Internal Sublayer Service (ISS): An augmented version of the MAC Service, defined in ~~6.6 of IEEE Std 802.1Q-2014~~IEEE Std 802.1AC.

Insert the following new definition Clause 3 in alphabetical order:

Mask: A set of consecutive bits used to select bits of a particular significance in a bit field of the same length as the mask.

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5. Conformance

5.4 Stream identification component recommended behavior

Change the lettered list in 5.4 as follows:

a) A Source MAC and VLAN Stream identification function (6.5);
b) ~~a)~~ An Active Destination MAC and VLAN Stream identification function (6.6).

5.5 Stream identification component optional behaviors

Change the lettered list in 5.5 as follows:

a) The items in 5.3 and 5.4 on more than one port;
b) The items in 5.3 and 5.4 for some number of Compound Streams greater than 1;
c) An IP Stream identification function (6.7); ~~and/or~~
d) A Mask-and-match Stream identification function (6.8); and/or
e) ~~d)~~ Additional types of Stream identification functions.

5.7 Talker end system recommended behaviors

Change the lettered list in 5.7 as follows:

a) A Source MAC and VLAN Stream identification function (6.5);
b) ~~a)~~ An Active Destination MAC and VLAN Stream identification function (6.6); and
c) ~~b)~~ A Stream splitting function (7.7).

5.8 Talker end system optional behaviors

Change the lettered list in 5.8 (as changed by IEEE Std 802.1CBcv-2021) as follows:

a) The items in 5.6 and 5.7 on more than one port;
b) The items in 5.6 and 5.7 for some number of Compound Streams greater than 1;
c) An IP Stream identification function (6.7);
d) A Mask-and-match Stream identification function (6.8);
e) ~~d)~~ Additional types of Stream identification functions;
f) ~~e)~~ The HSR sequence tag (7.9);
g) ~~f)~~ The PRP sequence trailer (7.10);
h) ~~g)~~ Additional types of Sequence encode/decode functions;
i) ~~h)~~ Support SMIv2 MIB modules for the management of talker end system functions (Clause 11) as required by item e in 5.6; and/or
j) ~~i)~~ Support YANG modules for the management of talker end system functions (Clause 12) as required by item e in 5.6.

5.10 Listener end system recommended behavior

Change the lettered list in 5.10 as follows:

a) A Source MAC and VLAN Stream identification function (6.5);
b) ~~a)~~ An Active Destination MAC and VLAN Stream identification function (6.6).

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5.11 Listener end system optional behaviors

Change the lettered list in 5.11 (as changed by IEEE Std 802.1CBcv-2021) as follows:

a) The items in 5.9 and 5.10 on more than one port;

b) The items in 5.9 and 5.10 for some number of Compound Streams greater than 1;

c) An IP Stream identification function (6.7);

d) A Mask-and-match Stream identification function (6.8);

e) ~~d)~~ Additional types of Stream identification functions;

f) ~~e)~~ The HSR sequence tag (7.9);

g) ~~f)~~ The PRP sequence trailer (7.10);

h) ~~g)~~ Additional types of Sequence encode/decode functions;

i) ~~h)~~ At least two instances of Individual recovery functions (7.5), each using the VectorRecoveryAlgorithm (7.4.3.4);

j) ~~i)~~ Support SMIv2 MIB modules for the management of listener end system functions (Clause 11) as required by item f in 5.9; and/or

k) ~~j)~~ Support YANG modules for the management of listener end system functions (Clause 12) as required by item f in 5.9.

5.13 Relay system recommended behaviors

Change 5.13 as follows:

A relay system should be able to instantiate the following in-facing functions on at least two ports, for both transmit and receive, for at least one Stream:

a) A Source MAC and VLAN Stream identification function (6.5);

b) ~~a)~~ Active Destination MAC and VLAN Stream identification functions (6.6) for encoding and decoding packets; ~~and~~

c) Either of the following:

   1) ~~b)~~ IP Stream identification functions (6.7);

   2) Mask-and-match Stream identification function (6.8) for identifying packets.

NOTE—IP Stream identification and Mask-and-match Stream identification enable~~s~~ a relay system to proxy for a FRER-unaware end system.

5.15 FRER C-component required and optional behaviors

Change list item a) in 5.15 as follows:

a) Shall meet all of the required and any or none of the optional behaviors for an IEEE 802.1Q C-VLAN component (5.5 of IEEE Std 802.1Q-~~2014~~2018).

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6. Stream identification

Change the first paragraph of the introduction of Clause 6 as follows:

Clause 7 of IEEE Std 802.1AC-2016 describes the IEEE 802.1 layering model, that Frame Replication and Elimination for Reliability (FRER) follows. Stream identification utilizes a single Service Access Point (SAP) to a connectionless packet service offered by the layer below it [e.g., the Intermediate Sublayer Service (ISS) of Clause 11 of IEEE Std 802.1AC-2016, or the Enhanced Internal Sublayer Service (EISS) of 6.8 of IEEE Std 802.1Q-2018], and offers an array of SAPs to the layers above it, corresponding to different Streams. The Stream identification model is illustrated in Figure 6-1.

Change the note after the second paragraph of the introduction of Clause 6 as follows:

NOTE—In principle, any number of different methods for identifying and encoding Streams can be defined. Several ~~required~~ methods are specified in the following subclauses (6.4, 6.5, 6.6, 6.7, and 6.8).

Change item c) in the lettered list in the introduction of Clause 6 as follows:

c) ~~Four~~Five specific Stream identification functions are described: Null Stream identification (6.4), Source MAC and VLAN Stream identification (6.5), Active Destination MAC and VLAN Stream identification (6.6), ~~and~~ IP Stream identification (6.7), and Mask-and-match Stream identification (6.8).

Change Table 6-1 as follows:

Table 6-1—Stream identification functions

Stream identification function	Active/passive	Examines	Overwrites	Reference
Null Stream identification	Passive	destination_address, vlan_identifier	None	6.4, 9.1.2
Source MAC and VLAN Stream identification	Passive	source_address, vlan_identifier	None	6.5, 9.1.3
Active Destination MAC and VLAN Stream identification	Active	destination_address, vlan_identifier	destination_address, vlan_identifier, priority	6.6, 9.1.4
IP Stream identification	Passive	destination_address, vlan_identifier, IP source address, IP destination address, DSCP, IP next protocol, source port, destination port	None	6.7, 9.1.5
Mask-and-match Stream identification function	Passive	destination_address, source_address, mac_service_data_unit	None	6.8, 9.1.6

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6.1 Stream service subparameters

Change the first paragraph of 6.1 as follows:

The ISS defined in IEEE Std 802.1AC and the EISS defined in IEEE Std 802.1Q include~~s~~ a connection_identifier parameter that is of local significance (to a system) only. The parameter is not carried across the underlying service. Stream identification makes use of this parameter to carry parametrized information. Stream identification has need for more than one subparameter, but an implementor can create mathematical algorithms to combine those subparameters (and/or other subparameters for other layers) into a single connection_identifier parameter, especially since the connection_identifier's values are undefined outside the system implementing them. In this document, parameters that are assumed to be encoded in the connection_identifier are deemed *subparameters*.

6.2 Stream identification function

Change the note at the end of 6.2 into two notes as follows:

NOTE 1—The Stream identification method does not necessarily involve an actual transformation of the packet. See 6.4 and 6.6 for examples of both cases.

NOTE 2—The order of precedence of Stream identification functions and the invocation of their instances, when more than one matches the same frame, is out of scope of this standard.

6.3 Stream identification in systems

Change the third sentence of the first paragraph of 6.3 as follows:

Diagram a in Figure 6-5 illustrates a relay system (e.g., 8.6 of IEEE Std 802.1Q-~~2014~~2018) with two ports, that has its FRER capabilities embedded in its forwarding function, and not shown explicitly in the diagram.

6.4 Null Stream identification

Change the second sentence of the first paragraph of 6.4 as follows:

It can be defined using the Enhanced Internal Sublayer Service (EISS) described in 6.9 of IEEE Std 802.1Q-~~2014~~2018, in which case it is enhanced with the extra stream_handle subparameter of the connection_identifier, specified in 6.1 of the present standard.

6.5 Source MAC and VLAN Stream identification

Change the second sentence of the first paragraph of 6.5 as follows:

It can be defined using the EISS described in 6.9 of IEEE Std 802.1Q-~~2014~~2018, in which case it is enhanced with the extra stream_handle subparameter of the connection_identifier, specified in 6.1 of the present standard.

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6.6 Active Destination MAC and VLAN Stream identification

Change the second sentence of the first paragraph of 6.6 as follows:

It can be defined using the EISS described in 6.9 of IEEE Std 802.1Q-~~2014~~2018, in which case it is enhanced with the extra stream_handle subparameter of the connection_identifier, specified in 6.1 of the present standard.

Change the second paragraph of 6.6 as follows:

In the Active Destination MAC and VLAN Stream identification, the destination_address, vlan_identifier, and priority parameters of the frame passed down the stack from the upper layers or up the stack from the lower layers are replaced with alternate values. The replacement values for frames transmitted down the stack to the Active Destination MAC and VLAN Stream identification, and used to recognize frames passed up the stack to the Active Destination MAC and VLAN Stream identification function, ~~are those listed in 9.1.2~~as well as ~~. T~~the replacement values for frames passed up the stack~~ (not including the priority parameter)~~ are described in 9.1.4. The replacement values for frames transmitted down the stack to the Active Destination MAC and VLAN Stream identification function are determined by the stream_handle subparameter passed down in the EISS request's connection_identifier.

6.7 IP Stream identification

Change the second sentence of the first paragraph of 6.7 as follows:

It can be defined using the union of the IP address primitives listed in 9.1.5 and parameters defined by the EISS described in 6.9 of IEEE Std 802.1Q-~~2014~~2018, in which case it is enhanced with the stream_handle subparameter of the connection_identifier, specified in 6.1 of the present standard.

Insert new subclause 6.8 after 6.7 as follows:

6.8 Mask-and-match Stream identification

The Mask-and-match Stream identification is a passive Stream identification that operates at the frame level. It can be defined using the Internal Sublayer Service (ISS) described in IEEE Std 802.1AC, in which case it is enhanced with the extra stream_handle subparameter of the connection_identifier, specified in 6.1 of the present standard.

It discards the stream_handle subparameter passed down the stack. It generates a stream_handle subparameter on frames passed up the stack based on information extracted from a subset of the frame's ISS parameters. It does not change any of a packet's parameters, other than the connection_identifier.

Input information for the Mask-and-match Stream identification function is obtained by masking one or more of the following ISS parameters:

— Source_address,
— Destination_address, and
— The first *N* octets of mac_service_data_unit, *N* being a system-dependent variable.

Stream identification is then done by comparing these masked ISS parameters with specific match values.

The Mask-and-match Stream identification function supports Stream identification schemes ranging from very simple, using a single mask applied to one of its input ISS parameters, to complex schemes involving

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masks applied to all input ISS parameters, and in particular a specific mac_service_data_unit mask to identify communication flows supported by various higher-layer protocols.

In order to instantiate the Mask-and-match Stream identification function, the tsnStreamIdIdentificationType managed object (9.1.1.6) is encoded using the OUI (00-80-C2) and the type values as shown in Table 9-1.

The managed objects for Mask-and-match Stream identification are described in 9.1.6.

Mask-and-match Stream identification can be coupled, for example, with Active Destination MAC and VLAN Stream identification (6.6) to assign a particular {MAC address, VLAN, priority} triplet to packets belonging to a particular unicast application Stream identified by the combination of the values of particular fields in the MAC service data unit, as shown in Figure 8-1, Port A, where Mask-and-match Stream identification would be in the box labeled “Passive Upper Stream identification functions (6.2).”

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7. Frame Replication and Elimination for Reliability

7.4 Sequencing function

7.4.1 Sequence generation function

7.4.1.3 SequenceGenerationReset

Insert the following note at the end of 7.4.1.3:

NOTE—SequenceGenerationReset can cause packet drop.

7.4.3 Base recovery function

Change the third paragraph and NOTE 1 in 7.4.3 as follows:

The sequence recovery function has two sequence recovery algorithms (7.4.3.4, 7.4.3.5) so that it can be used either for Intermittent Streams (item c in 7.1.1) or for Bulk Streams (item d in 7.1.1). As long as the maximum difference in the number of packets in flight among all of the paths taken by the Member Streams served by a given sequence recovery function does not exceed the size of the SequenceHistory variable (7.4.3.2.2, 10.4.1.6), the packets are delivered without duplication, but can be delivered out-of-order. If the difference exceeds this value, then ~~duplicate packets can be delivered~~ packets can be discarded.

NOTE 1—The requirements for conformance to this standard, particularly item c in 5.9 and item e in 5.12, specify that the sequence recovery function need only support a minimum difference in path length for the correct elimination of duplicates in Bulk Streams. If the actual path difference in a given network exceeds the capability of a sequence recovery function, ~~then duplicate packets will be delivered~~ then packets will be discarded. It is up to the user to see that the capabilities of the systems purchased match the needs of the particular network in which they are employed.

7.4.3.3 SequenceRecoveryReset

Insert the following note at the end of 7.4.3.3:

NOTE—Reset of Sequence recovery function may cause temporary duplicate delivery.

7.4.3.4 VectorRecoveryAlgorithm

Change the second, third, and fourth paragraphs of 7.4.3.4 as follows:

~~One can observe that if the managed object frerSeqRcvyHistoryLength contains the value 1, then this algorithm is suitable for Intermittent Streams (item c in 7.1.1). In that case, the SequenceHistory variable (7.4.3.2.2) merely records whether the RecovSeqNum (7.4.3.2.3) does or does not record the sequence_number subparameter of a received packet. [It does not immediately after SequenceRecoveryReset (7.4.3.3) is called.] If frerSeqRcvyHistoryLength contains a value greater than one, VectorRecoveryAlgorithm serves as the more complex algorithm suitable for Bulk Streams (item d in 7.1.1).~~

Immediately after SequenceRecoveryReset (7.4.3.3) is called, the VectorRecoveryAlgorithm accepts the first packet received as valid. After the first packet has been accepted, all subsequent packets that are in the ~~window last packet number accepted ± frerSeqRcvyHistoryLength are accepted, and~~ recovery window (i.e., last_packet_number_accepted – frerSeqRcvyHistoryLength + 1 to last_packet_number_accepted + frerSeqRcvyHistoryLength) are accepted, and those packets with sequence_number values outside that range are discarded. Each packet accepted and passed up the stack resets the timer variable RemainingTicks (7.4.3.2.4). If that variable ticks down to 0, meaning that no packet has been accepted in frerSeqRcvyResetMSec milliseconds (10.4.1.7), then SequenceRecoveryReset again resets the algorithm, and the next packet received is accepted.

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This timeout mechanism means that:

a) "Rogue" packets, meaning packets outside the~~ frerSeqRcvyHistoryLength window,~~ recovery window, are discarded as invalid.
b) If a Base recovery function somehow gets out of step with its corresponding Sequence generation function, then after frerSeqRcvyResetMSec milliseconds, the Base recovery function will be reset and data will again be passed.
c) If a Sequence generation function is reset, perhaps by rebooting a system, then Base recovery functions that have not been reset are likely to discard packets until the timeout has occurred.
d) If a Talker ~~or a relay system~~ fails in such a way as to repeatedly transmit packets with the same sequence_number subparameter (perhaps repeating exactly the same packet), ~~those packets will continue to be discarded, at least until the sequence_number wraps around~~then in the case of Individual recovery (7.5), all repeated packets are discarded. If only Sequence recovery (7.4.2) is used, then all except one repeated packets are discarded per RemainingTicks interval. If a relay system fails the same way, then in the case of Individual recovery (7.5), all packets are discarded. If only Sequence recovery (7.4.2) is used and if there is a correct Member Stream, then the failed Member Stream pollutes the correct Member Stream.

Change the pseudo-code at the end of 7.4.3.4 as follows:

```
void VectorRecoveryAlgorithm () {
   //  Check that sequence number is present in the packet
   unsigned int sequence_number;
   if (sequence_number == frerSeqRcvyInvalidSequenceValue) {
      frerCpsSeqRcvyTaglessPackets = frerCpsSeqRcvyTaglessPackets + 1;
      if (frerSeqRcvyTakeNoSequence) {
         frerCpsSeqRcvyPassedPackets = frerCpsSeqRcvyPassedPackets + 1;
         frerCpSeqRcvyPassedPackets  = frerCpSeqRcvyPassedPackets  + 1;
         RemainingTicks              =
                     ((frerSeqRcvyResetMSec*TicksPerSecond)+999)/1000;
         PRESENT_DATA;
      } else {
         frerCpsSeqRcvyDiscardedPackets =
                                   frerCpsSeqRcvyDiscardedPackets + 1;
         frerCpSeqRcvyDiscardPackets = frerCpSeqRcvyDiscardPackets + 1;
      }
      return;
   }
   // Compute signed difference modulo RecovSeqSpace.
   int delta = (sequence_number-RecovSeqNum) & (RecovSeqSpace - 1);
   if (0 != (delta & (RecovSeqSpace/2)))
      delta = delta - RecovSeqSpace;
   // Here, -(RecovSeqSpace/2)<=delta<=((RecovSeqSpace/2)-1)
   // After reset, accept any packet
   if (TakeAny) {
      TakeAny                     = false;
      SequenceHistory[0]          = 1;    // Shift, adding a "seen" bit
      RecovSeqNum                 = sequence_number;
      frerCpsSeqRcvyPassedPackets = frerCpsSeqRcvyPassedPackets + 1;
      frerCpSeqRcvyPassedPackets  = frerCpSeqRcvyPassedPackets  + 1;
      RemainingTicks              =
         ((frerSeqRcvyResetMSec * TicksPerSecond) + 999) / 1000;
      PRESENT_DATA;
   } else if (delta >= frerSeqRcvyHistoryLength  ||
```


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```
            delta <= -frerSeqRcvyHistoryLength     )
   {
      // Packet is out-of-range.  Count and discard it.
      frerCpsSeqRcvyRoguePackets  = frerCpsSeqRcvyRoguePackets  + 1;
      frerCpSeqRcvyDiscardPackets = frerCpSeqRcvyDiscardPackets + 1;
      // Reset timer if working on an individual Stream
      if (frerSeqRcvyIndividualRecovery)
         RemainingTicks           =
            ((frerSeqRcvyResetMSec * TicksPerSecond) + 999) / 1000;
   } else if (delta <= 0) {
      // Packet is old and in SequenceHistory; have we seen it before?
      if (0 == SequenceHistory[-delta]) {
         // Packet has not been seen.  Take it.
         SequenceHistory[-delta]     = 1;
         frerCpsSeqRcvyOutOfOrderPackets =
                                  frerCpsSeqRcvyOutOfOrderPackets  + 1;
         frerCpsSeqRcvyPassedPackets = frerCpsSeqRcvyPassedPackets + 1;
         frerCpSeqRcvyPassedPackets  = frerCpSeqRcvyPassedPackets  + 1;
         RemainingTicks              =
            ((frerSeqRcvyResetMSec * TicksPerSecond) + 999) / 1000;
         PRESENT_DATA;
      } else {
         // Packet has been seen.  Do not forward.  Count the discard.
         frerCpsSeqRcvyDiscardedPackets =
                                   frerCpsSeqRcvyDiscardedPackets + 1;
         frerCpSeqRcvyDiscardPackets = frerCpSeqRcvyDiscardPackets + 1;
         // Reset timer if working on an individual Stream
         if (frerSeqRcvyIndividualRecovery)
            RemainingTicks          =
               ((frerSeqRcvyResetMSec * TicksPerSecond) + 999) / 1000;
      }
   } else {
      // Packet is not too far ahead of the one we want.
      // Packet is out-of-order unless it directly follows RecovSeqNum
      if (delta != 1)
         frerCpsSeqRcvyOutOfOrderPackets =
                                   frerCpsSeqRcvyOutOfOrderPackets + 1;
      // Shift the history until bit 0 refers to sequence_number.
      while (0 != (delta = delta - 1))
         ShiftSequenceHistory(0);   // Shift, adding a "not seen" bit
      ShiftSequenceHistory(1);      // Shift, adding a "seen" bit
      RecovSeqNum                 = sequence_number;
      frerCpsSeqRcvyPassedPackets = frerCpsSeqRcvyPassedPackets + 1;
      frerCpSeqRcvyPassedPackets  = frerCpSeqRcvyPassedPackets  + 1;
      RemainingTicks              =
         ((frerSeqRcvyResetMSec * TicksPerSecond) + 999) / 1000;
      PRESENT_DATA;
   }
}
```


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7.4.3.5 MatchRecoveryAlgorithm

Change the second and third paragraphs of 7.4.3.5 as follows:

Immediately after SequenceRecoveryReset (7.4.3.3) is called, the MatchRecoveryAlgorithm accepts the first packet received as valid. After the first packet has been accepted, all subsequent packets either match the last packet number accepted, and are therefore discarded, or do not, in which case they are accepted. Each packet accepted and passed up the stack resets the timer variable RemainingTicks (7.4.3.2.4). Dropped packets also reset the timer variable RemainingTicks (7.4.3.2.4) in the case of Individual recovery. If that variable ticks down to 0, meaning that no packet has been accepted in frerSeqRcvyResetMSec milliseconds (10.4.1.7), then SequenceRecoveryReset again resets the algorithm, and the next packet received is accepted.

~~The timer mechanism prevents the MatchRecoveryAlgorithm from getting stuck forever, blocking packet 1, in case a Talker fails or is reset soon after initialization.~~

Change the pseudo-code at the end of 7.4.3.5 as follows:

```
void MatchRecoveryAlgorithm () {
   //  Check that sequence number is present in the packet
   unsigned int sequence_number;
   if (sequence_number~~+~~ == frerSeqRcvyInvalidSequenceValue) {
      frerCpsSeqRcvyTaglessPackets = frerCpsSeqRcvyTaglessPackets + 1;
      frerCpsSeqRcvyPassedPackets  = frerCpsSeqRcvyPassedPackets  + 1;
      frerCpSeqRcvyPassedPackets   = frerCpSeqRcvyPassedPackets   + 1;
      PRESENT_DATA;
      return;
   }
   // After reset, accept any packet
   if (TakeAny) {
      TakeAny                     = false;
      RecovSeqNum                 = sequence_number;
      frerCpsSeqRcvyPassedPackets = frerCpsSeqRcvyPassedPackets + 1;
      frerCpSeqRcvyPassedPackets  = frerCpSeqRcvyPassedPackets  + 1;
      RemainingTicks              =
         ((frerSeqRcvyResetMSec * TicksPerSecond) + 999) / 1000;
      PRESENT_DATA;
      return;
   }
   // Compute signed difference modulo RecovSeqSpace.
   int delta = (sequence_number-RecovSeqNum) & (RecovSeqSpace - 1);
   if (delta == 0) {
      // Packet has been seen.  Do not forward.  Count the discard.
      frerCpsSeqRcvyDiscardedPackets =
                                  frerCpsSeqRcvyDiscardedPackets + 1;
      frerCpSeqRcvyDiscardPackets    = frerCpSeqRcvyDiscardPackets + 1;
      // Reset timer if working on an individual Stream
      if (frerSeqRcvyIndividualRecovery)
         RemainingTicks          =
            ((frerSeqRcvyResetMSec * TicksPerSecond) + 999) / 1000;
   } else {
      // Packet has not been seen; accept it.
      // Packet is out-of-order unless it directly follows RecovSeqNum
      if (delta != 1)
```


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```
      frerCpsSeqRcvyOutOfOrderPackets =
                                frerCpsSeqRcvyOutOfOrderPackets + 1;
    RecovSeqNum                   = sequence_number;
    frerCpsSeqRcvyPassedPackets = frerCpsSeqRcvyPassedPackets + 1;
    frerCpSeqRcvyPassedPackets  = frerCpSeqRcvyPassedPackets  + 1;
    RemainingTicks                =
      ((frerSeqRcvyResetMSec * TicksPerSecond) + 999) / 1000;
    PRESENT_DATA;
  }
}
```

7.8 Redundancy tag

Change the second sentence of the first paragraph of 7.8 as follows:

It operates at the frame level and can be defined using the ISS defined by IEEE Std 802.1AC, or the EISS described in 6.9 of IEEE Std 802.1Q-~~2014~~2018, enhanced with the extra stream_handle and sequence_number subparameters specified in 6.1.

7.9 HSR sequence tag

Change the second sentence of the first paragraph of 7.9 as follows:

It operates at the frame level and can be defined using the ISS defined by IEEE Std 802.1AC, or the EISS described in 6.9 of IEEE Std 802.1Q-~~2014~~2018, enhanced with the extra stream_handle and sequence_number subparameters specified in 6.1.

7.10 PRP sequence trailer

Change the second sentence of the first paragraph of 7.10 as follows:

It operates at the frame level and can be defined using the ISS defined by IEEE Std 802.1AC, or the EISS described in 6.9 of IEEE Std 802.1Q-~~2014~~2018, enhanced with the extra stream_handle and sequence_number subparameters specified in 6.1.

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