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Transporting PTP messages (1588) over MPLS Networks
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Abstract

This document defines the method for transporting PTP messages (PDUs) over an MPLS network to enable a proper handling of these packets (e.g. implementation of Transparent Clocks (TC)) in LSRs.

The basic idea is to transport PTP messages inside dedicated MPLS LSPs. These LSPs only carry PTP messages and possibly Control and Management packets, but they do not carry customer traffic.

Two methods for transporting 1588 over MPLS are defined. The first method is to transport PTP messages directly over the dedicated MPLS LSP via UDP/IP encapsulation, which is suitable for IP/MPLS networks. The second method is to transport PTP messages inside a PW via Ethernet encapsulation, which is more suitable for MPLS-TP networks.

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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 [RFC2119].

When used in lower case, these words convey their typical use in common language, and are not to be interpreted as described in RFC2119 [RFC2119].

1. Introduction

The objective of Precision Time Protocol (PTP) is to synchronize independent clocks running on separate nodes of a distributed system. [IEEE] defines PTP messages for clock and time synchronization. The PTP messages include PTP PDUs over UDP/IP (Annex D & E of [IEEE]) and PTP PDUs over Ethernet (Annex F of [IEEE]). This document defines mapping and transport of the PTP messages defined in [IEEE] over MPLS networks.

PTP defines intermediate clock functions (called transparent clocks) between the source of time (Master) and the Slave clocks. Boundary Clocks (BC) form Master-Slave hierarchy with the Master clock as root. The messages related to synchronization, establishing the Master-Slave hierarchy, and signaling, terminate in the protocol engine of a boundary clock and are not forwarded. Management messages however, are forwarded to other ports on the boundary clock.

Transparent clocks modify a "correction field" (CF) within the synchronization messages to compensate for residence and propagation delays. Transparent clocks do not terminate synchronization, Master-Slave hierarchy control messages or signaling messages.

There is a need to transport PTP messages over MPLS networks. The MPLS network could be a transit network between 1588 Masters and Slaves. The accuracy of the recovered clock improves and the Slave logic simplifies when intermediate nodes (e.g. LSRs) properly handle PTP messages (e.g. perform TC), otherwise the jitter at the 1588 Slave may be excessive and therefore the Slave may not be able to properly recover the clock and time of day.

This document defines a "1588-aware LSR" that is able to identify 1588 timing flows carried over MPLS.

Transparent Clock (TC) function requires a 1588-aware LSR in the middle of an LSP to identify the PTP messages and perform proper update of the CF, via a 1-step or 2-step process.

More generally this document requires that an LSR should be able to properly handle the PTP messages. For instance for those cases when the TC function is not viable (e.g. due to layer violation) as an alternative it should be possible to instead control the delay for these messages on both directions across the node.

In the above cases it is beneficial that PTP packets can be easily identified when carried over MPLS.

This document provides two methods for transporting PTP messages over

MPLS. The main objectives are for LSRs to be able to deterministically detect and identify the PTP messages.

2. Terminology

1588: The timing and synchronization as defined by IEEE 1588

PTP: The timing and synchronization protocol used by 1588

Master: The Source of 1588 Timing and clock

Slave: The Destination of 1588 Timing and clock that tries to follow the Master clock

OC: Ordinary Clock

TC: Transparent Clock, a time stamping method applied by intermediate nodes between Master and Slave

BC: Boundary Clock, is a node that recovers the Master clock via a Slave function and uses that clock as the Master for other Slaves

PTP LSP: An LSP dedicated to carry PTP messages

PTP PW: A PW within a PTP LSP that is dedicated to carry PTP messages.

CW: Pseudowire Control Word

LAG: Link Aggregation

ECMP: Equal Cost Multipath

CF: Correction Field, a field inside certain PTP messages (message type 0-3)that holds the accumulative transit time inside intermediate switches

3. Problem Statement

When PTP messages are transported over MPLS networks, there is a need for intermediate LSRs to detect such messages and perform proper processing (e.g. Transparent Clock (TC)). Note the TC processing could be in the form of 1-Step or 2-Step time stamping.

PTP messages over Ethernet or IP can always be tunneled over MPLS. However the 1588 over MPLS mapping defined in this document is applicable whenever MPLS LSRs are 1588-aware and the intention is for those LSRs to perform proper processing on these packets.

When 1588-awareness is needed, PTP messages should not be transported over LSPs or PWs that are carrying customer traffic because LSRs perform Label switching based on the top label in the stack. To detect PTP messages inside such LSPs require special Hardware (HW) to do deep packet inspection at line rate. Even if one assumes a deep packet inspection HW at line rate exists, the payload can’t be deterministically identified by LSRs because the payload type is a context of the PW label and the PW label and its context are only known to the Edge routers (PEs) and LSRs don’t know what is a PW’s payload (Ethernet, ATM, FR, CES, etc). Even if one assumes only Ethernet PWs are permitted in an LSP, the LSRs don’t have the knowledge of whether PW Control Word (CW) is present or not and therefore can’t deterministically identify the payload.

Therefore a generic method is defined in this document that does not require deep packet inspection at line rate, and can deterministically identify PTP messages. The defined method is applicable to both MPLS and MPLS-TP networks.

4. Dedicated LSPs for PTP messages

Many methods were considered for identifying the 1588 messages when they are encapsulated in MPLS such as by using GAL/ACH or a new reserved label. These methods were not attractive since they either required deep packet inspection and snooping at line rate or they required use of scarce new reserved label. Also one of the goals was to reuse existing OAM and protection mechanisms.

The method defined in this document can be used by LSRs to identify PTP messages in MPLS tunnels by using dedicated LSPs to carry PTP messages.

Compliant implementations MUST use dedicated LSPs to carry PTP messages over MPLS. Let’s call these LSPs as the "PTP LSPs" and the labels associated with these LSPs as "PTP labels". These LSPs could be P2P or P2MP LSPs. The PTP LSP between Master and Slaves MAY be P2MP or P2P LSP while the PTP LSP between each Slave and Master SHOULD be P2P LSP. The PTP LSP between a Master and a Slave and the PTP LSP between the same Slave and Master MUST be co-routed. Alternatively, a single bidirectional co-routed LSP can be used. The PTP LSP MAY be MPLS LSP or MPLS-TP LSP.

The PTP LSPs could be configured or signaled via RSVP-TE/GMPLS. New RSVP-TE/GMPLS TLVs and objects are defined in this document to indicate that these LSPs are PTP LSPs.

We should be selective about the kind of traffic that flows over PTP LSPs as these will be handled as a special case by the LSR. The only LSP user plane traffic MUST be PTP, but the LSP MAY also carry essential MPLS/MPLS-TP control plane traffic such as BFD and LSP-Ping.

5. 1588 over MPLS Encapsulation

This document defines two methods for carrying PTP messages over MPLS. The first method is carrying IP encapsulated PTP messages over PTP LSPs and the second method is to carry PTP messages over dedicated Ethernet PWs (called PTP PWs) inside PTP LSPs.

5.1. 1588 over LSP Encapsulation

The simplest method of transporting PTP messages over MPLS is to encapsulate PTP PDUs in UDP/IP and then encapsulate them in PTP LSP. The 1588 over LSP format is shown in Figure 1.

```
+----------------------+
|   PTP Tunnel Label   |
+----------------------+
|        IPv4/6        |
+----------------------+
|         UDP          |
+----------------------+
|        PTP PDU       |
+----------------------+
```

Figure 1 - 1588 over LSP Encapsulation

This encapsulation is very simple and is useful when the networks between 1588 Master and Slave are IP/MPLS networks.

In order for an LSR to process PTP messages, the PTP Label must be the top label of the label stack.

The UDP/IP encapsulation of PTP MUST follow Annex D and E of [IEEE].

5.2. 1588 over PW Encapsulation

Another method of transporting 1588 over MPLS networks is by encapsulating PTP PDUs in Ethernet and then transporting them over Ethernet PW (PTP PW) as defined in [RFC4448], which in turn is transported over PTP LSPs. Alternatively PTP PDUs MAY be encapsulated in UDP/IP/Ethernet and then transported over Ethernet PW.

Both Raw and Tagged modes for Ethernet PW are permitted. The 1588 over PW format is shown in Figure 2.

```
+----------------+
|PTP Tunnel Label|
+----------------+
|    PW Label    |
+----------------+
|  Entropy Label |
|   (optional)   |
+----------------+
|  Control Word  |
+----------------+
|    Ethernet    |
|     Header     |
+----------------+
|     VLANs      |
|   (optional)   |
+----------------+
|    IPV4/V6     |
|   (optional)   |
+----------------+
|      UDP       |
|   (optional)   |
+----------------+
|    PTP PDU     |
+----------------+
```

Figure 2 - 1588 over PW Encapsulation

The Control Word (CW) as specified in [RFC4448] SHOULD be used to ensure a more robust detection of PTP messages inside the MPLS packet. If CW is used, the use of Sequence number is optional.

The use of VLAN and UDP/IP are optional. Note that 1 or 2 VLANs MAY exist in the PW payload.

In order for an LSR to process PTP messages, the top label of the label stack (the Tunnel Label) MUST be from PTP label range. However in some applications the PW label may be the top label in the stack, such as cases where there is only one-hop between PEs or in case of PHP. In such cases, the PW label SHOULD be chosen from the PTP Label range.

An Entropy label [I-D.ietf-pwe3-fat-pw] MAY be present at the bottom of stack.

The Ethernet encapsulation of PTP MUST follow Annex F of [IEEE] and the UDP/IP encapsulation of PTP MUST follow Annex D and E of [IEEE].

For 1588 over MPLS encapsulations that are PW based, there are some cases in which the PTP LSP label may not be present:

- o When PHP is applied to the PTP LSP, and the packet is received without PTP LSP label at PW termination point .

- o When the PW is established between two routers directly connected to each other and no PTP LSP is needed.

In such cases it is required for a router to identify these packets as PTP packets. This would require the PW label to also be a label that is distributed specifically for carrying PTP traffic (aka PTP PW label). Therefore there is a need to add extension to LDP/BGP PW label distribution protocol to indicate that a PW label is a PTP PW labels.

5.3. 1588 over pure MPLS mode

Editor Note: The encapsulation is general enough and can support transporting 1588 in a pure MPLS mode (i.e., without any IP/UDP or Ethernet headers). Should the WG pursue this?

6. 1588 Message Transport

1588 protocol comprises of the following message types:

- o Announce
- o SYNC
- o FOLLOW UP
- o DELAY REQ (Delay Request)
- o DELAY RESP (Delay Response)
- o PDELAY REQ (Peer Delay Request)
- o PDELAY RESP (Peer Delay Response)
- o PDELAY RESP FOLLOW UP (Peer Delay Response Follow up)
- o Management
- o Signaling

A subset of PTP message types that require TC processing are called Event messages:

- o SYNC
- o DELAY REQ (Delay Request)
- o PDELAY REQ (Peer Delay Request)
- o PDELAY RESP (Peer Delay Response)

SYNC and DELAY_REQ are exchanged between Master and Slave and MUST be transported over PTP LSPs. PDELAY_REQ and PDELAY_RESP are exchanged between adjacent routers and MAY be transported over single hop PTP LSPs. If Two Step Transparent clocks are present, then the FOLLOW_UP and DELAY_RESP messages must also be transported over the PTP LSPs.

For a given instance of 1588 protocol, SYNC and DELAY_REQ MUST be transported over two PTP LSPs that are in opposite directions. These PTP LSPs, which are in opposite directions MUST be congruent and co-routed. Alternatively, a single bidirectional co-routed LSP can be used.

Except as indicated above for the two-step Transparent clocks, Non-

Event PTP message types don’t need to be processed by intermediate routers. These message types MAY be carried in PTP Tunnel LSPs.

7. Protection and Redundancy

In order to ensure continuous uninterrupted operation of 1588 Slaves, usually as a general practice, Redundant Masters are tracked by each Slave. It is the responsibility of the network operator to ensure that physically disjoint PTP tunnels that don't share any link are used between the redundant Masters and a Slave.

When redundant Masters are tracked by a Slave, any PTP LSP or PTP PW failure will trigger the slave to switch to the Redundant Master. However LSP/PW protection such as Linear Protection Switching (1:1,1+1), Ring protection switching or MPLS Fast Reroute (FRR) SHOULD still be used to ensure the LSP/PW is ready for a future failure.

Note that any protection or reroute mechanism that adds additional label to the label stack, such as Facility Backup Fast Reroute, MUST ensure that the pushed label is a PTP Label to ensure proper processing of PTP messages by LSRs in the backup path.

8. ECMP

To ensure the proper operation of 1588 Slaves, the physical path for PTP messages from Master to Slave and vice versa must be the same for all PTP messages listed in section 7 and must not change even in the presence of ECMP in the MPLS network.

To ensure the forward and reverse paths are the same PTP LSPs and PWs MUST not be subject to ECMP.

9. OAM, Control and Management

In order to manage PTP LSPs and PTP PWs, they MAY carry OAM, Control and Management messages. These control and management messages can be differentiated from PTP messages via already defined IETF methods.

In particular BFD [RFC5880], [RFC5884] and LSP-Ping [RFC4389]MAY run over PTP LSPs via UDP/IP encapsulation or via GAL/G-ACH. These Management protocols are easily identified by the UDP Destination Port number or by GAL/ACH respectively.

Also BFD, LSP-Ping and other Management messages MAY run over PTP PW via one of the defined VCCVs (Type 1, 2 or 3) [RFC5085]. In this case G-ACH, Router Alert Label (RAL), or PW label (TTL=1) are used to identify such management messages.

10. QoS Considerations

The PTP messages are time critical and must be treated with the highest priority. Therefore 1588 over MPLS messages must be treated with the highest priority in the routers. This can be achieved by proper setup of PTP tunnels. It is recommended that the PTP LSPs are setup and marked properly to indicate EF-PHB for the CoS and Green for drop eligibility.

11. FCS Recalculation

Ethernet FCS MUST be recalculated at every LSR that performs the TC processing and FCS retention described in [RFC4720] MUST not be used.

12. UDP Checksum Correction

For UDP/IP encapsulation mode of 1588 over MPLS, the UDP checksum is optional when used for IPv4 encapsulation and mandatory in case of IPv6. When IPv4/v6 UDP checksum is used each 1588-aware LSR must either incrementally update the UDP checksum after the CF update or should verify the UDP checksum on reception from upstream and recalculate the checksum completely on transmission after CF update to downstream node.

13. Routing extensions for 1588aware LSRs

MPLS-TE routing relies on extensions to OSPF [RFC2328] [RFC5340] and IS-IS [ISO] [RFC1195] in order to advertise Traffic Engineering (TE) link information used for constraint-based routing.

Indeed, it is useful to advertise data plane TE node capabilities, such as the capability for a router to be 1588-aware. This capability MUST then be taken into account during path computation to prefer nodes that advertise themselves as 1588-aware, so that the PTP LSPs can be properly handled.

For this purpose, the following sections specify extensions to OSPF and IS-IS in order to advertise 1588 aware capabilities of a node.

Editor Note: There is an open issue on whether we must consider LSRs that may not want to support PTP on all ports. An example could be an LSR where a few blades have been upgraded to support PTP timestamping in silicon. In such cases, routers must explicitly indicate the ports that are 1588-aware. If the WG agrees about this then we will need to change the subsequent OSPF and IS-IS sections to advertise the 1588-aware capability on per port/interface basis, rather than per node as is current described.

13.1. 1588aware Node Capability for OSPF

This extension makes use of the Router Information (RI) Opaque LSA defined in [RFC4970]for both OSPFv2 and OSPFv3, by defining a new OSPF Router Information (RI) TLV - The 1588-aware Capability TLV.

The 1588-aware Capability TLV is OPTIONAL and is defined as follows:

```
 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
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |              Type             |             Length            |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |     Flags     |
 +-+-+-+-+-+-+-+-+
```

Figure 3: 1588-aware Capability TLV

Where:

Type, 16 bits: 1588-aware Capability TLV where the value is TBD

Length, 16 bits: Gives the length of the flags field in octets, and is currently set to 1

Flags, 8 bits: The bits are defined least-significant-bit (LSB) first, so bit 7 is the least significant bit of the flags octet.

```
 0 1 2 3 4 5 6 7
+-+-+-+-+-+-+-+-+
|   Reserved  |C|
+-+-+-+-+-+-+-+-+
```

Figure 4: Flags Format

Correction (C) field Update field, 1 bit: Setting the C bit to 1 indicates that the node is capable of recognizing the PTP event packets and can compensate for residence time by updating the PTP packet Correction Field. When this is set to 0, it means that this node cannot perform the residence time correction but is capable of performing MPLS frame forwarding of the frames with PTP labels using a method that support the end to end delivery of accurate timing. The exact method is not defined herein.

Reserved, 7 bits: Reserved for future use. The reserved bits must be ignored by the receiver.

The 1588-aware Capability TLV is applicable to both OSPFv2 and OSPFv3.

The 1588-aware Capability TLV MAY be advertised within an area-local or autonomous system (AS) scope Router Information (RI) LSA. But the 1588-aware Capability TLV SHOULD NOT be advertised into an area in more than one RI LSA irrespective of the scope of the LSA.

The flooding scope is controlled by the Opaque LSA type in OSPFv2 and by the S1 and S2 bits in OSPFv3. For area scope, the 1588-aware Capability TLV MUST be carried within an OSPFv2 Type 10 RI LSA or an OSPFv3 RI LSA with the S1 bit set and S2 bit clear. If the flooding scope is the entire routing domain (AS scope), the 1588-aware Capability TLV MUST be carried within an OSPFv2 Type 11 RI LSA or OSPFv3 RI LSA with the S1 bit clear and the S2 bit set.

13.2. 1588aware Node Capability for IS-IS

Generic capability advertisement mechanisms for IS-IS are defined in [RFC4971]. These allow a router to advertise its capabilities within an IS-IS area or an entire IS-IS routing domain. This document defines a new sub-TLV (named the 1588-aware Capability) to be carried within the IS-IS Router Capability TLV.

The IS-IS extensions defined in this document allow for discovering 1588-aware nodes within an IS-IS routing domain. Solutions for 1588-aware nodes discovery across AS boundaries are beyond the scope of this document, and are for further study.

The format of the IS-IS 1588-aware sub-TLV is identical to the TLV format used by the Traffic Engineering Extensions to IS-IS [RFC3784]. That is, the TLV is comprised of 1 octet for the type, 1 octet specifying the TLV length, and a value field. The Length field defines the length of the value portion in octets.

```
 0                   1                   2
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |     Type      |     Length    |    Flags      |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: 1588-aware Capability sub-TLV

Where:

Type, 8 bits: 1588-aware Capability sub-TLV where the value is TBD

Length, 8 bits: Gives the length of the flags field in octets, and is currently set to 1

Flags, 8 bits: The bits are defined least-significant-bit (LSB) first, so bit 7 is the least significant bit of the flags octet.

```
  0 1 2 3 4 5 6 7
 +-+-+-+-+-+-+-+-+
 |   Reserved  |C|
 +-+-+-+-+-+-+-+-+
```

Figure 6: Flags Format

Correction (C) field Update field, 1 bit: Setting the C bit to 1 indicates that the node is capable of recognizing the PTP event packets and can compensate for residence time by updating the PTP packet Correction Field. When this is set to 0, it means that this node cannot perform the residence time correction but is capable of performing MPLS frame forwarding of the frames with PTP labels using a method that support the end to end delivery of accurate timing. The exact method is not defined herein.

Reserved, 7 bits: Reserved for future use. The reserved bits must be ignored by the receiver.

The 1588-aware sub-TLV is optional and is carried within an IS-IS Capability TLV [RFC4971] to facilitate selection of 1588-aware nodes.

The flooding scope for 1588-aware node information advertised through IS-IS can be a single L1 area, an L1 area and the L2 sub-domain, or the entire IS-IS routing domain.

14. RSVP-TE Extensions for support of 1588

RSVP-TE signaling MAY be used to setup the PTP LSPs. A new RSVP object is defined to signal that this is a PTP LSP. The OFFSET to the start of the PTP message header MAY also be signaled. Implementations can trivially locate the correctionField (CF) location given this information. The OFFSET points to the start of the PTP header as a node may want to check the PTP messageType before it touches the correctionField (CF).

The LSRs that receive and process the RSVP-TE/GMPLS messages MAY use the OFFSET to locate the start of the PTP message header.

Note that the new object/TLV Must be ignored by LSRs that are not compliant to this specification.

The new RSVP 1588_PTP_LSP object should be included in signaling PTP LSPs and is defined as follows:

```
       0             1             2             3
+-------------+-------------+-------------+-------------+
|       Length (bytes)      |  Class-Num  |   C-Type    |
+-------------+-------------+-------------+-------------+
| Offset to locate the start of the PTP message header  |
+-------------+-------------+-------------+-------------+
```

Figure 7: RSVP 1588_PTP_LSP object

The ingress LSR MUST include this object in the RSVP PATH Message. It is just a normal RSVP path that is exclusively set up for PTP messages

15. Distributing PW labels

15.1. LDP extensions for distributing PW labels

TBD

15.2. BGP extensions for distributing PW labels

TBD

16. Behavior of LER/LSR

16.1. Behavior of 1588-aware LER

A 1588-aware LER advertises it's 1588-awareness via the OSPF procedure explained in earlier section of this specification. The 1588-aware LER then signals PTP LSPs by including the 1588_PTP_LSP object in the RSVP-TE signaling.

When a 1588 message is received from a non-MPLS interface, the LER MUST redirect them to a previously established PTP LSP. When a 1588 over MPLS message is received from an MPLS interface, the processing is similar to 1588-aware LSR processing.

16.2. Behavior of 1588-aware LSR

1588-aware LSRs are LSRs that understand the 1588_PTP_LSP RSVP object and can perform 1588 processing (e.g. TC processing).

A 1588-aware LSR advertises it's 1588-awareness via the OSPF procedure explained in earlier section of this specification.

When a 1588-aware LSR distributes a label for PTP LSP, it maintains this information. When the 1588-aware LSR receives an MPLS packet, it performs a label lookup and if the label lookup indicates it is a PTP label then further parsing must be done to positively identify that the payload is 1588 and not OAM, BFD or control and management. Ruling out non-1588 messages can easily be done when parsing indicates the presence of GAL, ACH or VCCV (Type 1, 2, 3) or when the UDP port number does not match one of the 1588 UDP port numbers.

After a 1588 message is positively identified in a PTP LSP, the PTP message type indicates what type of processing (TC) if any is required. After 1588 processing the packet is forwarded as a normal MPLS packet to downstream node.

16.3. Behavior of non-1588-aware LSR

It is most beneficial that all LSRs in the path of a PTP LSP be 1588-aware LSRs. This would ensure the highest quality time and clock synchronization by 1588 Slaves. However, this specification does not mandate that all LSRs in path of a PTP LSP be 1588-aware.

Non-1588-aware LSRs are LSRs that either don't have the capability to process 1588 packets (e.g. TC processing) or don't understand the 1588_PTP_LSP RSVP object.

Non-1588-aware LSRs ignore the RSVP 1588_PTP_LSP object and just switch the MPLS packets carrying 1588 messages as data packets and don’t perform any TC processing. However as explained in QoS section the 1588 over MPLS packets MUST be still be treated with the highest priority.

17. Other considerations

The use of Explicit Null (Label= 0 or 2) is acceptable as long as either the Explicit Null label is the bottom of stack label (applicable only to UDP/IP encapsulation) or the label below the Explicit Null label is a PTP label.

The use of Penultimate Hop Pop (PHP) is acceptable as long as either the PHP label is the bottom of stack label (applicable only to UDP/IP encapsulation) or the label below the PHP label is a PTP label.

18. Security Considerations

MPLS PW security considerations in general are discussed in [RFC3985] and [RFC4447],and those considerations also apply to this document.

An experimental security protocol is defined in [IEEE]. The PTP security extension and protocol provides group source authentication, message integrity, and replay attack protection for PTP messages.

19. IANA Considerations

19.1. IANA Considerations for OSPF

IANA has defined a registry for TLVs carried in the Router Information LSA defined in [RFC4970]. IANA is requested to assign a new TLV code-point for the PCED TLV carried within the Router Information LSA.

Value	Sub-TLV	References
TBD	1588aware node sub-TLV	(this document)

19.2. IANA Considerations for IS-IS

IANA has defined a registry for the sub-TLVs carried in the IS-IS Router Capability sub-TLVs defined in [RFC4971]. IANA is requested to assign a new sub-TLV code-point for the 1588aware node sub-TLV carried within the Router Capability sub-TLV.

Value	Sub-TLV	References
TBD	1588aware node sub-TLV	(this document)

19.3. IANA Considerations for RSVP

IANA is requested to assign a new Class Number for 1588 PTP LSP object that is used to signal PTP LSPs.

1588 PTP LSP Object

Class-Num of type 11bbbbbb

Suggested value TBD

Defined CType: 1 (1588 PTP LSP)

20. References

20.1. Normative References

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20.2. Informative References

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Network Time Mechanisms for Improving Computer Clock Accuracy
draft-marlow-tictoc-computer-clock-accuracy-00.txt

Abstract

This draft describes network time synchronization mechanisms which may enable increased accuracy, beyond that possible with the current Network Time Protocol version 4 (NTPv4) standard, to time and frequency of computer clocks. The mechanisms considered are those that will provide improved estimates as to when a packet is put on the network, transferred across a network, or taken from the network. Potential standardization actions will be considered for the mechanisms considered, though no such actions are recommended at this time.

Table of Contents

1. Introduction

The IETF Timing over IP Connection and Transfer of Clock (TICTOC) Working Group was formed to investigate emerging needs to distribute highly accurate time and frequency information over Internet Protocol (IP) and Multiprotocol Label Switching (MPLS) Packet Switched Networks (PSNs). In this draft, new mechanisms beyond those identified in the NTPv4 standard (i.e., Request For Comment (RFC)

5905) are considered to provide increased time synchronization accuracy for computer (i.e., operating system) clocks' time and frequency. The mechanisms considered are those that will provide improved estimates as to when a packet is put on the network, transferred across a network, or taken from the network. This draft identifies a set of mechanisms that are candidates for experimentation. Standardization considerations will be described for the mechanisms identified.

The purpose of this draft is to examine methods for improving NTPv4 time synchronization performance. The authors are requesting comments and contributions on the mechanisms described and on additional mechanisms that should be considered. It is hoped that discussions within the IETF TICTOC Working Group will motivate experimentation that will lead to standardization actions to enable better accuracy to those utilizing a future Network Time Protocol (NTP) specification.

1.1. Motivation for Increased Performance

There are two reasons to improve upon the time synchronization performance that is currently available from NTP. Not only is the increased performance needed for existing product designs that would make use of the added performance if it were available, but it is expected that new uses will be identified that were not even possible until performance is improved. This is similar to how network speeds are increased every several years, and the uses for the increased network bandwidth soon follow.

The current methods for achieving an increase in time synchronization performance involve use of a technology separate from the existing computer network (e.g., Inter-Range Instrumentation Group [IRIG] technology) or use of a technology like Precision Time Protocol (PTP), which is defined in the Institute of Electrical and Electronics Engineers (IEEE) 1588 standard. With PTP, the computer applications must interface with the installed PTP hardware in order to read time from its oscillator. There is a lot of resiliency built into NTP, which does not exist in the PTP hardware oscillator. It is unknown what happens to the time provided by the PTP hardware when a network switch in the network path to the time source is temporarily unavailable (i.e., the network switch gets rebooted). It would be beneficial to have the resiliency of the NTP algorithms be paired with the highly accurate PTP hardware-based time distribution.

1.2. NTP/PTP Commonality and Differences

NTP and PTP are both packet-based protocols for exchanging time with a time server over a computer network. Both protocols are used to determine the offset between two independent clocks. Both implement a hierarchical tree structure for obtaining time from a master time source through intermediary time sources to time clients. Both assume network paths are symmetric, and both have their own methods for addressing network delays that are not symmetric. NTP uses its algorithms to determine which of several consecutive time measurements are most accurate and uses that measurement. PTP makes use of hardware means of measuring delays as packets traverse intermediate network devices and corrects its received time information based upon those measured delays.

Because PTP has the ability to measure actual packet delays and to correct for them, PTP can provide the most accurate measurement of clock offset between two clocks. PTP does not define the method for synchronizing that clock once the highly accurate time measurements have been obtained. PTP is normally used to synchronize a hardware clock located on an interface card and does not synchronize the operating system clock. NTP, on the other hand, possesses the ability to synchronize the operating system clock based upon received clock offset measurements. The NTP algorithms have a lot of resiliency so that operating system clocks stay stable despite the conditions on the network.

2. Use Case Targeted

The use case considered by this internet draft is a dense concentration of computing elements connected by a network. A satellite-based time source (e.g., Global Positioning System [GPS]) is used for synchronizing primary time servers. Secondary time servers and leaf computing elements are synchronized to the primary time servers via the network. In this use case, there are approximately 150 or so total computers where there are 3 to 4 levels of time servers. These time servers may have to communicate to each other through layer 2 and layer 3 network switches (could be 10 to 20 different layer 2 subnetworks). All of the computers are connected together through gigabit or faster network connections. In this environment, there will be some groups of computers that will need to synchronize to each other to within a microsecond, while other groups of computers only have to be synchronized to each other to within a millisecond. In this use case, there is one interconnected time synchronization scheme where NTP, PTP, or a combination of both is used to meet all time synchronization needs.

2.1. Emerging Need for NTP and PTP Commonality

Due to its accuracy capabilities, PTP is beginning to replace NTP as the base protocol for time clients within dense computing sites. This results in an implementation in which some hosts use PTP while others use NTP within the same building and sometimes within the same room. Over time, hosts are being changed from NTP to PTP. This leads to an emerging need to provide similar approaches for basic time service functions for operational ease of managing the time distribution assets. Examples of functions where commonality is considered to be an emerging need include providing synchronization of the computer clock, providing management to time clients, and configuring timeservers. A standard means of synchronizing the computer clock for both protocols is in particular of interest because there appears to be no value in using different methods when the hosts that both protocols are supporting are often working within the same system.

In addition, there are highly accurate PTP time clients that could serve as highly accurate secondary timeservers for the NTP time clients if this capability were supported in vendor products.

3. Approach

The approach taken by the authors of this draft includes determining what the current accuracy capabilities are with NTPv4 and investigating additional mechanisms that may provide improvements in accuracy. Through experiments of those additional mechanisms, estimations of improvements can be calculated. Depending on the standardization difficulty and potential benefits offered, more than one standardization action may be recommended in the future.

4. Mechanisms Considered

4.1. NTP Interleave

NTP Interleave is an extension of the NTPv4 protocol, which is included in the current NTP distribution [1]. It is designed to be backward compatible (i.e., not affecting NTP implementations that do not use the interleave extensions). It also utilizes the same NTP packet format as the current standard NTPv4. NTP Interleave uses an IEEE 1588 PTP-like feature that provides a follow-up packet with a better estimate of when a previous NTP packet was sent on the network and a message exchange sequence to determine network mean path delay.

This mechanism could be used by some of the primary time servers for synchronizing secondary (i.e., lower stratum) time servers and leaf computing elements, which have very accurate time synchronization requirements.

Future experimentation may identify what gains are possible with this mechanism.

4.1.1. Standardization Considerations

If the NTP Interleave investigation generates promising results, this may initiate a standardization proposal to add this capability to the NTPv4 standard.

4.2. Use of IEEE 1588 PTP and 802.1AS Mechanisms in the Underlying Network Service (e.g., Network Interface Controller [NIC])

The purpose of investigating this mechanism is to determine if using special capabilities in the underlying network service can improve the timestamp estimates when NTP packets are put on the network, transferred across networks, or taken from the network.

4.2.1. Standardization Considerations

If the investigation of these mechanisms generates promising results, this may initiate a standardization proposal for additions to the NTPv4 standard to make use of these capabilities. Alternatively, a modification to the NTPv4 standard may be proposed, which would enable hardware assists to be incorporated into future NICs.

4.3. Use of IEEE 1588 PTP to Synchronize Computer Clocks

The purpose of investigating this mechanism is to determine the viability of using the IEEE 1588 to synchronize computing elements, which require very accurate synchronization. This mechanism considers bringing the 1588 synchronization all the way to the computer clock through a standardized clock discipline algorithm. Computing elements synchronized by 1588 are candidates to be time servers (by the use of NTP) for computing elements not synchronized by 1588. Based on their respective strengths, the natural way to merge NTP and PTP would be to use PTP as the means of obtaining extremely accurate time information from across the network and to let the NTP algorithms use that time to keep local clocks synchronized.

4.3.1. Standardization Considerations

If the investigation of this mechanism generates promising results, this may initiate a standardization proposal to specify a 1588 profile for use by NTP. It may be possible to replace the current NTP clock coordination services without affecting the NTP time management services or the clock access mechanisms used by each operating system. A variety of studies will be needed if this approach is pursued, including a study to determine if there are any issues for secondary time servers to run both NTP and PTP. If such issues are identified, standards activities may be needed in the IETF or in IEEE 1588.

5. Early Experimentation

Some preliminary experiments were performed that tested the new Interleave mode available in NTP version 4.2.6. This mode mimics the operation of PTP defined by IEEE 1588 where an additional follow-up message is sent so that a more accurate transmission time can be used. In this experiment, seven workstations running Red Hat Enterprise Linux (RHEL) 5 were used. These workstations are 2-years old and make use of two dual-core processors. Since the GPS-based (i.e., stratum 1) time server does not currently have version 4.2.6 of NTP available, which supports the interleave mode, one of the seven workstations was synchronized to the stratum 1 time server; then, served as the stratum 2 time server to the other six stratum 3 workstations. The stratum 2 server and four of the six other workstations were upgraded to use NTP version 4.2.6, while the remaining two workstations were left running version 4.2.2 of NTP that was included with RHEL 5.

Interleave mode was achieved by using the "xleave" option when either the broadcast mode or peer mode was used under NTP. The stratum 2 server was configured as a broadcast server, making use of the standard multicast address and using the "xleave" option. Two of the workstations running NTP 4.2.6 were configured as multicast clients so that the Interleave mode was utilized. The other two NTP 4.2.6 workstations were configured to synchronize to the stratum 2 server using standard client/server (unicast) mode. The two workstations running 4.2.2 of NTP were configured to be broadcast clients; however, they did not use Interleave mode since NTP 4.2.2 does not include Interleave support. All NTP polling intervals were configured to 16 seconds.

Offset measurements were obtained between the six clients and the stratum 2 server using the ntpdate command with the "-q" option. Measurements were taken every minute over a period of approximately four days. These workstations were not running any other major tasks, and NTP ran over a network with no discernable network load. All of the workstations were connected through the same Virtual Local Area Network on the same network switch (i.e., no routers involved). All of the network connections were 100 Mbit/sec Ethernet.

Some results were obtained from the experiments where the average and the standard deviation of the absolute value of clock offset were measured. The worst behaved NTP Interleave client was able to stay synchronized with an average clock offset of 9 microseconds with a standard deviation of 8 microseconds. The worst behaved computer that synchronized using client/server mode was able to maintain an average clock offset of 11 microseconds with a standard deviation of 10 microseconds. The worst behaved broadband (without NTP Interleave) client stayed synchronized with an average clock offset of 49 microseconds and with a standard deviation of 58 microseconds.

These results illustrate that broadcast with NTP Interleave does provide results that are better than having every client poll the server via unicast. However, the result is not significantly better (e.g., not an order of magnitude better). Preliminary experiments with hardware-based PTP have been performed in the past where the average offsets between PTP NICs and the PTP Grandmaster clock are in the hundreds of nanoseconds with standard deviations in the tens of nanoseconds.

5.1. Future Experimentation

The results so far should be treated as preliminary, and further experiments are needed to draw conclusions. One concern is that the clock offsets are in the microsecond range. The use of ntpdate may not be a valid way to accurately measure clock offsets at this level since ntpdate makes measurements across the network and is susceptible to errors caused by variations in network delay. Further work is needed to ensure valid offset measurements. An out-of-band measurement technique, which is not affected by variations in network delay, needs to be investigated for use in future experiments.

Another concern is that no load has been applied either to the processor or to the network carrying the NTP packets. Future experiments need to be performed to measure the resiliency of the NTP Interleave while under network and processor load and then make comparisons to the other time synchronization methods. This experiment was performed in a configuration in which the test workstations were connected to the same network switch. Future experiments should be performed to determine how performance is affected when a more complex network configuration is used.

Developing a standard to define time synchronization performance metrics would be beneficial by allowing different experimental efforts to be performed in a way that the results are comparable.

6. Analysis of Results

In 2008, it was reported [2] that the synchronization of computer clocks using NTPv4 over a Local Area Network (LAN) can approach values on the order of ~145us (mean plus 3 sigma). This has been demonstrated in the laboratory and was achieved across a single stratum (e.g., stratum 1 to stratum 2). Recently, using newer hardware and a newer version of NTP, time synchronization values were measured on the order of ~40us (mean plus 3 sigma). The variation in the time synchronization comprises the majority of the 40us value. The results need to be analyzed in detail, but in a little over two years, the time synchronization of computer clocks over a LAN has improved; most likely due to hardware improvements and minor software enhancements.

If this 40us synchronization can be maintained from stratum to stratum for all subsequent tiers in a well-engineered network with 3 to 5 stratums, a maximum theoretical time synchronization offset on the order of 120 to 200us could be achieved. A 50 percent improvement in the variability of clock synchronization from stratum to stratum would reduce this number to less than 125us. This does not imply that stratum-to-stratum accuracy should not be improved. On the contrary, by working on the accuracy and variability together all users of time synchronization will benefit. This needs to be accomplished without overloading the computer or the network.

A 50 percent improvement appears to be a reasonable goal; however, if the stratum-to-stratum synchronization variability could be improved by an order of magnitude, it is reasonable to anticipate maximum theoretical time synchronization offsets of 50us or less in a well-behaved LAN and potentially in the hundreds of microseconds for a Wide Area Network. Follow-on discussions within the IETF TICTOC Working Group are needed to define what level of improvement in accuracy would warrant a standardization action to add an Interleave option to the NTP standard.

7. Security Considerations

Security aspects of the aforementioned options will need to be considered in more detail.

8. Internet Assigned Numbers Authority (IANA) Considerations

No IANA actions are required as a result of the publication of this document.

9. Conclusions

Preliminary results tentatively indicate that an Interleave capability can provide a modest improvement to the accuracy achieved with NTPv4 and, as a result of these preliminary findings, the authors recommend conducting further testing to determine whether this should be added as an option to the NTPv4 standard. Preliminary results also tentatively indicate that Interleave will not provide accuracies in the range that PTP with hardware assists can; thus, the other two mechanisms described in this paper should be pursued in parallel.

Assuming any of the proposed mechanisms in this draft or other mechanisms proposed through IETF TICTOC discussions provide a significant improvement in computer clock time synchronization, it is recommended that the IETF TICTOC Working Group initiate work on a standards-track targeted working group Internet-Draft.

It would be of benefit to the IETF TICTOC Working Group to standardize the performance metrics used in describing the behavior of clock synchronization. Such a standard would enable better comparisons between the mechanisms considered. In addition to the same definitions of the metrics used, better agreement should be obtained in experiments being performed by different organizations.

The authors are interested in contributions on the mechanisms described in this draft as well as on additional mechanisms that may improve the accuracy of computer clocks synchronized via a network. The authors request that other experimental results on mechanisms that can improve NTPv4 accuracy be shared. It is hoped that discussions on this topic within the IETF TICTOC Working Group will lead to standardization actions to enable better accuracy to those utilizing a future NTP specification.

10. Informative References

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11. Acknowledgments

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Transport of Timing Packets over MPLS
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Abstract

The TICTOC charter specifies that the working group is concerned with highly accurate time and frequency distribution over native IP and MPLS-enabled IP Packet Switched Networks (PSNs). We discuss here issues specific to MPLS PSNs.

Status of this Memo

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1. Motivation

The TICTOC charter specifies that the working group is concerned with highly accurate time and frequency distribution over native IP and MPLS-enabled IP Packet Switched Networks (PSNs). To date, discussions have focused on NTPv4 and 1588-2008 timing distribution using UDP/IP encapsulations. The present document discusses transport of timing packets over MPLS PSNs, and is based on material presented and discussed in previous TICTOC meetings.

We first must address the question as to why special treatment is needed at all for transport of timing packets over MPLS. Timing packets in IP format can certainly be transported over MPLS without the LSRs along the path being aware of them. However, there advantages to being able to recognize, and potentially manipulate, timing packets.

For highly accurate timing distribution, timing packets are required to travel through the PSN with minimal, symmetric, and quasistationary delay, as well as minimal and uncorrelated packet delay variation. Thus, prioritization and symmetric routing of timing packets are minimal requirements. For the most demanding applications, timing distribution mechanisms avail themselves of "on-path support", such as Transparent Clock (TC) overwriting of header fields. None of these can be selectively applied to timing packets unless they can be recognized by the LSR.

2. Encapsulation Options

MPLS as a server layer presently permits three types of clients:
1. MPLS (via label stacking)
2. IP (either IPv4 or IPv6)
3. pseudowires (PWs)

although we can not rule out defining a new client for timing distribution. Taking into account the two defined associated channels that carry non-user traffic, namely the VCCV associated channel for PWs [RFC5085] and the GAL G-ACh defined for MPLS-TP [RFC5586] any proposal for carrying timing packets over MPLS will need to put the timing information in one of the following six formats:
1. a new MPLS client type
2. IP
3. an Ethernet PW

4. a new "timing" pseudowire type
5. a new VCCV channel type
6. a new G-ACh channel type.

We will discuss each of these options in turn.

2.1. Using IP

Since the two main timing distribution protocols have UDP/IP encapsulations, arguably the simplest method of transporting timing packets is in this format. There are several methods for intermediate LSRs to recognize the timing packets :

- o Deep Packet Inspection (i.e., peeking under the MPLS stack and identifying well-known port numbers)
- o using an arbitrary configured or signaled MPLS label
- o using a new reserved MPLS label
- o using a specific MPLS Traffic Class (ex-EXP).

It should be noted that there are very few available reserved labels, and that traffic class usage is not standardized.

If an arbitrary label is required to be signaled, then an extension to the signaling protocol will be required. Such an extension will identify the FEC as belonging to a timing flow.

2.2. Using an Ethernet PW

The UDP/IP packets of the timing distribution protocols of the previous subsection may be contained in Ethernet frames, that can be transported over an MPLS network in an Ethernet PW. In addition, IEEE 1588-2008 has a native Ethernet (non-IP) encapsulation.

Methods for identifying timing packets inside an Ethernet PW are similar to those of the previous subsection.

2.3. Defining a New MPLS Client or a new PW Type

IEEE 1588-2008 allows for different transport layers to be defined, with annexes to the standard defining UDP/IPv4, UDP/IPv6, Ethernet, and several other transport networks. It is possible to define a new transport mechanism for MPLS, which entails specifying how to encapsulate a PTP PDU in an MPLS packet. This can be done in the context of the PWE3 architecture (this was proposed in draft-ronc-ptp-mpls-00.txt, now expired) or without reference to that architecture. If the PWE3 architecture is used, then PWE3 features, such as the control word and the control protocol, may be used.

Whether the MPLS encapsulation is a PW or not, the timing packet will be recognized by virtue of its bottom-of-stack label. When additional labels are present, the LSR will need to search for the label with S=1. This technique is technically a violation of the MPLS architecture, but is presently performed for other purposes, e.g., ECMP avoidance [RFC4928].

The particular label(s) used to signify timing packets may be distributed by manual configuration or a signaling protocol. If the latter is employed, a new FEC type will need to be defined. If a PW is used, a new MPLS Pseudowire Type [RFC4446] will be needed for use in the PWE3 control protocol [RFC4447].

2.4. Using VCCV or the G-ACh

Timing is often distributed in order to enable proper functioning of applications that already define PWs between the end points of the timing flow. In this case, the timing information may be placed in the VCCV associated channel of the application’s PW. The associated channel is typically identified by having the same PW (bottom-of-stack) label as the application, but a control word with 0001 in its initial nibble. The timing packets may then be identified by a new channel type, or may use the IP channel type and then would be identified by the well-known port numbers. It is recognized that this requires the LSR to perform relatively deep packet inspection.

If there is no application PW between the timing end points, then we may still use the Generic Associated CHannel (G-ACh) defined in [RFC5586] in a similar manner. The G-ACh is identified by the G-ACh Label (GAL), which is a reserved MPLS label of value 13, at its bottom-of-stack. The format after the GAL is the same as that of VCCV, and thus the considerations of the previous paragraph apply.

3. IANA Considerations

This document requires no IANA actions.

4. References

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Precision Time Protocol Version 2 (PTPv2) Management Information Base draft-vinay-tictoc-ptp-mib-00.txt

Status of this Memo

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Abstract

This memo defines a portion of the Management Information Base (MIB) for use with network management protocols in TCP/IP-based internets. In particular, it defines objects for managing networks using Precision Time Protocol.

This memo specifies a MIB module in a manner that is both compliant to the SNMPv2 SMI, and semantically identical to the peer SNMPv1 definitions.

Table of Contents

1. Introduction

This memo defines a portion of the Management Information Base (MIB) for use with network management protocols in the Internet Community. In particular, it describes managed objects used for managing PTP devices including the ordinary clock, transparent clock, boundary clocks. It is envisioned this MIB will complement other managed objects defined to monitor, measure the performance of the PTP devices and telecom clocks. Those objects are considered out of scope for the current draft.

1.1. Change Log

This section tracks changes made to the revisions of the Internet Drafts of this document. It will be *deleted* when the document is published as an RFC. This section tracks changes made to the visions of the Internet Drafts of this document. It will be *deleted* when the document is published as an RFC.

2. The SNMP Management Framework

The SNMP Management Framework presently consists of five major components:

- o An overall architecture, described in [RFC 2271].

- o Mechanisms for describing and naming objects and events for the purpose of management. The first version of this Structure of Management Information (SMI) is called SMIv1 and described in [RFC 1155], [RFC 1212] and [RFC 1215].
  The second version, called SMIv2, is described in [RFC 2578], [RFC 2579] and [RFC 2580]

- o Message protocols for transferring management information. The first version of the SNMP message protocol is called SNMPv1 and described in [RFC 1157]. A second version of the SNMP message protocol, which is not an Internet standards track protocol, is called SNMPv2c and described in [RFC 1901] and [RFC 1905]. The third version of the message protocol is called SNMPv3 and described in [RFC 1906], [RFC 2572] and [RFC 2574].

- o Protocol operations for accessing management information. The first set of protocol operations and associated PDU formats is described in [RFC 1157]. A second set of protocol operations and associated PDU formats is described in [RFC 1905].

- o A set of fundamental applications described in [RFC 2573] and the view-based access control mechanism described in [RFC 2575].

Managed objects are accessed via a virtual information store, termed the Management Information Base or MIB. Objects in the MIB are defined using the mechanisms defined in the SMI.

This memo specifies a MIB module that is compliant to the SMIv2. A MIB conforming to the SMIv1 can be produced through the appropriate translations. The resulting translated MIB must be semantically equivalent, except where objects or events are omitted because no translation is possible (e.g., use of Counter64). Some machine readable information in SMIv2 will be converted into textual descriptions in SMIv1 during the translation process. However, this loss of machine readable information is not considered to change the semantics of the MIB.

3. Overview

The objects defined in this MIB are to be used when describing Precision Time Protocol (PTPv2).

4. Structure of MIB Module

```
IETF-PTP-MIB DEFINITIONS ::= BEGIN


ietfPtpMIB  MODULE-IDENTITY
    LAST-UPDATED    "201101280000Z"
    ORGANIZATION    "TICTOC Working Group"
    CONTACT-INFO

        "WG Email: tictoc@ietf.org

        Vinay Shankarkumar
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    DESCRIPTION
        "The MIB module for PTPv2 (IEEE (TM) 1588 - 2008)

        Overview of PTPv2 (IEEE (TM) 1588-2008)

        [IEEE1588-2008] defines a protocol enabling precise
        synchronization of clocks in measurement and control systems
        implemented with packet-based networks, the Precision Time
        protocol version 2 (PTPv2). This MIB does not address the
        standard IEEE(TM) 1588 (2002) and PTPv1. The protocol is
        applicable to network element communicating using IP. The
        protocol enables heterogeneous systems that include clocks
        of various inherent precision, resolution, and stability to
```

synchronize to a grandmaster clock.

The protocol supports system-wide synchronization accuracy in the sub-microsecond range with minimal network and local clock computing resources. [IEEE1588-2008] uses UDP/IP or Ethernet and can be adapted to other mapping. It includes formal mechanisms for message extensions, higher sampling rates, correction for asymmetry, a clock type to reduce error accumulation in large topologies, and specifications on how to incorporate the resulting additional data into the synchronization protocol. The [IEEE1588-2008] defines conformance and management capability also.

MIB description

This MIB is to support the Precision Time Protocol version 2 (PTPv2, hereafter designated as PTP) features of network Element System devices.

Acronyms:

ARB	arbitrary
BMC	best master clock
CAN	Controller Area Network
CP	Communication Profile (according to IEC 61784-1:200710)
CPF	Communication Profile Family (according to IEC 61784-1:2007)
DS	Differentiated Service
E2E	End-to-End
E2ETC	End-to-End Transparent Clock
EUI	Extended Unique Identifier.
FFO	Fractional Frequency Offset
GPS	Global Positioning System
IANA	Internet Assigned Numbers Authority
ICV	Integrity Check Value
ID	Identification
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
JD	Julian Date
JDN	Julian Day Number
MAC	Media Access Control (according to IEEE Std 802.3-2005)
MJD	Modified Julian Day
NIST	National Institute of Standards and Technology (see http://www.nist.gov)
NTP	Network Time Protocol (see [RFC 1305])
OUI	Organizational Unique Identifier (allocated by the IEEE)
P2P	Peer-to-Peer

P2PTC	Peer-To-Peer Transparent Clock
PHY	physical layer (according to IEEE Std 802.3 2005)
POSIX	Portable Operating System Interface (see ISO/IEC 9945:2003)
PPS	Pulse per Second
PTP	Precision Time Protocol
SA	Security Associations
SNTP	Simple Network Time Protocol
SOF	Start of Frame
TAI	International Atomic Time
TC	Traffic Class
TC	Transparent Clock
TLV	Type, Length, Value (according to IEEE Std 02.1AB)
ToD	Time of Day Synchronization
ToS	Type of Service
UCMM	UnConnect Message Manager
UDP/IP	User Datagram Protocol
UTC	Coordinated Universal Time

References:
[1] Precision clock synchronization protocol for networked measurement and control systems - IEC 61588 IEEE 1588(tm) Edition 2.0 2009-02

As defined in [IEEE1588-2008]:

Accuracy:
The mean of the time or frequency error between the clock under test and a perfect reference clock, over an ensemble of measurements. Stability is a measure of how the mean varies with respect to variables such as time, temperature, and so on.

The precision is a measure of the deviation of the error From the mean.

Atomic process:
A process is atomic if the values of all inputs to the Process are not permitted to change until all of the results of the process are instantiated, and the outputs of the process are not visible to other processes until the processing of each output is complete.

Boundary clock:
A clock that has multiple Precision Time Protocol(PTP) ports in a domain and maintains the timescale used in the domain. It may serve as the source of time, i.e., be a master clock,

and may synchronize to another clock, i.e., be a slave clock.

Clock:
A node participating in the Precision Time Protocol (PTP) that is capable of providing a measurement of the passage of time since a defined epoch.

Domain:
A logical grouping of clocks that synchronize to each other using the protocol, but that are not necessarily synchronized to clocks in another domain.

End-to-end transparent clock:
A transparent clock that supports the use of the end-to-end delay measurement mechanism between slave clocks and the master clock. Each node must measure the residence time of PTP event messages and accumulate it in Correction Field.

Epoch:
The origin of a timescale.

Event:
An abstraction of the mechanism by which signals or conditions are generated and represented.

Foreign master:
An ordinary or boundary clock sending Announce messages to another clock that is not the current master recognized by the other clock.

Grandmaster clock:
Within a domain, a clock that is the ultimate source of time for clock synchronization using the protocol.

Holdover:
A clock previously synchronized/syntonized to another clock (normally a primary reference or a master clock) but now free-running based on its own internal oscillator, whose frequency is being adjusted using data acquired while it had been synchronized/syntonized to the other clock. It is said to be in holdover or in the holdover mode, as long as it is within its accuracy requirements.

Link:
A network segment between two Precision Time Protocol ports supporting the peer delay mechanism of this standard. The peer delay mechanism is designed to measure the propagation time over such a link.

Management node:
A device that configures and monitors clocks.

Master clock:
In the context of a single Precision Time Protocol communication path, a clock that is the source of time to which all other clocks on that path synchronize.

Message timestamp point:
A point within a Precision Time Protocol event message serving as a reference point in the message. A timestamp is defined by the instant a message timestamp point passes the reference plane of a clock.

Multicast communication:
A communication model in which each Precision Time Protocol message sent from any PTP port is capable of being received and processed by all PTP ports on the same PTP communication path.

Node:
A device that can issue or receive Precision Time Protocol communications on a network.

One-step clock:
A clock that provides time information using a single event message.

On-pass support:
Indicates that each node in the synchronization chain from master to slave can support IEEE-1588.

Ordinary clock:
A clock that has a single Precision Time Protocol port in a domain and maintains the timescale used in the domain. It may serve as a source of time, i.e., be a master clock, or may synchronize to another clock, i.e., be a slave clock.

Parent clock:
The master clock to which a clock is synchronized.

Peer-to-peer transparent clock:
A transparent clock that, in addition to providing Precision Time Protocol event transit time information, also provides corrections for the propagation delay of the link connected to the port receiving the PTP event message. In the presence of peer-to-peer transparent clocks, delay measurements between slave clocks and the master clock are

performed using the peer-to-peer delay measurement mechanism.

Phase change rate:
The observed rate of change in the measured time with respect to the reference time. The phase change rate is equal to the fractional frequency offset between the measured frequency and the reference frequency.

PortNumber:
An index identifying a specific Precision Time Protocol port on a PTP node.

Primary reference:
A source of time and or frequency that is traceable to international standards.

Profile:
The set of allowed Precision Time Protocol features applicable to a device.

Precision Time Protocol communication:
Information used in the operation of the protocol, transmitted in a PTP message over a PTP communication path.

Precision Time Protocol communication path:
The signaling path portion of a particular network enabling direct communication among ordinary and boundary clocks.

Precision Time Protocol node:
PTP ordinary, boundary, or transparent clock or a device that generates or parses PTP messages.

Precision Time Protocol port:
A logical access point of a clock for PTP communications to the communications network.

Recognized standard time source:
A recognized standard time source is a source external to Precision Time Protocol that provides time and/or frequency as appropriate that is traceable to the international standards laboratories maintaining clocks that form the basis for the International Atomic Time and Universal Coordinated Time timescales. Examples of these are Global Positioning System, NTP, and National Institute of Standards and Technology (NIST) timeservers.

Requestor:
The port implementing the peer-to-peer delay mechanism that

initiates the mechanism by sending a Pdelay_Req message.

Responder:
The port responding to the receipt of a Pdelay_Req message as part of the operation of the peer-to-peer delay mechanism.

Synchronized clocks:
Two clocks are synchronized to a specified uncertainty if they have the same epoch and their measurements of the time of a single event at an arbitrary time differ by no more than that uncertainty.

Syntonized clocks:
Two clocks are syntonized if the duration of the second is the same on both, which means the time as measured by each advances at the same rate. They may or may not share the same epoch.

Timeout:
A mechanism for terminating requested activity that, at least from the requester’s perspective, does not complete within the specified time.

Timescale:
A linear measure of time from an epoch.

Traceability:
A property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties.

Translation device:
A boundary clock or, in some cases, a transparent clock that translates the protocol messages between regions implementing different transport and messaging protocols, between different versions of IEEE Std 1588-2008/IEC 61588:2009, or different Precision Time Protocol profiles.

Transparent clock:
A device that measures the time taken for a Precision Time Protocol event message to transit the device and provides this information to clocks receiving this PTP event message.

Two-step clock:
A clock that provides time information using the combination of an event message and a subsequent general message.

The below table specifies the object formats of the various textual conventions used.

Data type mapping	Textual Convention	SYNTAX
5.3.2 TimeInterval	ClockTimeInterval	OCTET STRING (SIZE(1..255))
5.3.3 Timestamp	ClockTimestamp	OCTET STRING(SIZE(6))
5.3.4 ClockIdentity	ClockIdentity	OCTET STRING (SIZE(1..255))
5.3.5 PortIdentity	ClockPortNumber	INTEGER(1..65535)
5.3.7 ClockQuality	ClockQualityClassType	

Simple master-slave hierarchy [1] section 6.6.2.4

```
---------------
- Ordinary    -
- Clock(1)    -
- GrandMaster -
-------M-------
       |
       1
       |
-------S-------------------------------
- Boundary                            -
- Clock(1)                            -
--------------M------------------M-----
              |                  |
              2                  3
              |                  |
         -----S------     -------S------------------
         - Ordinary -     - Boundary               -
         - Clock(2) -     - Clock(2)               -
         ------------     -----M-------------M------
                               |             |
                               4             5
                               |             |
                          -----S------  -----S------
                          - Ordinary -  - Ordinary -
                          - Clock(3) -  - Clock(4) -
                          ------------  ------------

Grandmaster

Boundary Clocks(0-N)   Ordinary Clocks(0-N)
Ordinary Clocks(0-N)

 Relationship cardinality
```

```
               PTP system 1 : N PTP Clock
               PTP Clock  1 : 1 Domain
               PTP Clock  1 : N PTP Ports
               PTP Port   N : N Physical Port (interface in IF-MIB)

           Transparent clock diagram from section 6.7.1.3 of [1]

                     +----------------------------+
                     |     Boundary clock - 1     |
                     +----------------------------+
                       |                        |
                       |                        |
               +-- A --+                        B
               |                                |
           +----------------------+             |
           |   Ordinary clock - 1|              |
           +----------------------+             |
                                        +----------------------+
           +---------------+            |      End-to-end      |
           |  Ordinary     |------------------|  transparent clock-  |
           |  clock 1-1    |            |       1 - 1          |
           +---------------+            +----------------------+
                                           |
                                           |
                                           C
                                           |
                                           |
                                        +----------------------+
           +---------------+            |      End-to-end      |
           |  Ordinary     |------------------|  transparent clock-  |
           |  clock 1-2    |            |       1 - 2          |
           +---------------+            +----------------------+


           The MIB refers to the sections of [IEEE1588-2008]."
```

4.1. Textual Conventions

```
   ClockDomainType ::= TEXTUAL-CONVENTION
       DISPLAY-HINT    "d"
       STATUS          current
       DESCRIPTION
           "The Domain is identified by an integer, the domainNumber,
           in the range of 0 to 255. An integer value that is used to
           assign each PTP device to a particular domain. The following
           values define the valid domains. [1] Section 7.1 Domains
           Table 2

                    Value       definition.
```

```
                    ---------   ------------------
                    0           Default domain
                    1           Alternate domain 1
                    2           Alternate domain 2
                    3           Alternate domain 3
                    4 - 127     User-defined domains
                    128 - 255   Reserved"

       REFERENCE       "Section 7.1 Domains and Table 2 of [1]"
       SYNTAX          Unsigned32 (0..255)

   ClockIdentity ::= TEXTUAL-CONVENTION
       STATUS          current
       DESCRIPTION
           "The clock Identity is an 8-octet array and will be
           presented in the form of a character array. The value of the
           ClockIdentity should be taken from the IEEE EUI-64
           individual assigned numbers as indicated in Section
           7.5.2.2.2 of [1].  The EUI-64 address is divided into the
           following fields.

                OUI byte[0-2]
                Extension identifier bytes:[3-7]

           The clock identifier can be constructed from existing EUI-48
           assignments and here is an abbreviated example extracted
           from section 7.5.2.2.2 [1].

                Company EUI-48 = 0xACDE4823456716
                EUI-64 = ACDE48FFFE23456716

           It is important to note the IEEE Registration Authority has
           deprecated the use of MAC-48 in any new design."

       REFERENCE       "Section 7.5.2.2.1 from [1]"
       SYNTAX          OCTET STRING (SIZE (1..255))

   ClockIntervalBase2 ::= TEXTUAL-CONVENTION
       DISPLAY-HINT    "d"
       STATUS          current
       DESCRIPTION
           "The interval included in message types Announce, Sync,
           Delay_Req, and Pdelay_Req as indicated in section 7.7.2.1 of
           [1].

           The mean time interval between successive messages shall be
           represented as the logarithm to the base 2 of this time
           interval measured in seconds on the local clock of the
           device sending the message. The values of these logarithmic
```

```
           attributes shall be selected from integers in the range -128
           to 127 subject to further limits established in an
           applicable PTP profile."

       REFERENCE
           "Section 7.7.2.1 General interval specification of [1]"
       SYNTAX          Integer32 (-128..127)

   ClockMechanismType ::= TEXTUAL-CONVENTION
       STATUS          current
       DESCRIPTION
           "The clock type based on whether End to End or peer to peer
           mechanisms are used. The mechanism used to calculate the
           Mean Path Delay as indicated in Table 9 of [IEEE1588-2008].

           Delay mechanism     Value(hex) Specification
           E2E                  01        The port is configured to use
                                          the delay request-response
                                          mechanism.

           P2P                  02        The port is configured to use
                                          the peer delay mechanism.
          DISABLED              FE        The port does not implement
                                          the delay mechanism."

       REFERENCE       "Sections 8.2.5.4.4, 6.6.4 and 7.4.2 of [1]."
       SYNTAX          INTEGER  {
                           e2e(1),
                           p2p(2),
                           disabled(254)
                       }

   ClockInstanceType ::= TEXTUAL-CONVENTION
       DISPLAY-HINT    "d"
       STATUS          current
       DESCRIPTION
           "The instance of the Clock of a given clock type in a given
           domain."
       SYNTAX          Unsigned32 (0..255)

   ClockPortNumber ::= TEXTUAL-CONVENTION
       DISPLAY-HINT    "d"
       STATUS          current
       DESCRIPTION
           "An index identifying a specific Precision Time Protocol
           (PTP) port on a PTP node."

       REFERENCE       "Section 7.5.2.3 Port Number and 5.3.5 of [1]"
       SYNTAX          Unsigned32 (0..65535)
```

```
   ClockPortState ::= TEXTUAL-CONVENTION
       STATUS          current
       DESCRIPTION
           "This is the value of the current state of the protocol
           engine associated with this port.
           Port state   Value     Description
           --------------------------------------------------------
           initializing   1       In this state a port initializes
                                  its data sets, hardware, and
                                  communication facilities.
           faulty         2       The fault state of the protocol.
           disabled       3       The port shall not place any
                                  messages on its communication path.
           listening      4       The port is waiting for the
                                  announceReceiptTimeout to expire or
                                  to receive an Announce message from
                                  a master.
           preMaster      5       The port shall behave in all respects
                                  as though it were in the MASTER state
                                  except that it shall not place any
                                  messages on its communication path
                                  except for Pdelay_Req, Pdelay_Resp,
                                  Pdelay_Resp_Follow_Up, signaling, or
                                  management messages.
           master         6       The port is behaving as a master
                                  port.
           passive        7       The port shall not place any
                                  messages on its communication path
                                  except for Pdelay_Req, Pdelay_Resp,
                                  Pdelay_Resp_Follow_Up, or signaling
                                  messages, or management messages
                                  that are a required response to
                                  another management message
           uncalibrated   8       The local port is preparing to
                                  synchronize to the master port.
           slave          9       The port is synchronizing to the
                                  selected master port."

       REFERENCE       "Section 8.2.5.3.1 portState and 9.2.5 of [1]"
       SYNTAX          INTEGER  {
                           initializing(1),
                           faulty(2),
                           disabled(3),
                           listening(4),
                           preMaster(5),
                           master(6),
                           passive(7),
                           uncalibrated(8),
```

```
                            slave(9)
                        }

   ClockProfileType ::= TEXTUAL-CONVENTION
       STATUS          current
       DESCRIPTION
           "Clock Profile used. From [1] section 3.1.30, Profile is the
           set of allowed Precision Time Protocol (PTP) features
           applicable to a device."

       REFERENCE       "Section 3.1.30 and 19.3 PTP profiles of [1]"
       SYNTAX          INTEGER  {
                            default(1),
                            telecom(2),
                            vendorspecific(3)
                        }

   ClockQualityAccuracyType ::= TEXTUAL-CONVENTION
       STATUS          current
       DESCRIPTION
           "The ClockQuality as specified in section 5.3.7, 7.6.2.5 and
           Table 6 of [1].

           The following values are not represented in the enumerated
           values.

                    0x01-0x1F Reserved
                    0x32-0x7F Reserved

           It is important to note that section 7.1.1 [RFC 2578]
           allows for gaps and enumerate values to start with zero when
           indicated by the protocol."

       REFERENCE       "Section 5.3.7, 7.6.2.5 and Table 6 of [1]"
       SYNTAX          INTEGER  {
                            reserved00(1),       -- 0
                            nanoSecond25(32),    -- 0x20
                            nanoSecond100(33),   -- 0x21
                            nanoSecond250(34),   -- 0x22
                            microSec1(35),       -- 0x23
                            microSec2dot5(36),   -- 0x24
                            microSec10(37),      -- 0x25
                            microSec25(38),      -- 0x26
                            microSec100(39),     -- 0x27
                            microSec250(40),     -- 0x28
                            milliSec1(41),       -- 0x29
                            milliSec2dot5(42),   -- 0x2A
                            milliSec10(43),      -- 0x2B
                            milliSec25(44),      -- 0x2C
```

```
                           milliSec100(45),     -- 0x2D
                           milliSec250(46),     -- 0x2E
                           second1(47),         -- 0x2F
                           second10(48),        -- 0x30
                           secondGreater10(49), -- 0x31
                           unknown(254),        -- 0xFE
                           reserved255(255)     -- 0xFF
                       }

   ClockQualityClassType ::= TEXTUAL-CONVENTION
       DISPLAY-HINT    "d"
       STATUS          current
       DESCRIPTION
           "The ClockQuality as specified in section 5.3.7, 7.6.2.4 and
           Table 5 of [1].

            Value   Description
            -----------------------------------------------------------
                 0  Reserved to enable compatibility with future
                    versions.
               1-5  Reserved
                 6  Shall designate a clock that is synchronized
                    to a primary reference time source.  The
                    timescale distributed shall be PTP.  A
                    clockClass 6 clock shall not be a slave to
                    another clock in the domain.
                 7  Shall designate a clock that has previously
                    been designated as clockClass 6 but that has
                    lost the ability to synchronize to a primary
                    reference time source and is in holdover mode
                    and within holdover specifications. The
                    timescale distributed shall be PTP.  A
                    clockClass 7 clock shall not be a slave to
                    another clock in the domain.
                 8  Reserved.
              9-10  Reserved to enable compatibility with future
                    versions.
             11-12  Reserved.
                13  Shall designate a clock that is synchronized
                    to an application-specific source of time.
                    The timescale distributed shall be ARB.  A
                    clockClass 13 clock shall not be a slave to
                    another clock in the domain.
                14  Shall designate a clock that has previously
                    been designated as clockClass 13 but that
                    has lost the ability to synchronize to an
                    application-specific source of time and is
                    in holdover mode and within holdover
                    specifications. The timescale distributed
```

```
                       shall be ARB.  A clockClass 14 clock shall
                       not be a slave to another clock in the domain.
                15-51  Reserved.
                   52  Degradation alternative A for a clock of
                       clockClass 7 that is not within holdover
                       specification.  A clock of clockClass 52
                       shall not be a slave to another clock in
                       the domain.
                53-57  Reserved.
                   58  Degradation alternative A for a clock of
                       clockClass 14 that is not within holdover
                       specification. A clock of clockClass 58 shall
                       not be a slave to another clock in the domain.
                59-67  Reserved.
               68-122  For use by alternate PTP profiles.
              123-127  Reserved.
              128-132  Reserved.
              133-170  For use by alternate PTP profiles.
              171-186  Reserved.
                  187  Degradation alternative B for a clock of
                       clockClass 7 that is not within holdover
                       specification. A clock of clockClass 187 may
                       be a slave to another clock in the domain.
              188-192  Reserved.
                  193  Degradation alternative B for a clock of
                       clockClass 14 that is not within holdover
                       specification. A clock of clockClass 193 may
                       be a slave to another clock in the domain.
              194-215  Reserved.
              216-232  For use by alternate PTP profiles.
              233-247  Reserved.
                  248  Default. This clockClass shall be used if
                       none of the other clockClass definitions apply.
              249-250  Reserved.
                  251  Reserved for ver. 1 compatibility; see Clause 18.
              252-254  Reserved.
                  255  Shall be the clockClass of a slave-only clock;
                       see 9.2.2."

       REFERENCE       "section 5.3.7, 7.6.2.4 and Table 5 of [1]."
       SYNTAX          Unsigned32 (0..255)

   ClockRoleType ::= TEXTUAL-CONVENTION
       STATUS             current
       DESCRIPTION
           "The Clock Role. The protocol generates a Master Slave
           relationship among the clocks in the system.

           Clock Role      Value     Description
```

```
            ------------------------------------------------------------
            Master clock      1       A clock that is the source of
                                      time to which all other clocks on
                                      that path synchronize.

            Slave clock       2       A clock which synchronizes to
                                      another clock (master)."
        SYNTAX          INTEGER  {
                            master(1),
                            slave(2)
                        }

    ClockStateType ::= TEXTUAL-CONVENTION
        STATUS          current
        DESCRIPTION
            "The clock state returned by PTP engine.

            Clock State       Value Description
            ------------------------------------------------------------
            Freerun state       1   Applies to a slave device that is
                                    not locked to a master. This is the
                                    initial state a slave starts out
                                    with when it is not getting any PTP
                                    packets from the master or because
                                    of some other input error (erroneous
                                    packets, etc).

            Holdover state      2   In this state the slave device is
                                    locked to a master but communication
                                    with the master is lost or the
                                    timestamps in the ptp packets are
                                    incorrect. But since the slave was
                                    locked to the master, it can run
                                    with the same accuracy for some
                                    time. The slave can continue to
                                    operate in this state for some time.
                                    If communication with the master is
                                    not restored for a while, the device
                                    is moved to the FREERUN state.

            Acquiring state     3   The slave device is receiving
                                    packets from a master and is trying
                                    to acquire a clock.

            Freq_locked state   4   The slave device is locked to the
                                    master with respect to frequency,
                                    but not phase aligned

            Phase_aligned state 5   The slave device is locked to the
```

```
                                  master with respect to frequency and
                                  phase."

        SYNTAX          INTEGER  {
                            freerun(1),
                            holdover(2),
                            acquiring(3),
                            frequencyLocked(4),
                            phaseAligned(5)
                        }

    ClockTimeSourceType ::= TEXTUAL-CONVENTION
        STATUS          current
        DESCRIPTION
            "The ClockQuality as specified in section 5.3.7, 7.6.2.6 and
            Table 7 of [1].

            The following values are not represented in the enumerated
            values.

            0xF0-0xFE  For use by alternate PTP profiles
            0xFF       Reserved

            It is important to note that section 7.1.1 [RFC 2578]
            allows for gaps and enumerate values to start with zero when
            indicated by the protocol."

        REFERENCE       "section 5.3.7, 7.6.2.6 and Table 7 of [1]."
        SYNTAX          INTEGER  {
                            atomicClock(16), -- 0x10
                            gps(32), -- 0x20
                            terrestrialRadio(48), -- 0x22
                            ptp(64), -- 0x40
                            ntp(80), -- 0x50
                            handSet(96), -- 0x60
                            other(144), -- 0x90
                            internalOsillator(160) -- 0xA0
                        }

    ClockTimeInterval ::= TEXTUAL-CONVENTION
        STATUS          current
        DESCRIPTION
            "This textual convention corresponds to the TimeInterval
            structure indicated in section 5.3.2 of [1]. It will be
            presented in the form of a character array.

            The TimeInterval type represents time intervals.

                 struct TimeInterval
```

```
                {
                     Integer64 scaledNanoseconds;
                };

           The scaledNanoseconds member is the time interval expressed
           in units of nanoseconds and multiplied by 2**16.

           Positive or negative time intervals outside the maximum
           range of this data type shall be encoded as the largest
           positive and negative values of the data type, respectively.

           For example, 2.5 ns is expressed as 0000 0000 0002 8000 in
           Base16."

       REFERENCE
           "Section 5.3.2 and section 7.7.2.1 Timer interval
           specification of [1]"
       SYNTAX          OCTET STRING (SIZE (1..255))

   ClockTxModeType ::= TEXTUAL-CONVENTION
       STATUS          current
       DESCRIPTION
           "Transmission mode.

           unicast. Using unicast communication channel.

           multicast. Using Multicast communication channel.

           multicast-mix. Using multicast-unicast comm. channel"
       SYNTAX          INTEGER  {
                           unicast(1),
                           multicast(2),
                           multicastmix(3)
                       }

   ClockType ::= TEXTUAL-CONVENTION
       STATUS          current
       DESCRIPTION
           "The clock types as defined in the MIB module description."

       REFERENCE       "section 6.5.1 of [1]."
       SYNTAX          INTEGER  {
                           ordinaryClock(1),
                           boundaryClock(2),
                           transparentClock(3),
                           boundaryNode(4)
                       }
```

4.2. The Notifications Subtree

```
   ietfPtpMIB Notifs  OBJECT IDENTIFIER
       ::= { ietfPtpMIB  0 }

   ietfPtpMIB Objects  OBJECT IDENTIFIER
       ::= { ietfPtpMIB  1 }

   ietfPtpMIB Conformance  OBJECT IDENTIFIER
       ::= { ietfPtpMIB  2 }

   ietfPtpMIB SystemInfo  OBJECT IDENTIFIER
       ::= { ietfPtpMIB Objects 1 }

   -- Conformance Information Definition

   ietfPtpMIB Compliances  OBJECT IDENTIFIER
       ::= { ietfPtpMIB Conformance 1 }

   ietfPtpMIB Groups  OBJECT IDENTIFIER
       ::= { ietfPtpMIB Conformance 2 }

   ietfPtpMIB Compliances1 MODULE-COMPLIANCE
       STATUS          current
       DESCRIPTION
           "Compliance statement for agents that provide read-only
           support for IETF-PTP-MIB. Such devices can only be monitored
           using this MIB module.

           The Module is implemented with support for read-only. In
           other words, only monitoring is available by implementing
           this MODULE-COMPLIANCE."
       MODULE          -- this module
       MANDATORY-GROUPS { ietfPtpMIB SystemInfoGroup }
       ::= { ietfPtpMIB Compliances 1 }

   ietfPtpMIB Compliances2 MODULE-COMPLIANCE
       STATUS          current
       DESCRIPTION
           "Compliance statement for agents that provide read-only
           support for IETF-PTP-MIB. Such devices can only be monitored
           using this MIB module.

           The Module is implemented with support for read-only. In
           other words, only monitoring is available by implementing
           this MODULE-COMPLIANCE."
       MODULE          -- this module
       MANDATORY-GROUPS {
                           ietfPtpMIB ClockCurrentDSGroup,
                           ietfPtpMIB ClockParentDSGroup,
                           ietfPtpMIB ClockDefaultDSGroup,
```

```
                           ietfPtpMIB ClockRunningGroup,
                           ietfPtpMIB ClockTimepropertiesGroup
                       }
       ::= { ietfPtpMIB Compliances 2 }

   ietfPtpMIB Compliances3 MODULE-COMPLIANCE
       STATUS          current
       DESCRIPTION
           "Compliance statement for agents that provide read-only
           support for IETF-PTP-MIB. Such devices can only be monitored
           using this MIB module.

           The Module is implemented with support for read-only. In
           other words, only monitoring is available by implementing
           this MODULE-COMPLIANCE."
       MODULE          -- this module
       MANDATORY-GROUPS {
                           ietfPtpMIB ClockPortGroup,
                           ietfPtpMIB ClockPortDSGroup,
                           ietfPtpMIB ClockPortRunningGroup,
                           ietfPtpMIB ClockPortAssociateGroup
                       }
       ::= { ietfPtpMIB Compliances 3 }

   ietfPtpMIB Compliances4 MODULE-COMPLIANCE
       STATUS          current
       DESCRIPTION
           "Compliance statement for agents that provide read-only
           support for IETF-PTP-MIB. Such devices can only be monitored
           using this MIB module.

           The Module is implemented with support for read-only. In
           other words, only monitoring is available by implementing
           this MODULE-COMPLIANCE."
       MODULE          -- this module
       MANDATORY-GROUPS {
                           ietfPtpMIB ClockTranparentDSGroup,
                           ietfPtpMIB ClockPortTransDSGroup
                       }
       ::= { ietfPtpMIB Compliances 4 }

   ietfPtpMIB SystemInfoGroup OBJECT-GROUP
       OBJECTS         {
                           ietfptpSystemDomainTotals,
                           ietfptpDomainClockPortsTotal,
                           ietfptpSystemProfile

                       }
       STATUS          current
```

```
       DESCRIPTION
           "Group which aggregates objects describing system-wide
           information"
       ::= { ietfPtpMIB Groups 1 }

   ietfPtpMIB ClockCurrentDSGroup OBJECT-GROUP
       OBJECTS          {
                            ietfptpClockCurrentDSStepsRemoved,
                            ietfptpClockCurrentDSOffsetFromMaster,
                            ietfptpClockCurrentDSMeanPathDelay
                        }
       STATUS           current
       DESCRIPTION
           "Group which aggregates objects describing PTP Current
           Dataset information"
       ::= { ietfPtpMIB Groups 2 }

   ietfPtpMIB ClockParentDSGroup OBJECT-GROUP
       OBJECTS          {
                            ietfptpClockParentDSParentPortIdentity,
                            ietfptpClockParentDSParentStats,
                            ietfptpClockParentDSOffset,
                            ietfptpClockParentDSClockPhChRate,
                            ietfptpClockParentDSGMClockIdentity,
                            ietfptpClockParentDSGMClockPriority1,
                            ietfptpClockParentDSGMClockPriority2,
                            ietfptpClockParentDSGMClockQualityClass,
                            ietfptpClockParentDSGMClockQualityAccuracy,
                            ietfptpClockParentDSGMClockQualityOffset
                        }
       STATUS           current
       DESCRIPTION
           "Group which aggregates objects describing PTP Parent
           Dataset information"
       ::= { ietfPtpMIB Groups 3 }

   ietfPtpMIB ClockDefaultDSGroup OBJECT-GROUP
       OBJECTS          {
                            ietfptpClockDefaultDSTwoStepFlag,
                            ietfptpClockDefaultDSClockIdentity,
                            ietfptpClockDefaultDSPriority1,
                            ietfptpClockDefaultDSPriority2,
                            ietfptpClockDefaultDSSlaveOnly,
                            ietfptpClockDefaultDSQualityClass,
                            ietfptpClockDefaultDSQualityAccuracy,
                            ietfptpClockDefaultDSQualityOffset
                        }
       STATUS           current
       DESCRIPTION
```

```
            "Group which aggregates objects describing PTP Default
            Dataset information"
        ::= { ietfPtpMIB Groups 4 }

    ietfPtpMIB ClockRunningGroup OBJECT-GROUP
        OBJECTS         {
                            ietfptpClockRunningState,
                            ietfptpClockRunningPacketsSent,
                            ietfptpClockRunningPacketsReceived
                        }
        STATUS          current
        DESCRIPTION
            "Group which aggregates objects describing PTP running state
            information"
        ::= { ietfPtpMIB Groups 5 }

    ietfPtpMIB ClockTimepropertiesGroup OBJECT-GROUP
        OBJECTS         {

    ietfptpClockTimePropertiesDSCurrentUTCOffsetValid,

    ietfptpClockTimePropertiesDSCurrentUTCOffset,
                            ietfptpClockTimePropertiesDSLeap59,
                            ietfptpClockTimePropertiesDSLeap61,
                            ietfptpClockTimePropertiesDSTimeTraceable,
                            ietfptpClockTimePropertiesDSFreqTraceable,
                            ietfptpClockTimePropertiesDSPTPTimescale,
                            ietfptpClockTimePropertiesDSSource
                        }
        STATUS          current
        DESCRIPTION
            "Group which aggregates objects describing PTP Time
            Properties information"
        ::= { ietfPtpMIB Groups 6 }

    ietfPtpMIB ClockTranparentDSGroup OBJECT-GROUP
        OBJECTS         {
                            ietfptpClockTransDefaultDSClockIdentity,
                            ietfptpClockTransDefaultDSNumOfPorts,
                            ietfptpClockTransDefaultDSDelay,
                            ietfptpClockTransDefaultDSPrimaryDomain
                        }
        STATUS          current
        DESCRIPTION
            "Group which aggregates objects describing PTP Transparent
            Dataset information"
        ::= { ietfPtpMIB Groups 7 }

    ietfPtpMIB ClockPortGroup OBJECT-GROUP
```

```
       OBJECTS          {
                            ietfptpClockPortName,
                            ietfptpClockPortSyncOneStep,
                            ietfptpClockPortCurrentPeerAddress,
                            ietfptpClockPortNumOfAssociatedPorts,
                            ietfptpClockPortCurrentPeerAddressType,
                            ietfptpClockPortRole
                        }
       STATUS           current
       DESCRIPTION
           "Group which aggregates objects describing information for a
           given PTP Port."
       ::= { ietfPtpMIB Groups 8 }

   ietfPtpMIB ClockPortDSGroup OBJECT-GROUP
       OBJECTS          {
                            ietfptpClockPortDSName,
                            ietfptpClockPortDSPortIdentity,
                            ietfptpClockPortDSAnnouncementInterval,
                            ietfptpClockPortDSAnnounceRctTimeout,
                            ietfptpClockPortDSSyncInterval,
                            ietfptpClockPortDSMinDelayReqInterval,
                            ietfptpClockPortDSPeerDelayReqInterval,
                            ietfptpClockPortDSDelayMech,
                            ietfptpClockPortDSPeerMeanPathDelay,
                            ietfptpClockPortDSGrantDuration,
                            ietfptpClockPortDSPTPVersion
                        }
       STATUS           current
       DESCRIPTION
           "Group which aggregates objects describing PTP Port Dataset
           information"
       ::= { ietfPtpMIB Groups 9 }

   ietfPtpMIB ClockPortRunningGroup OBJECT-GROUP
       OBJECTS          {
                            ietfptpClockPortRunningName,
                            ietfptpClockPortRunningState,
                            ietfptpClockPortRunningRole,
                            ietfptpClockPortRunningInterfaceIndex,
                            ietfptpClockPortRunningIPversion,
                            ietfptpClockPortRunningEncapsulationType,
                            ietfptpClockPortRunningTxMode,
                            ietfptpClockPortRunningRxMode,
                            ietfptpClockPortRunningPacketsReceived,
                            ietfptpClockPortRunningPacketsSent
                        }
       STATUS           current
       DESCRIPTION
```

```
           "Group which aggregates objects describing PTP running
           interface information"
       ::= { ietfPtpMIB Groups 10 }

   ietfPtpMIB ClockPortTransDSGroup OBJECT-GROUP
       OBJECTS         {
                           ietfptpClockPortTransDSPortIdentity,
                           ietfptpClockPortTransDSlogMinPdelayReqInt,
                           ietfptpClockPortTransDSFaultyFlag,
                           ietfptpClockPortTransDSPeerMeanPathDelay
                       }
       STATUS          current
       DESCRIPTION
           "Group which aggregates objects describing PTP TransparentDS
           Dataset information"
       ::= { ietfPtpMIB Groups 11 }

   ietfPtpMIB ClockPortAssociateGroup OBJECT-GROUP
       OBJECTS         {
                           ietfptpClockPortAssociatePacketsSent,
                           ietfptpClockPortAssociatePacketsReceived,
                           ietfptpClockPortAssociateAddress,
                           ietfptpClockPortAssociateAddressType,
                           ietfptpClockPortAssociateInErrors,
                           ietfptpClockPortAssociateOutErrors
                       }
       STATUS          current
       DESCRIPTION
           "Group which aggregates objects describing information on
           peer PTP ports for a given PTP clock-port."
       ::= { ietfPtpMIB Groups 12 }

   ietfPtpMIB ClockInfo  OBJECT IDENTIFIER
       ::= { ietfPtpMIB Objects 2 }
```

4.3. The Table Structures

```
   ietfptpSystemTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF ietfptpSystemEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "Table of count information about the PTP system for all
           domains."
       ::= { ietfPtpMIB SystemInfo 1 }

   ietfptpSystemEntry OBJECT-TYPE
       SYNTAX          ietfptpSystemEntry
       MAX-ACCESS      not-accessible
```

```
        STATUS          current
        DESCRIPTION
            "An entry in the table, containing count information about a
            single domain. New row entries are added when the PTP clock
            for this domain is configured, while the unconfiguration of
            the PTP clock removes it."
        INDEX           {
                            ietfptpDomainIndex,
                            ietfptpInstanceIndex
                        }
        ::= { ietfptpSystemTable 1 }

    ietfptpSystemEntry ::= SEQUENCE {
            ietfptpDomainIndex
    ClockDomainType,
            ietfptpInstanceIndex
    ClockInstanceType,
            ietfptpDomainClockPortsTotal                  Gauge32
    }

    ietfptpDomainIndex OBJECT-TYPE
        SYNTAX          ClockDomainType
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the domain number used to create
            logical group of PTP devices. The Clock Domain is a logical
            group of clocks and devices that synchronize with each other
            using the PTP protocol.

            0           Default domain
            1           Alternate domain 1
            2           Alternate domain 2
            3           Alternate domain 3
            4 - 127     User-defined domains
            128 - 255   Reserved"
        ::= { ietfptpSystemEntry 1 }

    ietfptpInstanceIndex OBJECT-TYPE
        SYNTAX          ClockInstanceType (0..255)
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the instance of the Clock for this
            domain."
        ::= { ietfptpSystemEntry 2 }

    ietfptpDomainClockPortsTotal OBJECT-TYPE
        SYNTAX          Gauge32
```

```
       UNITS           "ptp ports"
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the total number of clock ports
           configured within a domain."
       ::= { ietfptpSystemEntry 3 }

   ietfptpSystemDomainTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF ietfptpSystemDomainEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "Table of information about the PTP system for all clock
           modes -- ordinary, boundary or transparent."
       ::= { ietfPtpMIB SystemInfo 2 }

   ietfptpSystemDomainEntry OBJECT-TYPE
       SYNTAX          ietfptpSystemDomainEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "An entry in the table, containing information about a
           single clock mode for the PTP system. A row entry gets added
           when PTP clocks are configured on the router."
       INDEX           { ietfptpSystemDomainClockTypeIndex }
       ::= { ietfptpSystemDomainTable 1 }

   ietfptpSystemDomainEntry ::= SEQUENCE {
           ietfptpSystemDomainClockTypeIndex ClockType,
           ietfptpSystemDomainTotals         Gauge32
   }

   ietfptpSystemDomainClockTypeIndex OBJECT-TYPE
       SYNTAX          ClockType
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the clock type as defined in the
           Textual convention description."
       ::= { ietfptpSystemDomainEntry 1 }

   ietfptpSystemDomainTotals OBJECT-TYPE
       SYNTAX          Gauge32
       UNITS           "domains"
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the total number of PTP domains for
```

```
            this particular clock type configured in this node."
        ::= { ietfptpSystemDomainEntry 2 }

   ietfptpClockNodeTable OBJECT-TYPE
        SYNTAX          SEQUENCE OF ietfptpClockNodeEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "Table of information about the PTP system for a given
            domain."
        ::= { ietfPtpMIB SystemInfo 3 }

   ietfptpClockNodeEntry OBJECT-TYPE
        SYNTAX          ietfptpClockNodeEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "An entry in the table, containing information about a
            single domain. A entry is added when a new PTP clock domain
            is configured on the router."
        INDEX           {
                            ietfptpClockDomainIndex,
                            ietfptpClockTypeIndex,
                            ietfptpClockInstanceIndex
                        }
        ::= { ietfptpClockNodeTable 1 }

   ietfptpClockNodeEntry ::= SEQUENCE {
            ietfptpClockDomainIndex             ClockDomainType,
            ietfptpClockTypeIndex               ClockType,
            ietfptpClockInstanceIndex           ClockInstanceType,
            ietfptpSystemProfile                ClockProfileType
   }

   ietfptpClockDomainIndex OBJECT-TYPE
        SYNTAX          ClockDomainType
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the domain number used to create
            logical group of PTP devices."
        ::= { ietfptpClockNodeEntry 1 }

   ietfptpClockTypeIndex OBJECT-TYPE
        SYNTAX          ClockType
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the clock type as defined in the
```

```
           Textual convention description."
       ::= { ietfptpClockNodeEntry 2 }

   ietfptpClockInstanceIndex OBJECT-TYPE
       SYNTAX          ClockInstanceType (0..255)
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the instance of the Clock for this
           clock type for the given domain."
       ::= { ietfptpClockNodeEntry 3 }


   ietfptpSystemProfile OBJECT-TYPE
       SYNTAX          ClockProfileType
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the PTP Profile implemented on the
           system."
       REFERENCE       "Section 19.3 PTP profiles of [1]"
       ::= { ietfPtpMIB SystemInfo 1 }

   ietfptpClockCurrentDSTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF ietfptpClockCurrentDSEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "Table of information about the PTP clock Current Datasets
           for all domains."
       ::= { ietfPtpMIB ClockInfo 1 }

   ietfptpClockCurrentDSEntry OBJECT-TYPE
       SYNTAX          ietfptpClockCurrentDSEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "An entry in the table, containing information about a
           single PTP clock Current Datasets for a domain."
       REFERENCE
           "[IEEE1588-2008] Section 8.2.2 currentDS data set member
           specifications of [1]"
       INDEX           {
                           ietfptpClockCurrentDSDomainIndex,
                           ietfptpClockCurrentDSClockTypeIndex,
                           ietfptpClockCurrentDSInstanceIndex
                       }
       ::= { ietfptpClockCurrentDSTable 1 }
```

```
   ietfptpClockCurrentDSEntry ::= SEQUENCE {
           ietfptpClockCurrentDSDomainIndex      ClockDomainType,
           ietfptpClockCurrentDSClockTypeIndex   ClockType,
           ietfptpClockCurrentDSInstanceIndex    ClockInstanceType,
           ietfptpClockCurrentDSStepsRemoved     Counter32,
           ietfptpClockCurrentDSOffsetFromMaster ClockTimeInterval,
           ietfptpClockCurrentDSMeanPathDelay    ClockTimeInterval
   }

   ietfptpClockCurrentDSDomainIndex OBJECT-TYPE
       SYNTAX          ClockDomainType
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the domain number used to create
           logical group of PTP devices."
       ::= { ietfptpClockCurrentDSEntry 1 }

   ietfptpClockCurrentDSClockTypeIndex OBJECT-TYPE
       SYNTAX          ClockType
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the clock type as defined in the
           Textual convention description."
       ::= { ietfptpClockCurrentDSEntry 2 }

   ietfptpClockCurrentDSInstanceIndex OBJECT-TYPE
       SYNTAX          ClockInstanceType (0..255)
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the instance of the clock for this
           clock type in the given domain."
       ::= { ietfptpClockCurrentDSEntry 3 }

   ietfptpClockCurrentDSStepsRemoved OBJECT-TYPE
       SYNTAX          Counter32
       UNITS           "steps"
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "The current clock dataset StepsRemoved value.

           This object specifies the distance measured by the number of
           boundary clocks between the local clock and the Foreign
           master as indicated in the stepsRemoved field of Announce
           messages."
       REFERENCE       "[IEEE1588-2008] Section 8.2.2.2 stepsRemoved"
```

```
        ::= { ietfptpClockCurrentDSEntry 4 }

    ietfptpClockCurrentDSOffsetFromMaster OBJECT-TYPE
        SYNTAX          ClockTimeInterval
        UNITS           "Time Interval"
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the current clock dataset ClockOffset
            value. The value of the computation of the offset in time
            between
            a slave and a master clock."
        REFERENCE       "[IEEE1588-2008] Section 8.2.2.3 of [1]"
        ::= { ietfptpClockCurrentDSEntry 5 }

    ietfptpClockCurrentDSMeanPathDelay OBJECT-TYPE
        SYNTAX          ClockTimeInterval
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the current clock dataset
            MeanPathDelay value.

            The mean path delay between a pair of ports as measure by
            the delay request-response mechanism."
        REFERENCE       "[IEEE1588-2008] Section 8.2.2.4 mean path
    delay"
        ::= { ietfptpClockCurrentDSEntry 6 }

    ietfptpClockParentDSTable OBJECT-TYPE
        SYNTAX          SEQUENCE OF ietfptpClockParentDSEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "Table of information about the PTP clock Parent Datasets
            for all domains."
        ::= { ietfPtpMIB ClockInfo 2 }

    ietfptpClockParentDSEntry OBJECT-TYPE
        SYNTAX          ietfptpClockParentDSEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "An entry in the table, containing information about a
            single PTP clock Parent Datasets for a domain."
        REFERENCE
            "Section 8.2.3 parentDS data set member specifications of
            [1]"
        INDEX           {
```

```
                            ietfptpClockParentDSDomainIndex,
                            ietfptpClockParentDSClockTypeIndex,
                            ietfptpClockParentDSInstanceIndex
                        }
        ::= { ietfptpClockParentDSTable 1 }

    ietfptpClockParentDSEntry ::= SEQUENCE {
        ietfptpClockParentDSDomainIndex            ClockDomainType,
        ietfptpClockParentDSClockTypeIndex         ClockType,
        ietfptpClockParentDSInstanceIndex          ClockInstanceType,
        ietfptpClockParentDSParentPortIdentity     OCTET STRING,
        ietfptpClockParentDSParentStats            TruthValue,
        ietfptpClockParentDSOffset                 ClockIntervalBase2,
        ietfptpClockParentDSClockPhChRate          Integer32,
        ietfptpClockParentDSGMClockIdentity        ClockIdentity,
        ietfptpClockParentDSGMClockPriority1       Integer32,
        ietfptpClockParentDSGMClockPriority2       Integer32,
        ietfptpClockParentDSGMClockQualityClass
    ClockQualityClassType,
        ietfptpClockParentDSGMClockQualityAccuracy
    ClockQualityAccuracyType,
        ietfptpClockParentDSGMClockQualityOffset   Unsigned32
    }

    ietfptpClockParentDSDomainIndex OBJECT-TYPE
        SYNTAX          ClockDomainType
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the domain number used to create
            logical group of PTP devices."
        ::= { ietfptpClockParentDSEntry 1 }

    ietfptpClockParentDSClockTypeIndex OBJECT-TYPE
        SYNTAX          ClockType
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the clock type as defined in the
            Textual convention description."
        ::= { ietfptpClockParentDSEntry 2 }

    ietfptpClockParentDSInstanceIndex OBJECT-TYPE
        SYNTAX          ClockInstanceType (0..255)
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the instance of the clock for this
            clock type in the given domain."
```

```
        ::= { ietfptpClockParentDSEntry 3 }

    ietfptpClockParentDSParentPortIdentity OBJECT-TYPE
        SYNTAX          OCTET STRING
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the value of portIdentity of the port
            on the master that issues the Sync messages used in
            synchronizing this clock."
        REFERENCE
            "section 8.2.3.2 parentDS.parentPortIdentity of [1]"
        ::= { ietfptpClockParentDSEntry 4 }

    ietfptpClockParentDSParentStats OBJECT-TYPE
        SYNTAX          TruthValue
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the Parent Dataset ParentStats value.

            This value indicates whether the values of ParentDSOffset
            and ParentDSClockPhChRate have been measured and are valid.
            A TRUE value shall indicate valid data."
        REFERENCE       "section 8.2.3.3 parentDS.parentStats of [1]"
        ::= { ietfptpClockParentDSEntry 5 }

    ietfptpClockParentDSOffset OBJECT-TYPE
        SYNTAX          ClockIntervalBase2 (-128..127)
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the Parent Dataset
            ParentOffsetScaledLogVariance value.

            This value is the variance of the parent clocks phase as
            measured by the local clock."
        REFERENCE
            "section 8.2.3.4
            parentDS.observedParentOffsetScaledLogVariance [1]"
        ::= { ietfptpClockParentDSEntry 6 }

    ietfptpClockParentDSClockPhChRate OBJECT-TYPE
        SYNTAX          Integer32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the clock’s parent dataset
            ParentClockPhaseChangeRate value.
```

```
            This value is an estimate of the parent clocks phase change
            rate as measured by the slave clock."
        REFERENCE
            "section 8.2.3.5
            parentDS.observedParentClockPhaseChangeRate of [1]"
        ::= { ietfptpClockParentDSEntry 7 }

    ietfptpClockParentDSGMClockIdentity OBJECT-TYPE
        SYNTAX          ClockIdentity
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the parent dataset Grandmaster clock
            identity."
        REFERENCE
            "section  8.2.3.6 parentDS.grandmasterIdentity of [1]"
        ::= { ietfptpClockParentDSEntry 8 }

    ietfptpClockParentDSGMClockPriority1 OBJECT-TYPE
        SYNTAX          Integer32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the parent dataset Grandmaster clock
            priority1."
        REFERENCE
            "section 8.2.3.8 parentDS.grandmasterPriority1 of [1]"
        ::= { ietfptpClockParentDSEntry 9 }

    ietfptpClockParentDSGMClockPriority2 OBJECT-TYPE
        SYNTAX          Integer32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the parent dataset grandmaster clock
            priority2."
        REFERENCE
            "section 8.2.3.9 parentDS.grandmasterPriority2 of [1]"
        ::= { ietfptpClockParentDSEntry 10 }

    ietfptpClockParentDSGMClockQualityClass OBJECT-TYPE
        SYNTAX          ClockQualityClassType (0..255)
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the parent dataset grandmaster clock
            quality class."
        REFERENCE
```

```
            "section 8.2.3.7 parentDS.grandmasterClockQuality of [1]"
        ::= { ietfptpClockParentDSEntry 11 }

   ietfptpClockParentDSGMClockQualityAccuracy OBJECT-TYPE
        SYNTAX          ClockQualityAccuracyType
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the parent dataset grandmaster clock
            quality accuracy."
        REFERENCE
            "section 8.2.3.7 parentDS.grandmasterClockQuality of [1]"
        ::= { ietfptpClockParentDSEntry 12 }

   ietfptpClockParentDSGMClockQualityOffset OBJECT-TYPE
        SYNTAX          Unsigned32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the parent dataset grandmaster clock
            quality offset."
        REFERENCE
            "section 8.2.3.7 parentDS.grandmasterClockQuality of [1]"
        ::= { ietfptpClockParentDSEntry 13 }

   ietfptpClockDefaultDSTable OBJECT-TYPE
        SYNTAX          SEQUENCE OF ietfptpClockDefaultDSEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "Table of information about the PTP clock Default Datasets
            for all domains."
        ::= { ietfPtpMIB ClockInfo 3 }

   ietfptpClockDefaultDSEntry OBJECT-TYPE
        SYNTAX          ietfptpClockDefaultDSEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "An entry in the table, containing information about a
            single PTP clock Default Datasets for a domain."
        INDEX           {
                            ietfptpClockDefaultDSDomainIndex,
                            ietfptpClockDefaultDSClockTypeIndex,
                            ietfptpClockDefaultDSInstanceIndex
                        }
        ::= { ietfptpClockDefaultDSTable 1 }

   ietfptpClockDefaultDSEntry ::= SEQUENCE {
```

```
        ietfptpClockDefaultDSDomainIndex     ClockDomainType,
        ietfptpClockDefaultDSClockTypeIndex  ClockType,
        ietfptpClockDefaultDSInstanceIndex   ClockInstanceType,
        ietfptpClockDefaultDSTwoStepFlag     TruthValue,
        ietfptpClockDefaultDSClockIdentity   ClockIdentity,
        ietfptpClockDefaultDSPriority1       Integer32,
        ietfptpClockDefaultDSPriority2       Integer32,
        ietfptpClockDefaultDSSlaveOnly       TruthValue,
        ietfptpClockDefaultDSQualityClass    ClockQualityClassType,
        ietfptpClockDefaultDSQualityAccuracy ClockQualityAccuracyType,
        ietfptpClockDefaultDSQualityOffset   Integer32
    }

    ietfptpClockDefaultDSDomainIndex OBJECT-TYPE
        SYNTAX          ClockDomainType
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the domain number used to create
            logical group of PTP devices."
        ::= { ietfptpClockDefaultDSEntry 1 }

    ietfptpClockDefaultDSClockTypeIndex OBJECT-TYPE
        SYNTAX          ClockType
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the clock type as defined in the
            Textual convention description."
        ::= { ietfptpClockDefaultDSEntry 2 }

    ietfptpClockDefaultDSInstanceIndex OBJECT-TYPE
        SYNTAX          ClockInstanceType (0..255)
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the instance of the clock for this
            clock type in the given domain."
        ::= { ietfptpClockDefaultDSEntry 3 }

    ietfptpClockDefaultDSTwoStepFlag OBJECT-TYPE
        SYNTAX          TruthValue
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies whether the Two Step process is
            used."
        ::= { ietfptpClockDefaultDSEntry 4 }
```

```
   ietfptpClockDefaultDSClockIdentity OBJECT-TYPE
       SYNTAX          ClockIdentity
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the default Datasets clock identity."
       ::= { ietfptpClockDefaultDSEntry 5 }

   ietfptpClockDefaultDSPriority1 OBJECT-TYPE
       SYNTAX          Integer32
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the default Datasets clock
           Priority1."
       ::= { ietfptpClockDefaultDSEntry 6 }

   ietfptpClockDefaultDSPriority2 OBJECT-TYPE
       SYNTAX          Integer32
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the default Datasets clock
           Priority2."
       ::= { ietfptpClockDefaultDSEntry 7 }

   ietfptpClockDefaultDSSlaveOnly OBJECT-TYPE
       SYNTAX          TruthValue
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "Whether the SlaveOnly flag is set."
       ::= { ietfptpClockDefaultDSEntry 8 }

   ietfptpClockDefaultDSQualityClass OBJECT-TYPE
       SYNTAX          ClockQualityClassType (0..255)
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the default dataset Quality Class."
       ::= { ietfptpClockDefaultDSEntry 9 }

   ietfptpClockDefaultDSQualityAccuracy OBJECT-TYPE
       SYNTAX          ClockQualityAccuracyType
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the default dataset Quality
           Accuracy."
```

```
        ::= { ietfptpClockDefaultDSEntry 10 }

    ietfptpClockDefaultDSQualityOffset OBJECT-TYPE
        SYNTAX          Integer32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the default dataset Quality offset."
        ::= { ietfptpClockDefaultDSEntry 11 }

    ietfptpClockRunningTable OBJECT-TYPE
        SYNTAX          SEQUENCE OF ietfptpClockRunningEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "Table of information about the PTP clock Running Datasets
            for all domains."
        ::= { ietfPtpMIB ClockInfo 4 }

    ietfptpClockRunningEntry OBJECT-TYPE
        SYNTAX          ietfptpClockRunningEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "An entry in the table, containing information about a
            single PTP clock running Datasets for a domain."
        INDEX           {
                            ietfptpClockRunningDomainIndex,
                            ietfptpClockRunningClockTypeIndex,
                            ietfptpClockRunningInstanceIndex
                        }
        ::= { ietfptpClockRunningTable 1 }

    ietfptpClockRunningEntry ::= SEQUENCE {
            ietfptpClockRunningDomainIndex     ClockDomainType,
            ietfptpClockRunningClockTypeIndex  ClockType,
            ietfptpClockRunningInstanceIndex   ClockInstanceType,
            ietfptpClockRunningState           ClockStateType,
            ietfptpClockRunningPacketsSent     Counter64,
            ietfptpClockRunningPacketsReceived Counter64
    }

    ietfptpClockRunningDomainIndex OBJECT-TYPE
        SYNTAX          ClockDomainType
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the domain number used to create
            logical group of PTP devices."
```

```
        ::= { ietfptpClockRunningEntry 1 }

    ietfptpClockRunningClockTypeIndex OBJECT-TYPE
        SYNTAX          ClockType
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the clock type as defined in the
            Textual convention description."
        ::= { ietfptpClockRunningEntry 2 }

    ietfptpClockRunningInstanceIndex OBJECT-TYPE
        SYNTAX          ClockInstanceType (0..255)
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the instance of the clock for this
            clock type in the given domain."
        ::= { ietfptpClockRunningEntry 3 }

    ietfptpClockRunningState OBJECT-TYPE
        SYNTAX          ClockStateType
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the Clock state returned by PTP
            engine which was described earlier.

            Freerun state. Applies to a slave device that is not locked
            to a master. This is the initial state a slave starts out
            with when
            it is not getting any PTP packets from the master or because
            of some other input error (erroneous packets, etc).

            Holdover state. In this state the slave device is locked to
            a master but communication with the master is lost or the
            timestamps in the ptp packets are incorrect. But since the
            slave was locked to the master, it can run with the same
            accuracy for sometime. The slave can continue to operate in
            this state for some time. If communication with the master
            is not restored for a while, the device is moved to the
            FREERUN state.

            Acquiring state. The slave device is receiving packets from
            a master and is trying to acquire a lock.

            Freq_locked state. The slave device is locked to the master
            with respect to frequency, but is not phase aligned.
```

```
            Phase_aligned state. The slave device is locked to the
            master with respect to frequency and phase."
        ::= { ietfptpClockRunningEntry 4 }

   ietfptpClockRunningPacketsSent OBJECT-TYPE
        SYNTAX          Counter64
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the total number of all packet
            Unicast and multicast that have been sent out for this clock
            in this domain for this type."
        ::= { ietfptpClockRunningEntry 5 }

   ietfptpClockRunningPacketsReceived OBJECT-TYPE
        SYNTAX          Counter64
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the total number of all packet
            Unicast and multicast that have been received for this clock
            in this domain for this type."
        ::= { ietfptpClockRunningEntry 6 }

   ietfptpClockTimePropertiesDSTable OBJECT-TYPE
        SYNTAX          SEQUENCE OF ietfptpClockTimePropertiesDSEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "Table of information about the PTP clock Timeproperties
            Datasets for all domains."
        ::= { ietfPtpMIB ClockInfo 5 }

   ietfptpClockTimePropertiesDSEntry OBJECT-TYPE
        SYNTAX          ietfptpClockTimePropertiesDSEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "An entry in the table, containing information about a
            single PTP clock timeproperties Datasets for a domain."
        REFERENCE       "Section 8.2.4 of [1]"
        INDEX           {
                            ietfptpClockTimePropertiesDSDomainIndex,
                            ietfptpClockTimePropertiesDSClockTypeIndex,
                            ietfptpClockTimePropertiesDSInstanceIndex
                        }
        ::= { ietfptpClockTimePropertiesDSTable 1 }

   ietfptpClockTimePropertiesDSEntry ::= SEQUENCE {
```

```
        ietfptpClockTimePropertiesDSDomainIndex
    ClockDomainType,
        ietfptpClockTimePropertiesDSClockTypeIndex        ClockType,
        ietfptpClockTimePropertiesDSInstanceIndex
    ClockInstanceType,
        ietfptpClockTimePropertiesDSCurrentUTCOffsetValid TruthValue,
        ietfptpClockTimePropertiesDSCurrentUTCOffset      Integer32,
        ietfptpClockTimePropertiesDSLeap59                TruthValue,
        ietfptpClockTimePropertiesDSLeap61                TruthValue,
        ietfptpClockTimePropertiesDSTimeTraceable         TruthValue,
        ietfptpClockTimePropertiesDSFreqTraceable         TruthValue,
        ietfptpClockTimePropertiesDSPTPTimescale          TruthValue,
        ietfptpClockTimePropertiesDSSource
    ClockTimeSourceType
    }

    ietfptpClockTimePropertiesDSDomainIndex OBJECT-TYPE
        SYNTAX          ClockDomainType
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the domain number used to create
            logical group of PTP devices."
        ::= { ietfptpClockTimePropertiesDSEntry 1 }

    ietfptpClockTimePropertiesDSClockTypeIndex OBJECT-TYPE
        SYNTAX          ClockType
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the clock type as defined in the
            Textual convention description."
        ::= { ietfptpClockTimePropertiesDSEntry 2 }

    ietfptpClockTimePropertiesDSInstanceIndex OBJECT-TYPE
        SYNTAX          ClockInstanceType (0..255)
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the instance of the clock for this
            clock type in the given domain."
        ::= { ietfptpClockTimePropertiesDSEntry 3 }

    ietfptpClockTimePropertiesDSCurrentUTCOffsetValid OBJECT-TYPE
        SYNTAX          TruthValue
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the timeproperties dataset value of
```

```
            whether current UTC offset is valid."
        REFERENCE       "Section 8.2.4.2 of [1]"
        ::= { ietfptpClockTimePropertiesDSEntry 4 }

    ietfptpClockTimePropertiesDSCurrentUTCOffset OBJECT-TYPE
        SYNTAX          Integer32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the timeproperties dataset value of
            current UTC offset.

            In PTP systems whose epoch is the PTP epoch, the value of
            timePropertiesDS.currentUtcOffset is the offset
            between TAI and UTC; otherwise the value has no meaning. The
            value shall be in units of seconds.
            The initialization value shall be selected as follows:
            a) If the timePropertiesDS.ptpTimescale (see 8.2.4.8) is
            TRUE, the value is the value obtained from a
            primary reference if the value is known at the time of
            initialization, else.
            b) The value shall be the current number of leap seconds
            (7.2.3) when the node is designed."
        REFERENCE       "Section 8.2.4.3 of [1]"
        ::= { ietfptpClockTimePropertiesDSEntry 5 }

    ietfptpClockTimePropertiesDSLeap59 OBJECT-TYPE
        SYNTAX          TruthValue
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the Leap59 value in the clock Current
            Dataset."
        REFERENCE       "Section 8.2.4.4 of [1]"
        ::= { ietfptpClockTimePropertiesDSEntry 6 }

    ietfptpClockTimePropertiesDSLeap61 OBJECT-TYPE
        SYNTAX          TruthValue
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the Leap61 value in the clock Current
            Dataset."
        REFERENCE       "Section 8.2.4.5 of [1]"
        ::= { ietfptpClockTimePropertiesDSEntry 7 }

    ietfptpClockTimePropertiesDSTimeTraceable OBJECT-TYPE
        SYNTAX          TruthValue
        MAX-ACCESS      read-only
```

```
        STATUS          current
        DESCRIPTION
            "This object specifies the Timetraceable value in the clock
            Current Dataset."
        REFERENCE       "Section 8.2.4.6 of [1]"
        ::= { ietfptpClockTimePropertiesDSEntry 8 }

    ietfptpClockTimePropertiesDSFreqTraceable OBJECT-TYPE
        SYNTAX          TruthValue
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the Frequency Traceable value in the
            clock Current Dataset."
        REFERENCE       "Section 8.2.4.7 of [1]"
        ::= { ietfptpClockTimePropertiesDSEntry 9 }

    ietfptpClockTimePropertiesDSPTPTimescale OBJECT-TYPE
        SYNTAX          TruthValue
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the PTP Timescale value in the clock
            Current Dataset."
        REFERENCE       "Section 8.2.4.8 of [1]"
        ::= { ietfptpClockTimePropertiesDSEntry 10 }

    ietfptpClockTimePropertiesDSSource OBJECT-TYPE
        SYNTAX          ClockTimeSourceType
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the Timesource value in the clock
            Current Dataset."
        REFERENCE       "Section 8.2.4.9 of [1]"
        ::= { ietfptpClockTimePropertiesDSEntry 11 }

    ietfptpClockTransDefaultDSTable OBJECT-TYPE
        SYNTAX          SEQUENCE OF ietfptpClockTransDefaultDSEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "Table of information about the PTP transparent clock
            Default Datasets for all domains."
        ::= { ietfPtpMIB ClockInfo 6 }

    ietfptpClockTransDefaultDSEntry OBJECT-TYPE
        SYNTAX          ietfptpClockTransDefaultDSEntry
        MAX-ACCESS      not-accessible
```

```
        STATUS          current
        DESCRIPTION
            "An entry in the table, containing information about a
            single PTP transparent clock Default Datasets for a domain."
        REFERENCE       "Section 8.3.2 of [1]"
        INDEX           {
                            ietfptpClockTransDefaultDSDomainIndex,
                            ietfptpClockTransDefaultDSInstanceIndex
                        }
        ::= { ietfptpClockTransDefaultDSTable 1 }

    ietfptpClockTransDefaultDSEntry ::= SEQUENCE {
            ietfptpClockTransDefaultDSDomainIndex   ClockDomainType,
            ietfptpClockTransDefaultDSInstanceIndex ClockInstanceType,
            ietfptpClockTransDefaultDSClockIdentity ClockIdentity,
            ietfptpClockTransDefaultDSNumOfPorts    Counter32,
            ietfptpClockTransDefaultDSDelay         ClockMechanismType,
            ietfptpClockTransDefaultDSPrimaryDomain Integer32
    }

    ietfptpClockTransDefaultDSDomainIndex OBJECT-TYPE
        SYNTAX          ClockDomainType
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the domain number used to create
            logical group of PTP devices."
        ::= { ietfptpClockTransDefaultDSEntry 1 }

    ietfptpClockTransDefaultDSInstanceIndex OBJECT-TYPE
        SYNTAX          ClockInstanceType (0..255)
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the instance of the clock for this
            clock type in the given domain."
        ::= { ietfptpClockTransDefaultDSEntry 2 }

    ietfptpClockTransDefaultDSClockIdentity OBJECT-TYPE
        SYNTAX          ClockIdentity
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the value of the clockIdentity
            attribute of the local clock."
        REFERENCE       "Section 8.3.2.2.1 of [1]"
        ::= { ietfptpClockTransDefaultDSEntry 3 }

    ietfptpClockTransDefaultDSNumOfPorts OBJECT-TYPE
```

```
        SYNTAX          Counter32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the number of PTP ports of the
            device."
        REFERENCE       "Section 8.3.2.2.2 of [1]"
        ::= { ietfptpClockTransDefaultDSEntry 4 }

    ietfptpClockTransDefaultDSDelay OBJECT-TYPE
        SYNTAX          ClockMechanismType
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object, if the transparent clock is an end-to-end
            transparent clock, has the value shall be E2E; If the
            transparent clock is a peer-to-peer transparent clock, the
            value shall be P2P."
        REFERENCE       "Section 8.3.2.3.1 of [1]"
        ::= { ietfptpClockTransDefaultDSEntry 5 }

    ietfptpClockTransDefaultDSPrimaryDomain OBJECT-TYPE
        SYNTAX          Integer32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the value of the primary
            syntonization domain. The initialization value shall be 0."
        REFERENCE       "Section 8.3.2.3.2 of [1]"
        ::= { ietfptpClockTransDefaultDSEntry 6 }

    ietfptpClockPortTable OBJECT-TYPE
        SYNTAX          SEQUENCE OF ietfptpClockPortEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "Table of information about the clock ports for a particular
            domain."
        ::= { ietfPtpMIB ClockInfo 7 }

    ietfptpClockPortEntry OBJECT-TYPE
        SYNTAX          ietfptpClockPortEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "An entry in the table, containing information about a
            single clock port."
        INDEX           {
                            ietfptpClockPortDomainIndex,
```

```
                           ietfptpClockPortClockTypeIndex,
                           ietfptpClockPortClockInstanceIndex,
                           ietfptpClockPortTablePortNumberIndex
                       }
       ::= { ietfptpClockPortTable 1 }

   ietfptpClockPortEntry ::= SEQUENCE {
           ietfptpClockPortDomainIndex            ClockDomainType,
           ietfptpClockPortClockTypeIndex         ClockType,
           ietfptpClockPortClockInstanceIndex     ClockInstanceType,
           ietfptpClockPortTablePortNumberIndex   ClockPortNumber,
           ietfptpClockPortName                   DisplayString,
           ietfptpClockPortRole                   ClockRoleType,
           ietfptpClockPortSyncOneStep            TruthValue,
           ietfptpClockPortCurrentPeerAddressType InetAddressType,
           ietfptpClockPortCurrentPeerAddress     InetAddress,
           ietfptpClockPortNumOfAssociatedPorts   Gauge32
   }

   ietfptpClockPortDomainIndex OBJECT-TYPE
       SYNTAX          ClockDomainType
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the domain number used to create
           logical group of PTP devices."
       ::= { ietfptpClockPortEntry 1 }

   ietfptpClockPortClockTypeIndex OBJECT-TYPE
       SYNTAX          ClockType
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the clock type as defined in the
           Textual convention description."
       ::= { ietfptpClockPortEntry 2 }

   ietfptpClockPortClockInstanceIndex OBJECT-TYPE
       SYNTAX          ClockInstanceType (0..255)
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the instance of the clock for this
           clock type in the given domain."
       ::= { ietfptpClockPortEntry 3 }

   ietfptpClockPortTablePortNumberIndex OBJECT-TYPE
       SYNTAX          ClockPortNumber (1..65535)
       MAX-ACCESS      not-accessible
```

```
       STATUS          current
       DESCRIPTION
           "This object specifies the PTP Portnumber for this port."
       ::= { ietfptpClockPortEntry 4 }

   ietfptpClockPortName OBJECT-TYPE
       SYNTAX          DisplayString (SIZE  (1..64))
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the PTP clock port name configured on
           the router."
       ::= { ietfptpClockPortEntry 5 }

   ietfptpClockPortRole OBJECT-TYPE
       SYNTAX          ClockRoleType
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object describes the current role (slave/master) of
           the port."
       ::= { ietfptpClockPortEntry 6 }

   ietfptpClockPortSyncOneStep OBJECT-TYPE
       SYNTAX          TruthValue
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies that one-step clock operation between
           the PTP master and slave device is enabled."
       ::= { ietfptpClockPortEntry 7 }

   ietfptpClockPortCurrentPeerAddressType OBJECT-TYPE
       SYNTAX          InetAddressType
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the current peer’s network address
           used for PTP communication. Based on the scenario and the
           setup involved, the values might look like these -
           Scenario                   Value
           -------------------   ----------------
           Single Master         master port
           Multiple Masters      selected master port
           Single Slave          slave port
           Multiple Slaves       <empty>

           (In relevant setups, information on available
           slaves and available masters will be available through
```

```
            ietfptpClockPortAssociateTable)"
        ::= { ietfptpClockPortEntry 8 }

    ietfptpClockPortCurrentPeerAddress OBJECT-TYPE
        SYNTAX          InetAddress
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the current peer's network address
            used for PTP communication. Based on the scenario and the
            setup involved, the values might look like these -
            Scenario                   Value
            -------------------   ----------------
            Single Master         master port
            Multiple Masters      selected master port
            Single Slave          slave port
            Multiple Slaves       <empty>

            (In relevant setups, information on available
            slaves and available masters will be available through
            ietfptpClockPortAssociateTable)"
        ::= { ietfptpClockPortEntry 9 }

    ietfptpClockPortNumOfAssociatedPorts OBJECT-TYPE
        SYNTAX          Gauge32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies -
            For a master port - the number of PTP slave sessions (peers)
            associated with this PTP port.
            For a slave port - the number of masters available to this
            slave port (might or might not be peered)."
        ::= { ietfptpClockPortEntry 10 }

    ietfptpClockPortDSTable OBJECT-TYPE
        SYNTAX          SEQUENCE OF ietfptpClockPortDSEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "Table of information about the clock ports dataset for a
            particular domain."
        ::= { ietfPtpMIB ClockInfo 8 }

    ietfptpClockPortDSEntry OBJECT-TYPE
        SYNTAX          ietfptpClockPortDSEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
```

```
          "An entry in the table, containing port dataset information
          for a single clock port."
      INDEX           {
                          ietfptpClockPortDSDomainIndex,
                          ietfptpClockPortDSClockTypeIndex,
                          ietfptpClockPortDSClockInstanceIndex,
                          ietfptpClockPortDSPortNumberIndex
                      }
      ::= { ietfptpClockPortDSTable 1 }

  ietfptpClockPortDSEntry ::= SEQUENCE {
          ietfptpClockPortDSDomainIndex          ClockDomainType,
          ietfptpClockPortDSClockTypeIndex       ClockType,
          ietfptpClockPortDSClockInstanceIndex   ClockInstanceType,
          ietfptpClockPortDSPortNumberIndex      ClockPortNumber,
          ietfptpClockPortDSName                 DisplayString,
          ietfptpClockPortDSPortIdentity         OCTET STRING,
          ietfptpClockPortDSAnnouncementInterval Integer32,
          ietfptpClockPortDSAnnounceRctTimeout   Integer32,
          ietfptpClockPortDSSyncInterval         Integer32,
          ietfptpClockPortDSMinDelayReqInterval  Integer32,
          ietfptpClockPortDSPeerDelayReqInterval Integer32,
          ietfptpClockPortDSDelayMech            ClockMechanismType,
          ietfptpClockPortDSPeerMeanPathDelay    ClockTimeInterval,
          ietfptpClockPortDSGrantDuration        Unsigned32,
          ietfptpClockPortDSPTPVersion           Integer32
  }

  ietfptpClockPortDSDomainIndex OBJECT-TYPE
      SYNTAX          ClockDomainType
      MAX-ACCESS      not-accessible
      STATUS          current
      DESCRIPTION
          "This object specifies the domain number used to create
          logical group of PTP devices."
      ::= { ietfptpClockPortDSEntry 1 }

  ietfptpClockPortDSClockTypeIndex OBJECT-TYPE
      SYNTAX          ClockType
      MAX-ACCESS      not-accessible
      STATUS          current
      DESCRIPTION
          "This object specifies the clock type as defined in the
          Textual convention description."
      ::= { ietfptpClockPortDSEntry 2 }

  ietfptpClockPortDSClockInstanceIndex OBJECT-TYPE
      SYNTAX          ClockInstanceType (0..255)
      MAX-ACCESS      not-accessible
```

```
        STATUS          current
        DESCRIPTION
            "This object specifies the instance of the clock for this
            clock type in the given domain."
        ::= { ietfptpClockPortDSEntry 3 }

    ietfptpClockPortDSPortNumberIndex OBJECT-TYPE
        SYNTAX          ClockPortNumber (1..65535)
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the PTP portnumber associated with
            this PTP port."
        ::= { ietfptpClockPortDSEntry 4 }

    ietfptpClockPortDSName OBJECT-TYPE
        SYNTAX          DisplayString (SIZE  (1..64))
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the PTP clock port name."
        ::= { ietfptpClockPortDSEntry 5 }

    ietfptpClockPortDSPortIdentity OBJECT-TYPE
        SYNTAX          OCTET STRING
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the PTP clock port Identity."
        ::= { ietfptpClockPortDSEntry 6 }

    ietfptpClockPortDSAnnouncementInterval OBJECT-TYPE
        SYNTAX          Integer32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the Announce message transmission
            interval associated with this clock port."
        ::= { ietfptpClockPortDSEntry 7 }

    ietfptpClockPortDSAnnounceRctTimeout OBJECT-TYPE
        SYNTAX          Integer32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the Announce receipt timeout
            associated with this clock port."
        ::= { ietfptpClockPortDSEntry 8 }
```

```
   ietfptpClockPortDSSyncInterval OBJECT-TYPE
       SYNTAX          Integer32
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the Sync message transmission
           interval."
       ::= { ietfptpClockPortDSEntry 9 }

   ietfptpClockPortDSMinDelayReqInterval OBJECT-TYPE
       SYNTAX          Integer32
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the Delay_Req message transmission
           interval."
       ::= { ietfptpClockPortDSEntry 10 }

   ietfptpClockPortDSPeerDelayReqInterval OBJECT-TYPE
       SYNTAX          Integer32
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the Pdelay_Req message transmission
           interval."
       ::= { ietfptpClockPortDSEntry 11 }

   ietfptpClockPortDSDelayMech OBJECT-TYPE
       SYNTAX          ClockMechanismType
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the delay mechanism used. If the
           clock is an end-to-end clock, the value of the is e2e, else
           if the clock is a peer to-peer clock, the value shall be
           p2p."
       ::= { ietfptpClockPortDSEntry 12 }

   ietfptpClockPortDSPeerMeanPathDelay OBJECT-TYPE
       SYNTAX          ClockTimeInterval
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the peer meanPathDelay."
       ::= { ietfptpClockPortDSEntry 13 }

   ietfptpClockPortDSGrantDuration OBJECT-TYPE
       SYNTAX          Unsigned32
       MAX-ACCESS      read-only
```

```
        STATUS          current
        DESCRIPTION
            "This object specifies the grant duration allocated by the
            master."
        ::= { ietfptpClockPortDSEntry 14 }

    ietfptpClockPortDSPTPVersion OBJECT-TYPE
        SYNTAX          Integer32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the PTP version being used."
        ::= { ietfptpClockPortDSEntry 15 }



    ietfptpClockPortRunningTable OBJECT-TYPE
        SYNTAX          SEQUENCE OF ietfptpClockPortRunningEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "Table of information about the clock ports running dataset
            for a particular domain."
        ::= { ietfPtpMIB ClockInfo 9 }

    ietfptpClockPortRunningEntry OBJECT-TYPE
        SYNTAX          ietfptpClockPortRunningEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "An entry in the table, containing runing dataset
            information about a single clock port."
        INDEX           {
                            ietfptpClockPortRunningDomainIndex,
                            ietfptpClockPortRunningClockTypeIndex,
                            ietfptpClockPortRunningClockInstanceIndex,
                            ietfptpClockPortRunningPortNumberIndex
                        }
        ::= { ietfptpClockPortRunningTable 1 }

    ietfptpClockPortRunningEntry ::= SEQUENCE {
            ietfptpClockPortRunningDomainIndex        ClockDomainType,
            ietfptpClockPortRunningClockTypeIndex     ClockType,
            ietfptpClockPortRunningClockInstanceIndex ClockInstanceType,
            ietfptpClockPortRunningPortNumberIndex    ClockPortNumber,
            ietfptpClockPortRunningName               DisplayString,
            ietfptpClockPortRunningState              ClockPortState,
            ietfptpClockPortRunningRole               ClockRoleType,
```

```
        ietfptpClockPortRunningInterfaceIndex
   InterfaceIndexOrZero,
        ietfptpClockPortRunningIPversion          Integer32,
        ietfptpClockPortRunningEncapsulationType  Integer32,
        ietfptpClockPortRunningTxMode             ClockTxModeType,
        ietfptpClockPortRunningRxMode             ClockTxModeType,
        ietfptpClockPortRunningPacketsReceived    Counter64,
        ietfptpClockPortRunningPacketsSent        Counter64
   }

   ietfptpClockPortRunningDomainIndex OBJECT-TYPE
       SYNTAX          ClockDomainType
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the domain number used to create
           logical group of PTP devices."
       ::= { ietfptpClockPortRunningEntry 1 }

   ietfptpClockPortRunningClockTypeIndex OBJECT-TYPE
       SYNTAX          ClockType
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the clock type as defined in the
           Textual convention description."
       ::= { ietfptpClockPortRunningEntry 2 }

   ietfptpClockPortRunningClockInstanceIndex OBJECT-TYPE
       SYNTAX          ClockInstanceType (0..255)
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the instance of the clock for this
           clock type in the given domain."
       ::= { ietfptpClockPortRunningEntry 3 }

   ietfptpClockPortRunningPortNumberIndex OBJECT-TYPE
       SYNTAX          ClockPortNumber (1..65535)
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the PTP portnumber associated with
           this clock port."
       ::= { ietfptpClockPortRunningEntry 4 }

   ietfptpClockPortRunningName OBJECT-TYPE
       SYNTAX          DisplayString (SIZE  (1..64))
       MAX-ACCESS      read-only
```

```
        STATUS          current
        DESCRIPTION
            "This object specifies the PTP clock port name."
        ::= { ietfptpClockPortRunningEntry 5 }

    ietfptpClockPortRunningState OBJECT-TYPE
        SYNTAX          ClockPortState
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the port state returned by PTP
            engine.

            initializing - In this state a port initializes
                           its data sets, hardware, and
                           communication facilities.
            faulty       - The fault state of the protocol.
            disabled     - The port shall not place any
                           messages on its communication path.
            listening    - The port is waiting for the
                           announceReceiptTimeout to expire or
                           to receive an Announce message from
                           a master.
            preMaster    - The port shall behave in all respects
                           as though it were in the MASTER state
                           except that it shall not place any
                           messages on its communication path
                           except for Pdelay_Req, Pdelay_Resp,
                           Pdelay_Resp_Follow_Up, signaling, or
                           management messages.
            master       - The port is behaving as a master port.
            passive      - The port shall not place any
                           messages on its communication path
                           except for Pdelay_Req, Pdelay_Resp,
                           Pdelay_Resp_Follow_Up, or signaling
                           messages, or management messages
                           that are a required response to
                           another management message
            uncalibrated - The local port is preparing to
                           synchronize to the master port.
            slave        - The port is synchronizing to the
                           selected master port."
        ::= { ietfptpClockPortRunningEntry 6 }

    ietfptpClockPortRunningRole OBJECT-TYPE
        SYNTAX          ClockRoleType
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
```

```
            "This object specifies the Clock Role."
        ::= { ietfptpClockPortRunningEntry 7 }

    ietfptpClockPortRunningInterfaceIndex OBJECT-TYPE
        SYNTAX          InterfaceIndexOrZero
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the interface on the router being
            used by the PTP Clock for PTP communication."
        ::= { ietfptpClockPortRunningEntry 8 }

    ietfptpClockPortRunningIPversion OBJECT-TYPE
        SYNTAX          Integer32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the IP version being used for PTP
            communication (the mapping used)."
        ::= { ietfptpClockPortRunningEntry 9 }

    ietfptpClockPortRunningEncapsulationType OBJECT-TYPE
        SYNTAX          Integer32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the type of encapsulation if the
            interface is adding extra layers (eg. VLAN, Pseudowire
            encapsulation...) for the PTP messages."
        ::= { ietfptpClockPortRunningEntry 10 }

    ietfptpClockPortRunningTxMode OBJECT-TYPE
        SYNTAX          ClockTxModeType
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the clock transmission mode as

            unicast:       Using unicast communication channel.
            multicast:     Using Multicast communication channel.
            multicast-mix: Using multicast-unicast comm. channel"
        ::= { ietfptpClockPortRunningEntry 11 }

    ietfptpClockPortRunningRxMode OBJECT-TYPE
        SYNTAX          ClockTxModeType
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the clock receive mode as
```

```
            unicast:       Using unicast communication channel.
            multicast:     Using Multicast communication channel.
            multicast-mix: Using multicast-unicast comm. channel"
        ::= { ietfptpClockPortRunningEntry 12 }

    ietfptpClockPortRunningPacketsReceived OBJECT-TYPE
        SYNTAX          Counter64
        UNITS           "packets"
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the packets received on the clock
            port (cumulative)."
        ::= { ietfptpClockPortRunningEntry 13 }

    ietfptpClockPortRunningPacketsSent OBJECT-TYPE
        SYNTAX          Counter64
        UNITS           "packets"
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the packets sent on the clock port
            (cumulative)."
        ::= { ietfptpClockPortRunningEntry 14 }

    ietfptpClockPortTransDSTable OBJECT-TYPE
        SYNTAX          SEQUENCE OF ietfptpClockPortTransDSEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "Table of information about the transparent clock ports
            running dataset for a particular domain."
        ::= { ietfPtpMIB ClockInfo 10 }

    ietfptpClockPortTransDSEntry OBJECT-TYPE
        SYNTAX          ietfptpClockPortTransDSEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "An entry in the table, containing clock port transparent
            dataset information about a single clock port"
        INDEX           {
                            ietfptpClockPortTransDSDomainIndex,
                            ietfptpClockPortTransDSInstanceIndex,
                            ietfptpClockPortTransDSPortNumberIndex
                        }
        ::= { ietfptpClockPortTransDSTable 1 }
```

```
   ietfptpClockPortTransDSEntry ::= SEQUENCE {
           ietfptpClockPortTransDSDomainIndex        ClockDomainType,
           ietfptpClockPortTransDSInstanceIndex      ClockInstanceType,
           ietfptpClockPortTransDSPortNumberIndex    ClockPortNumber,
           ietfptpClockPortTransDSPortIdentity       ClockIdentity,
           ietfptpClockPortTransDSlogMinPdelayReqInt Integer32,
           ietfptpClockPortTransDSFaultyFlag         TruthValue,
           ietfptpClockPortTransDSPeerMeanPathDelay  ClockTimeInterval
   }

   ietfptpClockPortTransDSDomainIndex OBJECT-TYPE
       SYNTAX          ClockDomainType
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the domain number used to create
           logical group of PTP devices."
       ::= { ietfptpClockPortTransDSEntry 1 }

   ietfptpClockPortTransDSInstanceIndex OBJECT-TYPE
       SYNTAX          ClockInstanceType (0..255)
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the instance of the clock for this
           clock type in the given domain."
       ::= { ietfptpClockPortTransDSEntry 2 }

   ietfptpClockPortTransDSPortNumberIndex OBJECT-TYPE
       SYNTAX          ClockPortNumber (1..65535)
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the PTP port number associated with
           this port."
       REFERENCE       "Section 7.5.2 Port Identity of [1]"
       ::= { ietfptpClockPortTransDSEntry 3 }

   ietfptpClockPortTransDSPortIdentity OBJECT-TYPE
       SYNTAX          ClockIdentity
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the value of the PortIdentity
           attribute of the local port."
       REFERENCE       "Section 8.3.3.2.1 of [1]"
       ::= { ietfptpClockPortTransDSEntry 4 }

   ietfptpClockPortTransDSlogMinPdelayReqInt OBJECT-TYPE
```

```
        SYNTAX          Integer32
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the value of the logarithm to the
            base 2 of the minPdelayReqInterval."
        REFERENCE       "Section 8.3.3.3.1 of [1]"
        ::= { ietfptpClockPortTransDSEntry 5 }

    ietfptpClockPortTransDSFaultyFlag OBJECT-TYPE
        SYNTAX          TruthValue
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the value TRUE if the port is faulty
            and FALSE if the port is operating normally."
        REFERENCE       "Section 8.3.3.3.2 of [1]"
        ::= { ietfptpClockPortTransDSEntry 6 }

    ietfptpClockPortTransDSPeerMeanPathDelay OBJECT-TYPE
        SYNTAX          ClockTimeInterval
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies, (if the delayMechanism used is P2P)
            the value is the estimate of the current one-way propagation
            delay, i.e. <meanPathDelay> on the link attached to this
            port computed using the peer delay mechanism. If the value
            of the delayMechanism used is E2E, then the value will be
            zero."
        REFERENCE       "Section 8.3.3.3.3 of [1]"
        ::= { ietfptpClockPortTransDSEntry 7 }

    ietfptpClockPortAssociateTable OBJECT-TYPE
        SYNTAX          SEQUENCE OF ietfptpClockPortAssociateEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "Table of information about a given port's associated ports.

            For a master port - multiple slave ports which have
            established sessions with the current master port.
            For a slave port - the list of master clocks available for a
            given slave port.

            Session information (pkts, errors) to be displayed based on
            availability and scenario."
        ::= { ietfPtpMIB ClockInfo 11 }
```

```
   ietfptpClockPortAssociateEntry OBJECT-TYPE
       SYNTAX          ietfptpClockPortAssociateEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "An entry in the table, containing information about a
           single associated port for the given clockport."
       INDEX           {
                           ietfptpClockPortCurrentDomainIndex,
                           ietfptpClockPortCurrentClockTypeIndex,
                           ietfptpClockPortCurrentClockInstanceIndex,
                           ietfptpClockPortCurrentPortNumberIndex,
                           ietfptpClockPortAssociatePortIndex
                       }
       ::= { ietfptpClockPortAssociateTable 1 }

   ietfptpClockPortAssociateEntry ::= SEQUENCE {
           ietfptpClockPortCurrentDomainIndex        ClockDomainType,
           ietfptpClockPortCurrentClockTypeIndex     ClockType,
           ietfptpClockPortCurrentClockInstanceIndex ClockInstanceType,
           ietfptpClockPortCurrentPortNumberIndex    ClockPortNumber,
           ietfptpClockPortAssociatePortIndex        Unsigned32,
           ietfptpClockPortAssociateAddressType      InetAddressType,
           ietfptpClockPortAssociateAddress          InetAddress,
           ietfptpClockPortAssociatePacketsSent      Counter64,
           ietfptpClockPortAssociatePacketsReceived  Counter64,
           ietfptpClockPortAssociateInErrors         Counter64,
           ietfptpClockPortAssociateOutErrors        Counter64
   }

   ietfptpClockPortCurrentDomainIndex OBJECT-TYPE
       SYNTAX          ClockDomainType
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the given port’s domain number."
       ::= { ietfptpClockPortAssociateEntry 1 }

   ietfptpClockPortCurrentClockTypeIndex OBJECT-TYPE
       SYNTAX          ClockType
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the given port’s clock type."
       ::= { ietfptpClockPortAssociateEntry 2 }

   ietfptpClockPortCurrentClockInstanceIndex OBJECT-TYPE
       SYNTAX          ClockInstanceType
       MAX-ACCESS      not-accessible
```

```
        STATUS          current
        DESCRIPTION
            "This object specifies the instance of the clock for this
            clock type in the given domain."
        ::= { ietfptpClockPortAssociateEntry 3 }

    ietfptpClockPortCurrentPortNumberIndex OBJECT-TYPE
        SYNTAX          ClockPortNumber
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the PTP Port Number for the given
            port."
        ::= { ietfptpClockPortAssociateEntry 4 }

    ietfptpClockPortAssociatePortIndex OBJECT-TYPE
        SYNTAX          Unsigned32 (1..65535)
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "This object specifies the associated port's serial number
            in the current port's context."
        ::= { ietfptpClockPortAssociateEntry 5 }

    ietfptpClockPortAssociateAddressType OBJECT-TYPE
        SYNTAX          InetAddressType
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the peer port's network address type
            used for PTP communication."
        ::= { ietfptpClockPortAssociateEntry 6 }

    ietfptpClockPortAssociateAddress OBJECT-TYPE
        SYNTAX          InetAddress
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the peer port's network address used
            for PTP communication."
        ::= { ietfptpClockPortAssociateEntry 7 }

    ietfptpClockPortAssociatePacketsSent OBJECT-TYPE
        SYNTAX          Counter64
        UNITS           "packets"
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "The number of packets sent to this peer port from the
```

```
            current port."
        ::= { ietfptpClockPortAssociateEntry 8 }

    ietfptpClockPortAssociatePacketsReceived OBJECT-TYPE
        SYNTAX          Counter64
        UNITS           "packets"
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "The number of packets received from this peer port by the
            current port."
        ::= { ietfptpClockPortAssociateEntry 9 }

    ietfptpClockPortAssociateInErrors OBJECT-TYPE
        SYNTAX          Counter64
        UNITS           "packets"
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the input errors associated with the
            peer port."
        ::= { ietfptpClockPortAssociateEntry 10 }

    ietfptpClockPortAssociateOutErrors OBJECT-TYPE
        SYNTAX          Counter64
        UNITS           "packets"
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "This object specifies the output errors associated with the
            peer port."
        ::= { ietfptpClockPortAssociateEntry 11 }

    END
```

5. Relationship to the Interface MIB

This section clarifies the relationship of this MIB to the Interfaces MIB [RFC 2233]. Several areas of correlation are addressed in the following subsections. The implementor is referred to the Interfaces MIB document in order to understand the general intent of these areas.

6. MIB modules required for IMPORTS

```
MODULE-IDENTITY,
OBJECT-TYPE,
Integer32,
Gauge32,
Unsigned32,
Counter32,
Counter64
    FROM SNMPv2-SMI
OBJECT-GROUP,
MODULE-COMPLIANCE
    FROM SNMPv2-CONF
TEXTUAL-CONVENTION,
TruthValue,
DisplayString
    FROM SNMPv2-TC
InetAddressType,
InetAddress
    FROM INET-ADDRESS-MIB
InterfaceIndexOrZero
    FROM IETF-TC
```

7. Security Considerations

This MIB contains readable objects whose values provide information related to PTP objects. While unauthorized access to the readable objects is relatively innocuous, unauthorized access to the write-able objects could cause a denial of service, or could cause unauthorized creation and/or manipulation of tunnels. Hence, the support for SET operations in a non-secure environment without proper protection can have a negative effect on network operations.

SNMPv1 by itself is such an insecure environment. Even if the network itself is secure (for example by using IPSec), even then, there is no control as to who on the secure network is allowed to access and SET (change/create/delete) the objects in this MIB.

It is recommended that the implementers consider the security features as provided by the SNMPv3 framework. Specifically, the use of the User-based Security Model [RFC 2574] and the View-based Access Control Model [RFC 2575] is recommended.

It is then a customer/user responsibility to ensure that the SNMP entity giving access to this MIB, is properly configured to give access to those objects only to those principals (users) that have legitimate rights to access them.

8. IANA Considerations

To be added.

9. References

9.1. Normative References

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9.2. Informative References

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[RFC 2233] "The Interfaces Group MIB using SMIv2", K. McCloghrie, F. Kastenholz, November 1997, RFC 2233

[RFC 2271] Harrington, D., Presuhn, R., and B. Wijnen, "An Architecture for Describing SNMP Management Frameworks", RFC 2271, Cabletron Systems, Inc., BMC Software, Inc., IBM T. J. Watson Research, January 1998

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[RFC 2578] McCloghrie, K., Perkins, D., and J. Schoenwaelder, "Structure of Management Information Version 2 (SMIv2)", STD 58, RFC 2578, April 1999.

[RFC 2579] McCloghrie, K., Perkins, D., and J. Schoenwaelder, "Textual Conventions for SMIv2", STD 58, RFC 2579, April 1999.

[RFC 2580] McCloghrie, K., Perkins, D., and J. Schoenwaelder, "Conformance Statements for SMIv2", STD 58, RFC 2580, April 1999.

10. Acknowledgements

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Internet-Draft Huawei Technologies
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Expires: April 19, 2011

IPsec security for packet based synchronization
draft-xu-tictoc-ipsec-security-for-synchronization-00.txt

Abstract

Cellular networks often use Internet standard technologies to handle synchronization. This document analyses the need for security methods for synchronization messages distributed over the Internet. This document also gives a solution on how to mark the synchronization message when IPSec is implemented in end to end frequency synchronization."

Status of this Memo

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Table of Contents

1. Introduction

When transfering timing in internet, a shared infrastructure is used, and hence the path is no longer physically deterministic. It leaves open the possibility to disrupt, corrupt or even spoof the timing flow, where a timing signal purports to come from a higher quality clock than it actually does. In the extreme, this may be used to attack the integrity of the network, to disrupt the synchronization flow, or cause authentication failures. On the other hand, it may be possible for unauthorized users to request service from a clock server. This may overload a clock server and compromise its ability to deliver timing to authorized users.

For the cellular backhaul applications, two kinds of synchronization is needed, one is the recovery of an accurate and stable frequency synchronization signal as a reference for the radio signal (e.g. GSM, UMTS FDD, LTE FDD). In addition to frequency synchronization, phase/time synchronization are also needed in Mobile technologies, This is the case for the TDD technologies such as UMTS TDD,LTE TDD.

Frequency synchronization is normally implemented in an end-to-end scenario where none of the intermediate nodes in the network have to recognize and process the synchronization packets. However In phase/ time synchronization, a hop-by-hop scenario will request intermediate nodes to process the synchronization packets If very accurate phase/ time is needed (e.g. sub-microsecond accuracy).

Femtocell is the typical cellular backhaul application that requires time synchronization. A Femtocell is defined as a wireless base station for deployment in residential environments and is typically connected to the mobile core network via a public broadband connection (eg., DSL modem, cable modem). Femtocell improves cellular network coverage and saves cost for operators. Just like a typical macrocell (larger base station), Femtocells (residential base stations) require a certain level of synchronization (frequency or phase/time) on the air interface, predominantly frequency requirements.

The [3GPP.33.320] specification defines some of the high-level network architecture aspects of a Home NodeB (3G UMTS) and a Home eNodeB (4G LTE). In addition, the Femto Forum organization also provides a network reference model very similar to 3GPP. Both architectures have commonalities as illustrated in Figure 1.

```
          +-------------+
          |             |
          |  Femtocell  |<------------------------------+
          |             |                               |
          +-------------+                               |
                                                        |
                                                        |
                                           /---------------------\
                                           |                     |
                                           |   Public Network    |
                                           |                     |
                                           \---------------------/
                                                        |
                                                        |
          +------------+            +-------------+     |
          |Clock Server|----------->|             |     |
          +------------+            |             |     |
                                    | Security GW |->---+
          +------------+            |             |
          |Femto GW    |----------->|             |
          +------------+            +-------------+
```

Figure 1. Typical Architecture of a Femtocell Network

The network architecture shows that a public network is used to establish connectivity between Femtocell and core network elements (e.g., Security Gateway, Femto Gateway, Clock server, etc.). With respect to synchronization process, Femtocell will therefore see synchronization messages exchanged over the public network (e.g, Internet). This presents a set of unique challenges for mobile operators.

One challenge involves the security aspects of such the Femto architecture. In both reference models, the communication between Femtocell and Femto Gateway is secured by a mandatory Security Gateway function. The Security Gateway is mandatory since the Femto Gateway and Clock server communicate to Femtocell via a public backhaul broadband connection (also known as the 3GPP iuh interface or Femto Forum Fa interface). The [3GPP.33.320] specification requires that the Femtocell SHALL support receiving time synchronization messages over the secure backhaul link between Femtocell and the Security Gateway, and Femtocell SHALL use IKEv2 protocol to set up at least one IPsec tunnel to protect the traffic with Security Gateway.

This document provides analysis on security requirements for packet-based synchronization and proposes IPsec security solution for end to end frequency synchronization.

2. Terminology used in this document

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].

3. Security requirements for synchronization

The ITUT [G.8265] specification provides general consideration on synchronization security. Because packet-based timing streams may be observed at different points in the network, there may be cases where timing packets flow across multiple network domains which may introduce specific security requirements. There may also be aspects of security that may be related to both the network (e.g. authentication and/or authorization) and to the synchronization protocol itself. ITUT [G.8265] specification recommends to use existing, standards-based security techniques to help ensure the integrity of the synchronization. Examples may include encryption and/or authentication techniques, or network techniques for separating traffic, such as VLANs or LSPs. Specifically for the performance issue, it may not be possible to implement some security requirements without actually degrading the overall level of timing or system performance. From above analysis, following synchronizations requirements are listed:

1. synchronization client SHOULD be prevented from connecting to rogue clock servers
2. clock servers SHOULD be prevented from providing service to unauthorized synchronization client
3. Security mechanisms to achieve synchronization SHOULD minimize any degradation in performance and this side effect SHOULD be controlled to meet specific synchronization requirements(e.g., Femtocell synchronization)

4. Security mechanism for synchronization

There are mainly two kinds of security mechanism used in current synchronization: authentication-based and encryption-based.

For the authentication-based security mechanism, a shared secret key between the synchronization client and the clock servers is used to compute an authentication code (known as an "Integrity Check Value", ICV) over the entire message datagram. [IEEE1588] contains an experimental security annex defining an authentication-based approach. This approach also implements a challenge-response mechanism to confirm the creation of any security association (SA) between a clock servers and a synchronization client. A limitation of the process is that no method of sharing the key is proposed in [IEEE1588]. This MUST be handled by other means.

For the encryption-based security mechanism, a shared-key approach is also used. Instead of creating an ICV, the shared key is used to encrypt the contents of the packet completely. The encryption might be performed in the synchronization device itself, or it might be performed in a separate device, e.g. a secure gateway. An example might be where the timing packets have to pass through an encrypted tunnel (e.g. an IPSec tunnel). Full encryption might be required for various reasons. The contents of the packet may be considered secret, such as might be the case where accuracy of the time distribution is being sold as a service. Alternatively, it may be because other traffic from a device is considered secret, and hence it is easier to encrypt all traffic.

IPsec,as a popular security mechanism, is being considered in some mobile applications, especially in case of unsecure backhaul links (e.g. Femtocells, [3GPP.33.320]) being involved. IPsec can provide data source authentication, confidentiality, integrity that is suitable to end to end synchronization without intermediate nodes . For example, if only frequency synchronization is needed, an end-to-end scenario where none of the intermediate nodes in the network have to recognise and process the synchronization packets might be suitable to use IPsec security mechansim. In this case, the synchronization packets will be encrypted if the packed is transported in the IPSec tunnel.

IPsec can meet synchronization rquirement 1 and 2 in section 3, however IPsec still need some enhancement to meet requirement 3 . Normally, device will decrypt IPSec message in IP layer, but in order to improve the synchronization accuracy, some synchronization protocol (e.g. [IEEE1588]) requests to process the synchronization message in hardware, therefore the synchronization device may need to identify synchronization messages in physical layer before the message is decrypted. How to identify the synchronization messages in IPsec becomes the most important issue to keep the synchronization accuracy in IPsec synchronization scenario.

5. ESP format enhancement

As discussed above section, it has advantage to identify whether the tunnel packets received by synchronization client are the special timing packets or not. This section proposes a solution to identify the timing packets When using IPsec to protect the whole time synchronization message. The main thought is to use time packet identifier which is included in a new defined flexible ESP format to identify whether the received data packet is a timing packet or not.

5.1. Existing ESP format

ESP provides confidentiality, data integrity, access control, and data source authentication to IP datagrams as specified in [RFC4303]. The ESP contains several parts (Figure 2): Security Parameters Index(SPI) and Sequence Number(SQN),ESP Payload,ESP trailer and the ICV. SPI and SQN are used to identity a SA and replay protection respectively. ESP trailer is comprised of Padding, Pad length, Next Header. The integrity scope is from SPI to Next Header. The encryption protection is provided for the Payload Data and ESP trailer. For SPI and SQN, only the authentication of data integrity is provided.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ ----
|               Security Parameters Index (SPI)                 | ^Int.
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ |Cov-
|                      Sequence Number                          | |ered
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ | ----
|                    Payload Data* (variable)                   | |   ^
~                                                               ~ |   |
|                                                               | |Conf.
+               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ |Cov-
|               |     Padding (0-255 bytes)                     | |ered*
+-+-+-+-+-+-+-+-+               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ |   |
|                               |  Pad Length   | Next Header   | v   v
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ ------
|         Integrity Check Value-ICV   (variable)                |
~                                                               ~
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2. Top-Level Format of an ESP Packet

Except for the fields discussed above, there are no other reserved bits in ESP. However, In the protection of time packets over IPsec scenario, the time packet is encrypted in Payload Data, the receiver could not identify whether it is the time packet or not.

5.2. Flexible ESP format

This documents proposes to define a new flexible ESP format. The new extended ESP format not only contains the fields described in [RFC4303], but also has additional authentication information. The additional authentication information is comprised of ESP special usage flags(one octet zeros),extended data type, extended data length, and Authentication Payload (Figure 3). In the extended ESP additional authentication information, it includes a data type to identify the time packets, and could also identify whether the time packet is the event message or not by addintional time-packet information in Authentication Payload. In addition, the authentication of data integrity for the whole extended Data is provided. The figure of the proposed flexible ESP format is as following:

```
     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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |               Security Parameters Index (SPI)                 |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      Sequence Number (32-bit)                 |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 0 0 0 0 0 0 0 |     Type      |         Length                |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   ~                                                               ~
   |                 Authentication Payload (variable)             |
   ~                                                               ~
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Payload Data* (variable)                   |
   ~                                                               ~
   |                                                               |
   +               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |               |     Padding (0-255 bytes)                     |
   +-+-+-+-+-+-+-+-+               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                               | Pad Length    | Next Header   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |         Integrity Check Value-ICV   (variable)                |
   ~                                                               ~
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3. New defined ESP format with 32-bit Sequence Number

o Security Parameters Index(32-bit)-Defined in [RFC4303].

- o Sequence Number (32-bit or the extended 64-bit)-Defined in [RFC4303].
- o One octet zero bits - The inspection bits, used to distinguish from the existing ESP.
- o ED-Type(Extended Data Type (8-bit))- The message type flag in extended additional authentication information which indicates the message type in encryped Payload Data.
- o ED-Length(Extended Data Length (16-bit))- The length of extended additional authentication data contains the whole extended additional authentication information.
- o Authentication Payload- It contains additional message information, and also contains the information of integrity for extended data, such as, integrity algorithm, and the extended data integrity check value. it is an optional part to provide more information of encrypted messages in Payload Data and also provide authentication of data integrity for extended data, which includes One octet zero bits, Extended Data Type, Extended Data Length and Authentication Payload data.
- o Other fields- Defined in [RFC4303].

In Femtocell scenario, as the link between Security Gateway and clock server is normally security path, the message transmitted between them are in plain text. When Security Gateway receives the message, it identifies the time packet at first, then put appropriate value to Data type field to identify the message type in Payload Data, after that, it could put more packet information into Authentication Payload, such as UDP port number or timestamps, then Extended Data Length, Algorithm ID, Extended Data integrity Check value (Figure 4), could also be filled consequently. following figure illustrates on how to use this new flexible ESP format to identify time packet.

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |               Security Parameters Index (SPI)                 |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                      Sequence Number (32-bit)                 |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |0 0 0 0 0 0 0 0|0 0 0 0 0 0 0 1|        Length                 |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                                                               |
    ~                    Time packets information                   ~
    |                                                               |
    +                               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                               | Algorithm or Algorithm ID     |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                   Time packets identifier ICV                 |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                    Payload Data* (variable)                   |
    ~                                                               ~
    |                                                               |
    +               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |               |     Padding (0-255 bytes)                     |
    +-+-+-+-+-+-+-+-+               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                               |  Pad Length   | Next Header   |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |          Integrity Check Value-ICV   (variable)               |
    ~                                                               ~
    |                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4. New defined ESP format with 32-bit Sequence Number for time-packet

- o Extended Data Type (8-bit) - The value 0x1 here indicates that the extended context is time packet.
- o Extended Data Length (16-bit)- The length of whole extended additional authentication data
- o Time packets information(variable)- the addintional message information, such as UDP port number or timestamps. It is a part of Authentication payload.
- o Algorithm or Algorithm ID- It indicates which algorithm could be used to generate the extended data ICV. It is a part of Authentication payload.The integrity algorithm negotiated during IKEv2 could be used, also Algorithm ID field in the extended additional authentication data could be marked to indicate the integrity algorithm, such as HMAC- SHA1, HMAC-256, or others. It

      is a part of Authentication payload.

   o Extended Data integrity Check value (variable) - Time packets identifier integrity Check value.It is a part of Authentication payload.

   Time packets information, Algorithm or Algorithm ID and Extended Data integrity Check value form the Authentication Payload, it is an optinal field and used to guarantee the integrity of transmission. As the integrity protection is only for the Extended Data but not for the whole ESP packet, the time delay of calculation can be decreased. In addition, if the integrity protection is not necessary, this part of security validation could be ignored.

6. Example

In this section, the procedure to identify time packet in Security Gateway scenario is depicted.

```
 +-------------+                      +------------+     +-------------+
 |             |                      |            |     |             |
 |  Femtocell  |<-------------------->|Security GW |-----|Clock Server |
 |             |                      |            |     |             |
 +-------------+                      +------------+     +-------------+
        |      establish IPSec Tunnel             |                   |
        |<----------------------------------->|                   |
        |                                     |                   |
        |                 Sync Request        |                   |
        |-----------------------------------|------------------->|
        |                                     |                   |
        |                 Sync Response       |                   |
        |<----------------------------------|-------------------|
        |                                     |                   |
        |       message with time packets     |                   |
        |<----------------------------------|-------------------|
        |                                     |                   |
 +--------------+                             |                   |
 |identify the  |                             |                   |
 |timing packet |                             |                   |
 |              |                             |                   |
 +--------------+                             |                   |
```

Figure 5. example procedure

In the Security Gateway scenario, The IPsec with tunnel mode is established between Femtocell and Security Gateway. After Femtocell and Clock server exchange the Sync Request and Sync Response, the clock server will send the time packets to Femtocell to implement frequency synchronization with the protection of IPsec tunnel. When Femtocell receives the message, it can identify whether it is time packet, and can also identify whether the time packet is the event message by the time packet information in the unencryped field as defined in the new ESP format. If the message is time packet and identifies that it is the event message, Femtocell will do special process for the event message, such as recording the message receiving time. On the server side, When Security Gateway receives the message, it identifies the time packet at first, then put appropriate value to Data type field to identify the message type in Payload Data, after that, it could put more packet information into Authentication Payload, such as UDP port number or timestamps, then Extended Data Length, Algorithm ID, Extended Data integrity Check value, could also be filled consequently.

7. IPv4/v6 consideration for IPsec based sychronization

IPsec is a security mechanism used both for IPv4 and IPv6, and ESP-based solution has no impact on the IPv4 header and makes the transition/migration from IPv4 to IPv6 seamless.

8. Security Considerations

This protocol variation inherits all the security properties of regular ESP as described in [RFC4303].

This document defines a new flexible ESP format, which contains Extended Data Type Extended Data Length and additional authentication paylaod. The authentication of data integrity for the extended data is provided, and the data type is carried in the unencryption part. Therefore the receiver could identify whether the receiving messages are time packets or not.

9. IANA Considerations

There have been no IANA considerations so far in this document.

10. Acknowledgments

The authors appreciate the valuable work and contribution done to this document by Marcus Wong.

11. References

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