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Enterprise Profile for the Precision Time Protocol
With Mixed Multicast and Unicast Messages

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Abstract

        This document describes a profile for the use of the Precision
Time Protocol in an IPV4 or IPv6 Enterprise information system
environment. The profile uses the End to End Delay Measurement
Mechanism, allows both multicast and unicast Delay Request and Delay
Response Messages.

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1. Introduction

   The Precision Time Protocol ("PTP"), standardized in IEEE 1588,
   has been designed in its first version (IEEE 1588-2002) with the
   goal to minimize configuration on the participating nodes. Network
   communication was based solely on Multicast messages, which unlike
   NTP did not require that a receiving node ("slave clock" in
   [IEEE1588] needs to know the identity of the time sources in the
   network (the Master Clocks).

   The so-called "Best Master Clock Algorithm" ([IEEE1588] Clause
   9.3), a mechanism that all participating PTP nodes must follow,
   set up strict rules for all members of a PTP domain to determine
   which node shall be the active sending time source (Master Clock).
   Although the multicast communication model has advantages in
   smaller networks, it complicated the application of PTP in larger
   networks, for example in environments like IP based
   telecommunication networks or financial data centers. It is

considered inefficient that, even if the content of a message applies only to one receiver, it is forwarded by the underlying network (IP) to all nodes, requiring them to spend network bandwidth and other resources like CPU cycles to drop the message.

The second revision of the standard (IEEE 1588-2008) is the current version (also known as PTPv2) and introduced the possibility to use unicast communication between the PTP nodes in order to overcome the limitation of using multicast messages for the bi-directional information exchange between PTP nodes. The unicast approach avoided that, in PTP domains with a lot of nodes, devices had to throw away up to 99% of the received multicast messages because they carried information for some other node. PTPv2 also introduced so-called "PTP profiles" ([IEEE1588] Clause 19.3). This construct allows organizations to specify selections of attribute values and optional features, simplifying the configuration of PTP nodes for a specific application. Instead of having to go through all possible parameters and configuration options and individually set them up, selecting a profile on a PTP node will set all the parameters that are specified in the profile to a defined value. If a PTP profile definition allows multiple values for a parameter, selection of the profile will set the profile-specific default value for this parameter. Parameters not allowing multiple values are set to the value defined in the PTP profile. A number of PTP features and functions are optional and a profile should also define which optional features of PTP are required, permitted or prohibited. It is possible to extend the PTP standard with a PTP profile by using the TLV mechanism of PTP (see [IEEE1588] Clause 13.4), defining an optional Best Master Clock Algorithm and a few other ways. PTP has its own management protocol (defined in [IEEE1588] Clause 15.2) but allows a PTP profile specify an alternative management mechanism, for example SNMP.

2. Conventions 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 RFC-2119 [RFC2119].

In this document, these words will appear with that interpretation only when in ALL CAPS. Lower case uses of these words are not to be interpreted as carrying RFC-2119 significance.

3. Technical Terms

Acceptable Master Table: A PTP Slave Clock may maintain a list of

masters which it is willing to synchronize to.

Alternate Master: A PTP Master Clock, which is not the Best Master, may act as a master with the Alternate Master flag set on the messages it sends.

Announce message: Contains the master clock properties of a Master clock. Used to determine the Best Master.

Best Master: A clock with a port in the master state, operating consistently with the Best Master Clock Algorithm.

Best Master Clock Algorithm: A method for determining which state a port of a PTP clock should be in. The algorithm works by identifying which of several PTP Master capable clocks is the best master. Clocks have priority to become the acting Grandmaster, based on the properties each Master Clock sends in its Announce Message.

Boundary Clock: A device with more than one PTP port. Generally boundary clocks will have one port in slave state to receive timing and then other ports in master state to re-distribute the timing.

Clock Identity: In IEEE 1588-2008 this is an 64-bit number assigned to each PTP clock which must be unique. Often the Ethernet MAC address is used since there is already an international infrastructure for assigning unique numbers to each device manufactured.

End to End Delay Measurement Mechanism: A network delay measurement mechanism in PTP facilitated by an exchange of messages between a Master Clock and Slave Clock.

Grandmaster: the primary master clock within a domain of a PTP system

IEEE 1588: The timing and synchronization standard which defines PTP, and describes The node, system, and communication properties necessary to support PTP.

Master clock: a clock with at least one port in the master state.

NTP: Network Time Protocol, defined by RFC 5905, see [NTP].

Ordinary Clock: A clock that has a single Precision Time Protocol (PTP) port in a domain and maintains the timescale used in the domain. It may serve as a master clock, or be a slave clock.

Peer to Peer Delay Measurement Mechanism: A network delay
measurement mechanism in PTP facilitated by an exchange of
messages between adjacent devices in a network.

Preferred Master: A device intended to act primarily as the
Grandmaster of a PTP system, or as a back up to a Grandmaster.

PTP: The Precision Time Protocol, the timing and synchronization
protocol define by IEEE 1588.

PTP port: An interface of a PTP clock with the network. Note that
there may be multiple PTP ports running on one physical interface,
for example a Unicast slave which talks to several Grandmaster
clocks in parallel.

PTPv2: Refers specifically to the second version of PTP defined by
IEEE 1588-2008.

Rogue Master: A clock with a port in the master state, even though
it should not be in the master state according to the Best Master
Clock Algorithm, and does not set the alternate master flag.

Slave clock: a clock with at least one port in the slave state,
and no ports in the master state.

Slave Only Clock: An Ordinary clock which cannot become a Master
clock.

TLV: Type Length Value, a mechanism for extending messages in
networked communications.

Transparent Clock. A device that measures the time taken for a
PTP event message to transit the device and then updates the
message with a correction for this transit time.

Unicast Discovery: A mechanism for PTP slaves to establish a
unicast communication with PTP masters using a configures table of
master IP addresses and Unicast Message Negotiation.

Unicast Negotiation: A mechanism in PTP for Slave Clocks to
negotiate unicast Sync, announce and Delay Request Message Rates
from a Master Clock.

[4](#). **Problem Statement**

This document describes a version of PTP intended to work in large
enterprise networks. Such networks are deployed, for example in
financial corporations. It is becoming increasingly common in
such networks to perform distributed time tagged measurements,

such as one-way packet latencies and cumulative delays on software
systems spread across multiple computers. Furthermore there is
often a desire to check the age of information time tagged by a
different machine. To perform these measurements it is necessary
to deliver a common precise time to multiple devices on a network.

Accuracy currently required can be as tight as within 1
microseconds to the Grandmaster. This profile does not specify
timing performance requirements, but such requirements explain why
the needs cannot always be met by NTP, as commonly implemented.
Such accuracy cannot usually be achieved with a traditional time
transfer such as NTP, without adding non-standard customizations
such as hardware time stamping, fast message rates, non-linear
servo loops, and on path support. These features are currently
part of PTP, or are allowed by it. Because PTP has a complex range
of features and options it is necessary to create a profile for
enterprise networks to achieve interoperability between equipment
manufactured by different vendors.

Although enterprise networks can be large, it is becoming
increasingly common to deploy multicast protocols, even across
multiple subnets. For this reason it is desired to make use of
multicast whenever the information going to many destinations is
the same. It is also advantageous to send information which is
unique to one device as a unicast message. The latter can be
essential as the number of PTP slaves becomes hundreds or
thousands.

PTP devices operating in these networks need to be robust. This
includes the ability to ignore PTP messages which can be
identified as improper, and to have redundant sources of time.

5. Network Technology

This PTP profile SHALL operate only in networks characterized by
UDP [RFC768] over either IPv4 [RFC791] or IPv6 [RFC2460], as
described by Annexes D and E in [IEEE1588] respectively. If a
network contains both IPv4 and IPv6, then they SHALL be treated as
separate communication paths. Clocks which communicate using IPv4
can interact with clocks using IPv6 if there is an intermediary
device which simultaneously communicates with both IP versions. A
boundary clock might perform this function, for example. A PTP
domain SHALL use either IPv4 or IPv6 over a communication path,
but not both. The PTP system MAY include switches and routers.
These devices MAY be transparent clocks, boundary clocks, or
neither, in any combination. PTP Clocks MAY be Preferred Masters,
Ordinary Clocks, or Boundary Clocks. The ordinary clocks may be
Slave Only Clocks, or be master capable.

Note that clocks SHOULD always be identified by their clock ID and
not the IP or Layer 2 address. This is important in IPv6 networks

since Transparent clocks are required to change the source address
of any packet which they alter. In IPv4 networks some clocks
might be hidden behind a NAT, which hides their IP addresses from
the rest of the network. Note also that the use of NATs may place
limitations on the topology of PTP networks, depending on the port
forwarding scheme employed. Details of implementing PTP with NATs
are out of scope of this document.

Similar to NTP, PTP makes the assumption that the one way network
delay for Sync Messages and Delay Response Messages are the same.
When this is not true it can cause errors in the transfer of time
from the Master to the Slave. It is up to system integrator to
design the network so that such effects do not prevent the PTP
system from meeting the timing requirements. The details of
network asymmetry are outside the scope of this document. See for
example, [G8271].

6. Time Transfer and Delay Measurement

Master clocks, Transparent clocks and Boundary clocks MAY be
either one-step clocks or two-step clocks. Slave clocks MUST
support both behaviors. The End to End Delay Measurement Method
MUST be used.

Note that, in IP networks, Sync messages and Delay Request
messages exchanged between a master and slave do not necessarily
traverse the same physical path. Thus, wherever possible, the
network SHOULD be traffic engineered so that the forward and
reverse routes traverse the same physical path. Traffic
engineering techniques for path consistency are out of scope of
this document.

In all three of the delay measurement modes, Sync messages MUST
be sent as PTP event multicast messages (UDP port 319) to the PTP
primary IP address.   Two step clocks SHALL send Follow-up
messages as PTP general messages (UDP port 320). Announce messages
MUST be sent as multicast messages (UDP port 320) to the PTP
primary address. The PTP primary IP address is 224.0.1.129 for
IPv4 and FF0X:0:0:0:0:0:0:181 for Ipv6.

6.1. Unicast Delay Measurement Mode

All Delay Request PTP event messages and Delay Response PTP
general messages MUST be sent as unicast messages. Unicast
Discovery and Unicast Message Negotiation options MUST NOT be
utilized.

6.2. Multicast Delay Measurement Mode

All Delay Request PTP event messages and Delay Response general
messages MUST be sent as multicast messages.

6.3. Hybrid delay Measurement Mode

Delay Request Messages MAY be sent as either multicast or unicast
PTP event messages. Master clocks SHALL respond to multicast Delay
Request messages with multicast Delay Response PTP general
messages. Master clocks SHALL respond to unicast Delay Request PTP
event messages with unicast Delay Response PTP general messages.

The default mode for Enterprise Profile PTP Master Clocks is
Hybrid Delay Measurement Mode. This allow for the use of Ordinary
clocks which do not support the Enterprise Profile, as long as
they are slave Only Clocks.

7. Default Message Rates

The Sync, Announce and Delay Request default message rates SHALL
each be once per second. The Sync and Delay Request message rates
MAY be set to other values, but not less than once every 128
seconds, and not more than 128 messages per second. The Announce
message rate SHALL NOT be changed from the default value. The
Announce Receipt Timeout Interval SHALL be three Announce
Intervals for Preferred Masters, and four Announce Intervals for
all other masters.

8. Timing Domains

All Master Clocks in the Enterprise Profile SHALL operate with the
PTP timing domain set in the range 0-3 when any part of the domain
is operating in either the Multicast Delay Measurement Mode, or
the Hybrid Delay Measurement Mode. The default timing domain for
operation with this configuration is Domain 0. All Master Clocks
in the Enterprise Profile SHOULD operate with the PTP timing
domain set in the range 40-60 when the entire domain is acting in
the Unicast Delay Measurement Mode. The default timing domain for
this configuration is Domain 40. If it is not known in advance
which modes will be operating in a domain, then domains 0-3 SHOULD
be used.

9. Requirements for Master Clocks

Master clocks SHALL obey the standard Best Master Clock Algorithm
from [IEEE1588]. Clocks which are master capable MAY act as
Alternate masters according to [IEEE1588]. Preferred Master

Clocks SHOULD operate as Alternate Masters when they are not the
Best Master. Using multiple masters can mitigate rogue master and

man-in-the-middle attacks such as delay attacks, packet
interception / manipulation attacks. Assuming the path to each
master is different, an attacker would have to attack more than
one path simultaneously.

The Announce Messages SHALL include a TLV which indicates that the
clock is operating in the Enterprise Profile. The TLV shall have
the following structure:

TLV Type (Enumeration16): ORGANIZATION_EXTENSION value = 0003 hex

Length Field (UInteger16): value = 2. The number of octets in the
Data Field

Organization Id (3 Octets): The Organization ID value for the IETF
assigned by IEEE = TBD

Organization SubType (Enumeration24) value = 000001hex (Enterprise
PTP Profile version 1)

Data Field, Delay Measurement Mode (Enumeration16):

        Value 00hex = Multicast Delay Measurement Mode

        Value 01hex = Unicast Delay Measurement Mode

        Value 02hex = Hybrid Delay Measurement Mode

        Values 03-FFhex = reserved for future use.

The TLV represents the Delay Request Mode of the Master, not
necessarily the Grandmaster. So for example, one port of a
Boundary clock could be set to Unicast Delay Measurement Mode,
while the rest of the network is Hybrid Delay Measurement Mode.

10.   Requirements for Slave Clocks

Slave clocks MUST be able to operate properly in a network which
contains Alternate Masters. Slaves SHOULD make use of information
from the Alternate Masters in their clock control subsystems.
Slave Clocks MUST be able to operate properly in the presence of a
Rogue Master. Slaves SHOULD NOT Synchronize to a Rogue Master.
Slaves MAY use an Acceptable Master Table. If the Best Master is
not an Acceptable Master, but an Alternate Master is an Acceptable
Master, then the Slave SHOULD synchronize to the acceptable
Alternate Master.

   Note that IEEE 1588-2008 requires slave clocks to support both
   two-step or one-step Master clocks. See [IEEE1588], section
   11.2.

   Since Announce messages are sent as multicast messages in all
   mode, slaves can obtain the IP addresses of master from the
   Announce messages. Note that the IP source addresses of Sync and
   Follow-up messages may have been replaced by the source addresses
   of a transparent clock, so slaves MUST send Delay Request messages
   to the IP address in the Announce message. Sync and Follow-up
   messages can be correlated with the Announce message using the
   clock ID, which is never altered by Transparent clocks.

11. Requirements for Transparent Clocks

   Transparent clocks SHALL NOT change the transmission mode of an
   Enterprise profile PTP message. For example a Transparent clock
   SHALL NOT change a unicast message to a multicast message.
   Transparent clocks SHALL NOT alter the Enterprise Profile TLV of
   an Announce message, or any other part of an Announce message.

12. Management and Signaling Messages

   PTP Management messages MAY be used. Any PTP management message
   which is sent with the targetPortIdentity.clockIdentity set to all
   1s (all clocks) MUST be sent as a multicast message. Management
   messages with any other value of for the Clock Identity is
   intended for a specific clock and MUST be sent as a unicast
   message. Similarly, if any signaling messages are used they
   MUST also be sent as unicast messages whenever the message is
   intended for a specific clock.

13. Forbidden PTP Options

   Clocks operating in the Enterprise Profile SHALL NOT use peer to
   peer timing for delay measurement. Clocks operating in the
   Enterprise Profile SHALL NOT use Unicast Message Negotiation to
   determine message rates. Slave clocks operating in the Enterprise
   Profile SHALL NOT use Unicast Discovery to establish connection to
   Master clocks. Grandmaster Clusters are NOT ALLOWED. Clocks
   operating in the Enterprise Profile SHALL NOT use Alternative Time
   Scales.

14. Interoperation with Other PTP Profiles

   Clocks operating in the Enterprise profile will not interoperate

with clocks operating in the Power Profile [C37.238], because the

Enterprise Profile requires the End to End Delay Measurement
Mechanism and the Power Profile requires the Peer to Peer Delay
Measurement Mechanism.

Clocks operating in the Enterprise profile will not interoperate
with clocks operating in the Telecom Profile for Frequency
Synchronization[G8265.1], because the Enterprise Profile forbids
Unicast Message Negotiation, and Unicast Discovery. These
features are part of the default manner of operation for the
Telecom Profile for Frequency Synchronization.

Clocks operating in the Enterprise profile will interoperate with
clocks operating in the default profile if the default profile
clocks operate on IPv4 or IPv6 networks, use the End to End Delay
Measurement Mechanism, and use management messages in unicast when
those messages are directed at a specific clock. If any of these
requirements are not met than Enterprise Profile clocks will not
interoperate with Default Profile Clocks. The Default Profile is
described in Annex J of [IEEE1588].

Enterprise Profile Clocks will interoperate with clocks operating
in other profiles if the clocks in the other profiles obey the
rules of the Enterprise Profile. These rules MUST NOT be changed
to achieve interoperability with other profiles.

15.   Security Considerations

Protocols used to transfer time, such as PTP and NTP can be
important to security mechanisms which use time windows for keys
and authorization. Passing time through the networks poses a
security risk since time can potentially be manipulated.

The use of multiple simultaneous masters, using the IEEE 1588
Alternate Master option can mitigate problems from rogue masters
and man-in-the-middle attacks. See sections 9 and 10. Additional
security mechanisms are outside the scope of this document.

16.   IANA Considerations

There are no IANA requirements in this specification.

17.   References

17.1.   Normative References

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18.   Acknowledgments

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