                 Control Protocol Extensions for the Setup of
        Time-Division Multiplexing (TDM) Pseudowires in MPLS Networks

Status of This Memo

   This document specifies an Internet standards track protocol for the
   Internet community, and requests discussion and suggestions for
   improvements. Please refer to the current edition of the "Internet
   Official Protocol Standards" (STD 1) for the standardization state
   and status of this protocol. Distribution of this memo is unlimited.

Abstract

   This document defines extension to the Pseudowire Emulation Edge-to-
   Edge (PWE3) control protocol RFC 4447 and PWE3 IANA allocations RFC
   4446 required for the setup of Time-Division Multiplexing (TDM)
   pseudowires in MPLS networks.

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1. Introduction

   This document defines an extension to the PWE3 control protocol
   [RFC4447] and PWE3 IANA allocations [RFC4446] required for the setup
   of TDM pseudowires in MPLS networks.

   Structure-agnostic TDM pseudowires have been specified in [RFC4553],
   and structure-aware ones have been specified in [RFC5086] and
   [RFC5087].

   [RFC4447] defines extensions to the Label Distribution Protocol (LDP)
   [RFC5036] that are required to exchange PW labels for PWs emulating
   various Layer 2 services (Ethernet, Frame Relay (FR), Asynchronous
   Transfer Mode (ATM), High-Level Data Link Control (HDLC), etc.). The
   setup of TDM PWs requires both interpretation of the existing
   information elements of these extensions and exchange of additional
   information.

   The setup of TDM PWs using L2TPv3 will be defined in a separate
   document.

   The status of attachment circuits of TDM PWs can be exchanged between
   the terminating Provider Edges (PEs) using the PW Status mechanism
   defined in [RFC4447] without any changes. However, usage of this
   mechanism is NOT RECOMMENDED for TDM PWs since the indication of the
   status of the TDM attachment circuits is carried in-band in the data
   plane.

   The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
   document are to be interpreted as described in [RFC2119].

2. PW FEC for Setup of TDM PWs

   [RFC4447] uses the LDP Label Mapping message [RFC5036] for
   advertising the FEC-to-PW Label binding, and defines two types of PW
   Forwarding Equivalence Classes (FECs) that can be used for this
   purpose:

   1. PWId FEC (FEC 128). This FEC contains:

      a) PW type

      b) Control bit (indicates presence of the control word)

      c) Group ID

      d) PW ID

     e) Interface parameters Sub-TLV

   2. Generalized PW FEC (FEC 129). This FEC contains only:

     a) PW type

     b) Control bit

     c) Attachment Group Identifier (AGI), Source Attachment Individual
        Identifier (SAII), and Target Attachment Individual Identifier
        (TAII) that replace the PW ID

The Group ID and the Interface Parameters are contained in separate
TLVs, called the PW Grouping TLV and the Interface Parameters TLV.

Either of these types of PW FEC MAY be used for the setup of TDM PWs
with the appropriate selection of PW types and interface parameters.

The PW types for TDM PWs are allocated in [RFC4446] as follows:

o   0x0011   Structure-agnostic E1 over Packet [RFC4553]
o   0x0012   Structure-agnostic T1 (DS1) over Packet [RFC4553]
o   0x0013   Structure-agnostic E3 over Packet [RFC4553]
o   0x0014   Structure-agnostic T3 (DS3) over Packet [RFC4553]
o   0x0015   CESoPSN basic mode [RFC5086]
o   0x0016   TDMoIP AAL1 mode [RFC5087]
o   0x0017   CESoPSN TDM with CAS [RFC5086]
o   0x0018   TDMoIP AAL2 mode [RFC5087]

The two endpoints MUST agree on the PW type, as both directions of
the PW are required to be of the same type.

The Control bit MUST always be set for TDM PWs since all TDM PW
encapsulations always use a control word.

PW type 0x0012 MUST also be used for the setup of structure-agnostic
TDM PWs between a pair of J1 attachment circuits (see [RFC4805]).

3. Interface Parameters for TDM PWs

3.1. Overview

   The interface parameters that are relevant for the setup of the TDM
   PWs are listed below.

Interface Parameter	Sub-TLV ID	Length	Description
CEP/TDM Payload Bytes	0x04	4	Section 3.2
CEP/TDM Bit-Rate	0x07	6	Section 3.3
Number of TDMoIP AAL1	0x0E	4	Section 3.4
Cells per Packet			
TDMoIP AAL1 Mode	0x10	4	Section 3.5
TDMoIP AAL2 Options	0x11	8 or	Section 3.6
		larger	
		see note	
Fragmentation	0x09	4	Section 3.7
Indicator			
TDM Options	0x0B	4, 8,	Section 3.8
		or 12	

   If not explicitly indicated otherwise in the appropriate description,
   the value of the interface parameter is interpreted as an unsigned
   integer of the appropriate size (16 or 32 bits).

   Note: The length of basic TDMoIP AAL2 Options interface parameter is
   8 bytes, and when the optional Channel ID (CID) mapping bases field
   is used, there is one additional byte for each trunk transported.
   Thus, if 1 trunk is being supported, this message occupies 9 bytes.
   Since there can be no more than 248 CIDs in a given PW, this can
   never exceed 256 (this when each channel comes from a different
   trunk). 248 channels translates to less than 9 E1s, and so, for this
   case, the length is

no more than 17 bytes. A single PE is not required to support more
than 10 AAL2 PWs (i.e., up to 2480 individual channels, which is more
than carried by a fully populated STM1). Thus, the memory required
to store all the AAL2 mapping information is typically between 80 and
170 bytes per PE.

3.2. CEP/TDM Payload Bytes

This parameter is used for the setup of all SAToP and CESoPSN PWs
(i.e., PW types 0x0011, 0x0012, 0x0013, 0x0014, 0x0015, and 0x0017)
and employs the following semantics:

1. The two endpoints of a TDM PW MUST agree on the same value of this
   parameter for the PW to be set up successfully.

2. Presence of this parameter in the PWId FEC or in the Interface
   Parameters Field TLV is OPTIONAL. If this parameter is omitted,
   default payload size defined for the corresponding service (see
   [RFC4553], [RFC5086]) MUST be assumed.

3. For structure-agnostic emulation, any value consistent with the
   MTU of the underlying PSN MAY be specified.

4. For CESoPSN PWs:

   a) The specified value P MUST be an integer multiple of N, where N
      is the number of timeslots in the attachment circuit.

   b) For trunk-specific NxDS0 with CAS:

      i) (P/N) MUST be an integer factor of the number of frames per
         corresponding trunk multiframe (i.e., 16 for an E1 trunk and
         24 for a T1 or J1 trunk).

     ii) The size of the signaling sub-structure is not accounted for
         in the specified value P.

5. This parameter MUST NOT be used for the setup of TDMoIP PWs (i.e.,
   PWs with PW types 0x0016 and 0x0018).

3.3. CEP/TDM Bit-Rate (0x07)

This interface parameter represents the bit-rate of the TDM service
in multiples of the "basic" 64 Kbit/s rate. Its usage for all types
of TDM PWs assumes the following semantics:

1. This interface parameter MAY be omitted if the attachment circuit
   bit-rate can be unambiguously derived from the PW type (i.e., for
   structure-agnostic emulation of E1, E3, and T3 circuits). If this
   value is omitted for the structure-agnostic emulation of T1 PW
   type, the basic emulation mode MUST be assumed.

2. If present, only the following values MUST be specified for
   structure-agnostic emulation (see [RFC4553]:

   a) Structure-agnostic E1 emulation - 32

   b) Structure-agnostic T1 emulation:

      i) MUST be set to 24 in the basic emulation mode

     ii) MUST be set to 25 for the "Octet-aligned T1" emulation mode

   c) Structure-agnostic E3 emulation - 535

   d) Structure-agnostic T3 emulation - 699

3. For all kinds of structure-aware emulation, this parameter MUST be
   set to N, where N is the number of DS0 channels in the
   corresponding attachment circuit.

Note: The value 24 does not represent the actual bit-rate of the T1
or J1 circuit (1,544 Mbit/s) in units of 64 kbit/s. The values
mentioned above are used for convenience.

Note: A 4-byte space is reserved for this parameter for compatibility
with [RFC4842].

3.4. Number of TDMoIP AAL1 Cells per Packet

This parameter MAY be present for TDMoIP AAL1 mode PWs (PW type
0x0016) and specifies the number of 48-byte AAL1 PDUs per MPLS
packet. Any values consistent with the MTU of the underlying PSN MAY
be specified. If this parameter is not specified, it defaults to 1
PDU per packet for low bit-rates (CEP/TDM Bit-Rate less than or equal
to 32), and to 5 for high bit-rates (CEP/TDM Bit-Rate of 535 or 699).
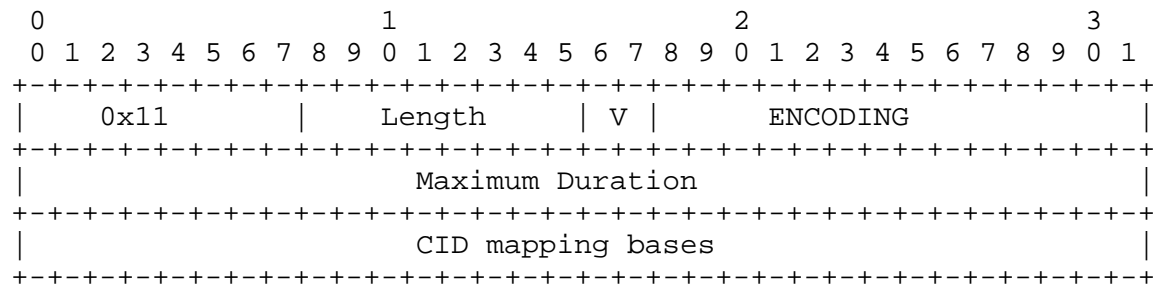
3.5. TDMoIP AAL1 Mode

   This parameter MAY be present for TDMoIP AAL1 mode PWs (PW type
   0x0016) and specifies the AAL1 mode. If this parameter is not
   present, the AAL1 mode defaults to "structured". When specified, the
   values have the following significance:

      0 - unstructured AAL1
      2 - structured AAL1
      3 - structured AAL1 with CAS

   The two endpoints MUST agree on the TDMoIP AAL1 mode.

3.6. TDMoIP AAL2 Options

   This parameter MUST be present for TDMoIP AAL2 mode PWs (PW type
   0x0018) and has the following format:

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |    0x11       |    Length     | V |         ENCODING          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                       Maximum Duration                        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                       CID mapping bases                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   The fields in this parameter are defined as follows:

   V defines the Voice Activity Detection (VAD) capabilities. Its
   values have the following significance:

      0 means that activity is only indicated by signaling.
      1 means that voice activity detection is employed.
      3 means this channel is always active. In particular, this
        channel may be used for timing recovery.

   Encoding specifies native signal processing performed on the payload.
   When no native signal processing is performed (i.e., G.711 encoding),
   this field MUST be zero. Other specific values that can be used in
   this field are beyond the scope of this specification, but the two
   directions MUST match for the PW setup to succeed.

Maximum Duration specifies the maximum time allowed for filling an
AAL2 PDU, in units of 125 microseconds. For unencoded 64 kbps
channels, this numerically equals the maximum number of bytes per PDU
and MUST be less than 64. For other encoding parameters, larger
values may be attained.

CID mapping bases is an OPTIONAL parameter; its existence and length
are determined by the length field. If the mapping of AAL2 CID
values to a physical interface and time slot is statically
configured, or if AAL2 switching [Q.2630.1] is employed, this
parameter MUST NOT appear. When it is present, and the channels
belong to N physical interfaces (i.e., N E1s or T1s), it MUST be N
bytes in length. Each byte represents a number to be subtracted from
the CID to get the timeslot number for each physical interface. For
example, if the CID mapping bases parameter consists of the bytes 20
and 60, this signifies that timeslot 1 of trunk 1 corresponds to CID
21, and timeslot 1 of trunk 2 is called 61.

3.7. Fragmentation Indicator

This interface parameter is specified in [RFC4446], and its usage is
explained in [RFC4623]. It MUST be omitted in the FEC of all TDM PWs
excluding trunk-specific NxDS0 services with CAS using the CESoPSN
encapsulation. In the case of these services, it MUST be present in
the PW FEC if the payload size specified value P differs from
Nx(number of frames per trunk multiframe).

3.8. TDM Options

This is a new interface parameter. Its Interface Parameter ID (0x0B)
has been assigned by IANA, and its format is shown in Figure 1 below:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Parameter ID |    Length     |R|D|F|X|SP |CAS|    RSVD-1     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0|    PT       |    RSVD-2      |              FREQ             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                             SSRC                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
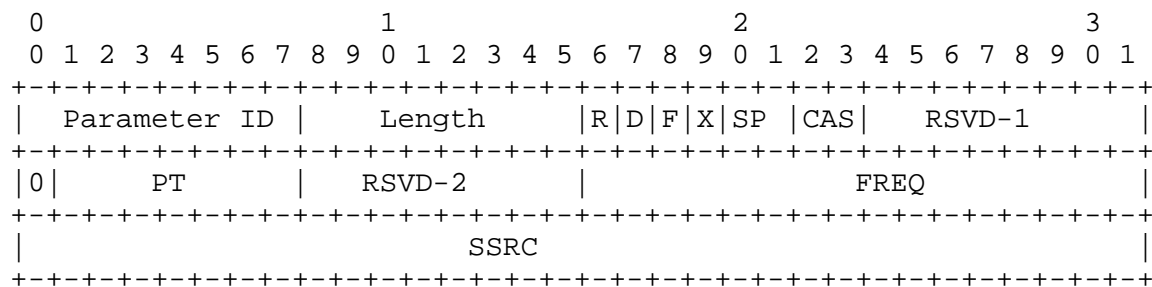
Figure 1. Format of the TDM Options Interface Parameter Sub-TLV

The fields shown in this diagram are used as follows:

Parameter ID   Identifies the TDM PW Options interface
                      parameter, 0x0B.

Length   4, 8, or 12 (see below).

R   The RTP Header Usage bit: if set, indicates that
                       the PW endpoint distributing this FEC expects to
                       receive RTP header in the encapsulation. RTP
                       header will be used only if both endpoints expect
                       to receive it. If this bit is cleared, Length
                       MUST be set to 4; otherwise, it MUST be either 8
                       or 12 (see below). If the peer PW endpoint
                       cannot meet this requirement, the Label Mapping
                       message containing the FEC in question MUST be
                       rejected with the appropriate status code (see
                       Section 4 below).

D   The Differential timestamping Mode bit: if set,
                       indicates that the PW endpoint distributing this
                       FEC expects the peer to use Differential
                       timestamping mode in the packets sent to it. If
                       the peer PW endpoint cannot meet this
                       requirement, the Label Mapping message containing
                       the FEC in question MUST be rejected with the
                       appropriate status code (see Section 4 below).

F, X   Reserved for future extensions. MUST be cleared
                       when distributed and MUST be ignored upon
                       reception.

SP   Encodes support for the CESoPSN signaling packets
                       (see [RFC5086]):

                       o '00' for PWs that do not use signaling packets

                       o '01' for CESoPSN PWs carrying TDM data packets
                          and expecting Customer Edge (CE) application
                          signaling packets in a separate PW

                       o '10' for a PW carrying CE application
                          signaling packets with the data packets in a
                          separate PW

                       o '11' for CESoPSN PWs carrying TDM data and CE
                          application signaling on the same PW

        CAS   MUST be cleared for all types of TDM PWs
                            excluding trunk-specific NxDS0 services with CAS.
                            For these services, it encodes the trunk framing
                            like the following:

                                o '01' - an E1 trunk

                                o '10' - a T1/ESF trunk

                                o '11' - a T1 SF trunk

        RSVD-1 and RSVD-2   Reserved bits, which MUST be set to 0 by the PW
                            endpoint distributing this FEC and MUST be
                            ignored by the receiver.

        PT   Indicates the value of Payload Type in the RTP
                            header expected by the PW endpoint distributing
                            this FEC. A value of 0 means that the PT value
                            check will not be used for detecting malformed
                            packets.

        FREQ   Frequency of timestamping clock in units of 8
                            kHz.

        SSRC   Indicates the value of the Synchronization source
                            ID (SSRC ID) in the RTP header expected by the PW
                            endpoint distributing this FEC. A value of 0
                            means that the SSRC ID value check will not be
                            used for detecting misconnections.
                            Alternatively, Length can be set to 8 in this
                            case.

     Notes:

     1. This interface parameter MAY be omitted in the following cases:

        a) SAToP PWs that do not use RTP header [RFC4553].

        b) Basic CESoPSN NxDS0 services without CE application signaling
           [RFC5086].

        c) TDMoIP AAL1 mode 0 or 2 PWs that do not use RTP .

        d) TDMoIP AAL2 PWs that do not relay CAS signaling and do not use
           RTP.

2. This interface parameter MUST be present in the following cases:

   a) All TDM PWs that use RTP headers.

   b) CESoPSN PWs that carry basic NxDS0 services and use CESoPSN
      signaling packets to carry CE application signaling. This case
      is discussed in detail in Section 4 below.

   c) CESoPSN PWs that carry trunk-specific NxDS0 services with CAS.

   d) TDMoIP AAL1 mode 1 PWs.

   e) TDMoIP AAL2 PWs that relay CAS signaling.

3. If RTP header and possibly the Differential timestamping mode are
   used, the value of the Length field MUST be set to 8 or 12 in
   order to accommodate the Timestamping Clock Frequency and SSRC
   fields.

4. Usage or non-usage of the RTP header MUST match for the two
   directions making up the TDM PW. However, it is possible to use
   the Differential timestamping mode in just one direction.

4. Extending CESoPSN Basic NxDS0 Services with CE Application Signaling

   [RFC5086] states that basic NxDS0 services can be extended to carry
   CE application signaling (e.g., CAS) in special signaling packets
   carried in a separate PW.

   The following rules define the setup of matching pairs of CESoPSN PWs
   using the PW ID FEC and the extensions defined above:

   1. The two PWs MUST:

      a) Have the same PW type.

      b) Use the same setup method (i.e., either both use the PWId FEC,
         or both use the Generalized PW FEC).

      c) Have the same values of all the Interface Parameters listed in
         Section 3.1 above with the exception of the code point in the
         SP field of the TDM Options parameter:

         i) For the PW carrying TDM data packets, the SP bits MUST be
            set to '01'.

         ii) For the PW carrying the signaling packets, the SP bits MUST
             set to '10'.

   2. If the PWId FEC has been used:

      a) The value of PW ID for the CESoPSN PW carrying TDM data packets
         MUST be even.

      b) The value of PW ID for the CESoPSN PW carrying CE application
         signaling MUST be the next (odd) value after the (even) PW ID
         of the CESoPSN PW carrying TDM data packets.

   When using the Generalized PW FEC for the setup of the two PWs, no
   specific rules for matching the two FECs are defined.
   Implementation-specific mechanisms MAY be employed to verify the
   proper matching of the TDM data PW with its associated CE signaling
   PW.

   If one of the two associated PWs has been established and the other
   failed to be established, or for any reason fails after having been
   established, the established PW MUST be torn down.

5. LDP Status Codes

   In addition to the status codes defined in Sections 5.1 and 7.2 of
   [RFC4447], the following status codes defined in [RFC4446] MUST be
   used to indicate the reason of failure to establish a TDM PW:

   1. Incompatible bit-rate:

      a) In the case of a mismatch of T1 encapsulation modes (basic vs.
         octet-aligned).

      b) In the case of a mismatch in the number of timeslots for NxDS0
         basic services or trunk-specific NxDS0 services with CAS.

   2. CEP/TDM misconfiguration:

      a) In the case of a mismatch in the desired usage of RTP header.

      b) In the case of a mismatch of the desired Timestamping Clock
         Frequency.

      c) In the case of a mismatch of expected signaling packets
         behavior for basic CESoPSN NxDS0 services extended to carry CE
         application signaling in separate signaling packets.

      d) In the case of trunk-specific NxDS0 services with CAS if the
         framing types of the trunks are different.

   e) In the case of TDMoIP AAL1 PWs with different AAL1 modes
      specified by the endpoints.

   3. The generic misconfiguration error MAY be used to indicate any
      setup failure not covered above.

   In cases 2a, 2b, 2c, and 2e above, the user MAY reconfigure the
   endpoints and attempt to set up the PW once again.

   In the case of 2d, the failure is fatal.

   Note that setting of the Control bit (see Section 2 above) to zero
   MUST result in an LDP status of "Illegal C-Bit".

6. Using the PW Status TLV

   The TDM PW control word carries status indications for both
   attachment circuits (L and M fields) and the PSN (R field) indication
   (see [RFC4553], [RFC5086], and [RFC5087]). Similar functionality is
   available via use of the PW Status TLV (see Section 5.4.2 of
   [RFC4447]). If the latter mechanism is employed, the signaling PE
   sends its peer a PW Status TLV for this PW, setting the appropriate
   bits (see Section 3.5 of [RFC4446]):

      o Pseudowire Not Forwarding
      o Local Attachment Circuit (ingress) Receive Fault
      o Local Attachment Circuit (egress) Transmit Fault
      o Local PSN-facing PW (ingress) Receive Fault
      o Local PSN-facing PW (egress) Transmit Fault

   As long as the TDM PW interworking function is operational, usage of
   the Status TLV is NOT RECOMMENDED in order to avoid contention
   between status indications reported by the data and control plane.
   However, if the TDM PW interworking function (IWF) itself fails while
   the PWE3 control plane remains operational, a Status TLV with all of
   the above bits set SHOULD be sent.

7. IANA Considerations

   Most of the IANA assignments required by this document are already
   listed in [RFC4446]. Additional assignments have been made for four
   Interface Parameter Sub-TLV types (see Section 3.1):

      o TDM Options (0x0B)
      o Number of TDMoIP AAL1 cells per packet (0x0E)
      o TDMoIP AAL1 mode (0x10)
      o TDMoIP AAL2 Options (0x11)

8. Security Considerations

   This document does not have any additional impact on the security of
   PWs above that of basic LDP-based setup of PWs specified in
   [RFC4447].

9. Acknowledgements

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Authors' Addresses

   Alexander ("Sasha") Vainshtein
   ECI Telecom
   30 ha-Sivim St.,
   PO Box 500 Petah-Tiqva, 49517 Israel

   EMail: Alexander.Vainshtein@ecitele.com

   Yaakov (Jonathan) Stein
   RAD Data Communications
   24 Raoul Wallenberg St., Bldg C
   Tel Aviv 69719
   ISRAEL

   Phone: +972 3 645-5389
   EMail: yaakov_s@rad.com