Title: ADD AND DROP ELEMENTS FOR NTP ON-PATH-SUPPORT AND METHOD FOR INTER-OPERATING BETWEEN NTP AND IEEE-1588 PROTOCOL DOMAINS

Abstract: A method and system for providing add/drop elements at boundaries between NTP domains and IEEE-1588 domains. The add/drop elements encapsulate incoming NTP messaging time-stamps within 1588 messages, and update the NTP time-stamp information upon entry/exit from the IEEE-1588 domain. The add/drop element system is particularly useful for overcoming the requirements for extra time gateways in order to achieve timing parity between IETF NTP and IEEE1588v2.
ADD AND DROP ELEMENTS FOR NTP ON-PATH-SUP PORT AND METHOD FOR INTER-OPERATING BETWEEN NTP AND IEEE-1588 PROTOCOL DOMAINS

Field of the invention

[001] The invention relates to add/drop elements for providing on-path-support for NTP (Network Time Protocol) and is particularly concerned with encapsulating NTP timing messages within IEEE-1588 messaging.

Background of the Invention

[002] Time distribution protocols, such as IETF NTP (Network Time Protocol version 3 & 4) and IEEE-1588 Version 2 are used for supporting the distribution of time (and thus frequency) over Packet Switched Networks. NTP relies on UDP (User Datagram Protocol) or TCP/IP (Transmission Control Protocol / Internet Protocol), whereas IEEE-1588 V2 typically relies on UDP/IP or Ethernet (and is also supported over other protocols such as DeviceNet). NTP and IEEE1588 may be deployed together on the same network transparently to each other.

[003] NTP is usually dedicated to applications with moderate time requirements (applications with demands for accuracies in the millisecond range) whereas IEEE-1588 V2 is usually identified as the preferred candidate for more stringent applications (within microsecond accuracy). This performance gap in terms of achievable time accuracy between these two protocols is a barrier for an optimal sharing of synchronization resources that would yield to OPEX/CAPEX savings. Having the same level of performance between NTP and IEEE-1588 V2 would allow for using existing NTP elements for more stringent applications. This would reduce the overall Synchronization OPEX (regarding load sharing/balancing and protection issues) or ease the overall synchronization resource deployment.

[004] As timing distribution protocols, NTP and IEEE-1588 V2 both confront similar issues in propagating timing throughout a network including delay asymmetry between messages travelling in different directions over a link between two network
elements and Packet Delay Variation (PDV) arising in buffering and switching of messages.

[005] "On-path-support" in the case of IEEE-1588 refers to features of the communication path that can be used to improve time. Some examples of such features include End-to-End, Peer-to-Peer Transparent Clocks, Boundary Clocks). These were introduced in the IEEE-1588 V2 specification for fighting against the issues of delay-asymmetry and Packet Delay Variation issues.

[006] By way of example, referring to Fig. 1 there may be seen a network 100 having an IEEE-1588 V2 Master Clock 110 with 119a and 119b Slave Clocks. Communication paths 111a and 111b are established between Master Clock 110 and Slave Clocks 119a and 119b respectively. Network elements 112a, 112b, 112c, 112d; and 122a, 122b, 122c, and 122d represent network switches (and/or routers). Associated with network elements 112a, 112b, 112c, and 112d are on-path-support clock elements 113a, 113b, 113c, and 115 respectively. Elements 113a, 113b, and 113c are IEEE-1588 V2 Transparent Clocks, and element 115 is an IEEE-1588 V2 Boundary Clock. Region 117 highlights an on-path-support domain consisting of switches (or routers) 112b, 112c, and 112d and their respective on-path-support clock elements 113b, 113c, and 115. Elements 114a and 114b represent mobile base stations supported by IEEE-1588 V2 Slave Clocks 119a and 119b respectively.

[007] Likewise (Fig. 1) there may be seen NTP Server 120 having NTP Client 129. NTP communication path 121a and 121b are established between NTP Server 120 and NTP Client 129, illustrating the inherent possibility of non-optimized NTP connections. On-path-support clock elements (e.g Transparent Clocks) 123a, 123b, 123c, and 123d are associated with switches (or routers) 122a, 122b, 122c, and 122d respectively. Element 124 represents a mobile base station supported by NTP Client 129 although under the existing state-of-art NTP protocol may not be sufficiently accurate to support mobile services (in many if not most implementations).
Presently, NTP is much more extensively deployed than IEEE-1588. If NTP V4 and IEEE-1588 V2 could somehow be brought to parity regarding timing accuracies, then they could be equally deployed in the case of stringent applications (such as mobile networks). This could provide a more flexible and optimal use of synchronization resources especially regarding the more expensive network element synchronization sources such as NTP Servers and IEEE-1588 Masters.

In order for this parity to be accomplished, NTP would have to be improved in order to reach the level of IEEE1588 V2 performance.

One approach that would be possible in order to improve the time distribution from an NTP server to an NTP client is to take advantage of the IEEE-1588 on-path-support. It would be possible to connect the different time protocol domains (from NTP to IEEE-1588 to NTP) with relevant "clock" nodes embedding a dual protocol stack located at protocol domain boundaries. This could be implemented as a first "clock" node with the dual functionality (NTP Client + IEEE-1588 Master) and another node with the dual functionality (IEEE-1 588 Slave + NTP Server).

A disadvantage of this solution is that time distribution performance may be dependent of the deployment of these aforementioned dual protocol clock nodes as gateway elements between time protocol domains. In operation, these gateway elements would have to ensure the interworking between IETF NTP and IEEE-1588 V2 domains/segments with IEEE-1588 V2 Master Clock features in terms of accuracy and stability. As a result, the associated clocks (oscillators) within the gateway elements would not be inexpensive. In addition, this domain segmentation approach suffers from the additional bandwidth consumption of the superposition of IEEE-1 588 V2 signaling messages related to independent master/slave "links".

A further major drawback of this method is that of not being able to balance/share the time distribution load between NTP servers and IEEE-1588 V2 masters. This results in an increase in costs of synchronization deployment and protection schemes. Moreover, the implied static/manual configuration of clock
(oscillators) at the gateway level shouldn't easily applied in an inter-operator/domain context.

[013] What is therefore required is some method or mechanism for inter-operating NTP and IEEE-1588 protocols which brings NTP timing distribution performance to IEEE-1588 performance level.
Summary of the Invention

[014] An object of the present invention is to provide an improved method and system for inter-operating between NTP and IEEE-1588 protocol domains.

[015] According to an aspect of the present invention there is provided a method for providing inter-operation between an IEEE-1588 protocol region having on-path-support elements (for messaging) and an NTP protocol region wherein NTP messages traverse the IEEE-1588 protocol region. The architecture (Fig. 2) has a first NTP ADD/DROP element at the protocol region boundary (between the NTP protocol region and the IEEE-1588 protocol region) where NTP messages enter (direction from NTP server to NTP client taken as an example) the IEEE-1588 region. The system also has a second NTP ADD/DROP element at the protocol region boundary (between the IEEE-1588 protocol region and the NTP protocol region) where at NTP messages exit (direction from NTP server to NTP client) the IEEE-1588 region. The first NTP ADD/DROP element encapsulates incoming NTP messaging time-stamps within IEEE-1588 messages entering said IEEE-1588 protocol region, and the second NTP ADD/DROP element de-encapsulates the NTP messaging time-stamps for forwarding them to the NTP Client and updates said messaging time-stamps with timing information provided by IEEE-1588 (timing information).

[016] Advantageously, the first NTP ADD/DROP element possesses a local clock which times a buffering delay incurred by the NTP messaging time-stamp while awaiting an IEEE-1588 message. This buffering delay is used by the first NTP ADD/DROP element to increment the NTP messaging time-stamp. The local clock may have an inherent accuracy on the order of one microsecond and a precision on the order of 100 ppm.

[017] Also advantageously, the encapsulation performed by the first NTP ADD/DROP element uses the Type_Length_Value field of the IEEE-1588 messages within which it is encapsulates the NTP message.
According to another embodiment of the invention, there is provided a method for providing inter-operation between an IEEE-1588 protocol region having on-path-support for messaging and an NTP protocol region wherein NTP messages traverse the IEEE-1588 protocol region. The method includes the steps of encapsulating an NTP timing message within an IEEE-1588 timing message upon entry (taking the NTP-server-to-NTP-client direction as an illustration) of the NTP timing message into the IEEE-1588 protocol region and then de-encapsulating the NTP timing message from the IEEE-1588 timing message upon exit from said IEEE-1588 protocol region. In addition, upon the exit there is the adjusting of a time-stamp of the NTP timing message according to the timing information conveyed by the IEEE-1588 timing message.

Under some configurations there is the additional step of incrementing the time-stamp of the NTP timing message by an amount representative of a buffering delay experienced by NTP messages before their encapsulation within the IEEE-1588 timing message.

Advantageously, the incrementing step is performed prior to the encapsulation. In some embodiments the buffering delay is measured by a clock located at the network element which performs the encapsulating step. In some preferred embodiments, the clock has an accuracy on the order of one microsecond and a precision on the order of 100 ppm.

In certain embodiments the encapsulating step uses the Type_Length_Value field of the IEEE-1588 messages.
Brief Description of the drawings

[022] The present invention will be further understood from the following detailed description of embodiments of the invention, with reference to the drawings in which:

[023] Fig. 1 illustrates a network having elements supporting NTP and IEEE-1588 timing protocols as known in the art;

[024] Fig. 2 illustrates a network having elements supporting inter-operation of NTP and IEEE-1588 timing protocols according to an embodiment of the invention; and

[025] Fig. 3 illustrates a timing diagram showing the relationships of various timing delays which occur in messages between network elements according to an embodiment of the invention.

[026] It is noted that in the attached figures, like features bear similar labels.
Detailed Description

According to a proposed embodiment, inter-operation of the NTP and IEEE-1588 protocols may be performed by using the IEEE-1588 V2 on-path-support signaling for carrying the NTP protocol messages. This is done by performing a protocol inter-working at the intersection of protocol time domains. In such a solution, IEEE-1588 V2 Transparent Clocks would not have to be up-graded as per a dual protocol solution. The encapsulation and des-encapsulation of the NTP signaling would be performed by NTP "ADD/DROP" elements. As will be seen from the following discussions, the clock requirements for these ADD/DROP elements are strongly relaxed compared to the clock requirements for the gateway elements previously described.

As a basic building block, the NTP ADD/DROP elements are implemented at the protocol domain boundaries/intersection points. As such, the NTP ADD/DROP elements have to guarantee the coherence and continuity between NTP and IEEE-1588 V2, and particularly between NTP time-stamps and both IEEE-1588 V2 time-stamps and correction fields.

Referring to Fig. 2 there may be seen a network 200 illustrating an embodiment of the invention. In this network, like reference numbers refer to like network elements of Fig. 1, so that there may be seen an IEEE-1588 V2 Master Clock 210 with 219a and 219b Slave Clocks. Communication paths 211a and 211b are established between Master Clock 210 and Slave Clocks 219a and 219b respectively. Network elements 212a, 212b, 212c, 212d; and 222a, 222b, 222c, and 222d represent network switches (or routers). Associated with switches (or routers) 212a, 212b, 212c, and 212d are on-path-support clock elements 213a, 213b, 213c, and 215 respectively. Elements 213a, 213b, and 213c are IEEE-1588 V2 Transparent Clocks, and element 215 is an IEEE-1588 V2 Boundary Clock. Region 217 highlights an on-path-support domain consisting of switches (or routers) 212b, 212c, and 212d and their respective IEEE-1588 V2 on-path-support clocks 213b,
Elements 216a and 216b represent NTP ADD/DROP Elements associated with switches 212b and 212d respectively at the boundary of region 217. Pipeline 218 represents the communication path where the NTP messages are encapsulated within IEEE-1588 V2 messages and carried across region 117. Elements 214a and 214b represent mobile base stations synchronized by IEEE-1588 V2 Slave Clocks 219a and 219b respectively.

Likewise (Fig. 2) there may be seen NTP Server 220 having NTP Client 229. NTP communication path 221 is established between NTP Server 220 and NTP Client 229. NTP Transparent Clocks 223a and 223c are associated with switches or routers 222a and 222c respectively. Element 224 represents a mobile base station synchronized by NTP Client 229[comment].

In operation, the IEEE-1588 V2 correction fields in SYNC and DELAY_REQ messages are cumulative due to the Network Element traversal delays, with initializations and treatments at the Master/Slave levels. NTP ADD/DROP elements are assumed not to be necessarily located at the Master/Slave levels and have thus to take into account Input and Output IEEE-1588 V2 correction fields in order to improve the NTP time accuracy. These IEEE-1588 V2 fields are updated by the IEEE-1588 V2 Transparent Clocks within the on-path-support domain like region 117.

In such a configuration NTP messaging is carried within the IEEE-1588 V2 messaging. One way to encapsulate NTP within IEEE-1588 V2 is to take advantage of the flexible IEEE-1588 V2 structure through using a Type Length Value field to encapsulate the message.

Therefore, NTP ADD/DROP elements are required to "encapsulate" the NTP messaging (time-stamps) within the existing domain crossing IEEE-1588 V2 messages and to update the time information of the NTP protocol with the IEEE-1588 V2 one (correction field) at the ADD/DROP element level upon exit of the domain. Thus, referring to Fig. 2, the NTP timing messages from NTP Server 220 would pass through switch 220a and arrive at NTP ADD/DROP element 216a at the entry to
IEEE-1588 V2 protocol domain region 117. NTP ADD/DROP element 216a would encapsulate the NTP timing message within concurrent IEEE-1588 V2 messages arriving at switch 212b and being updated by Transparent Clock 213b. Of course the NTP timing message would have to wait for the next IEEE-1588 V2 message to arrive before the encapsulation could be performed.

[034] This wait requires that the NTP ADD/DROP element owns an internal clock to be able to time the buffering delays experienced by NTP message at the ADD level, as the NTP messages wait for their IEEE-1588 V2 carrier messages. However, this clock is may take the form of a relatively inexpensive clock regarding the requirements for the time correction. Due to the IEEE-1588 V2 protocol, the buffering time can not exceed the time between two IEEE-1588 V2 messages, which is typically 10ms. As well, in order to achieve the parity effect that is the inter-operating objective of the invention, the time accuracy should be close to a micro-second or more accurate. Combining these two features yields a frequency accuracy requirement on the order of 100 ppm for the ADD/DROP clock.

[035] Specifics of the timing inter-operation is illustrated in Fig. 3 and the annotations therein in which:

[036] A is the NTP Server, such as NTP Server 220 in Fig. 2;
[037] B is the NTP Client, such as NTP Client 229 in Fig. 2;
[038] C is an ADD/DROP element, such as ADD/DROP element 216a in Fig. 2;
[039] D is an ADD/DROP element, such as ADD/DROP element 216b in Fig. 2;
[040] t is the IEEE-1588 time-stamp;
[041] T is the NTP time-stamp which will be adjusted; and
[042] OFFSET is the time offset between B and A
Without any support, the NTP relies on the following equation system:

\[ T_2 - T_1 = \text{OFFSET} + \text{Delay}_{AB} \]
\[ T_4 - T_3 = -\text{OFFSET} + \text{Delay}_{BA} \]

Then, with reference to the IEEE-1588 V2 delay correction in event messages protocol (wherein \( CF_n \) represents the Correction Field):

\[ CF_1 \] is observed in the Sync message at C;
\[ CF_2 \] is observed in the Sync message at D;
\[ CF_3 \] is observed in the Delay_Req message at D; and
\[ CF_4 \] is observed in the Delay_Req message at C.

In considering a IEEE-1588V2 Transparent Clock supported link it may be assumed that:

\[ \text{Delay}_{AB} = \text{non\_corrected\_Delay}_{AB} + (CF_2 - CF_1) \]
\[ \text{Delay}_{BA} = \text{non\_corrected\_Delay}_{BA} + (CF_4 - CF_3) \]

Then, by rearrangement:

\[ T_2 - T_1' = \text{OFFSET} + \text{non\_corrected\_Delay}_{AB} \]
\[ T_4 - T_3' = -\text{OFFSET} + \text{non\_corrected\_Delay}_{BA} \]

And this may be written as:

\[ T_2 - T_1' = \text{OFFSET} + \text{non\_corrected\_Delay}_{AB} \]
\[ T_4 - T_3' = -\text{OFFSET} + \text{non\_corrected\_Delay}_{BA} \]

This equation system is compliant with the NTP equation system recited above. That is, the NTP protocol algorithm implemented would be unchanged in the use of these timing supplements. The inter-operation is performed by introducing:

\[ T_1' = T_1 + CF_2 - CF_1 \]
\[ T_3' = T_3 + CF_4 - CF_3 \]
Note that on Fig. 3, the encapsulation of the last NTP message carrying \((T_3, T_4, T_5)\) in an IEEE-1588 V2 message (in the Delay_Resp message through an ADD/DROP element) is optional.

In general, the ADD/DROP NTP elements are responsible for:

- detecting NTP message packets and IEEE-1588 V2 message packets;
- updating the NTP messaging (time-stamps) according to the buffering delays experienced by NTP message at the ADD level, as NTP messages wait for their IEEE-1588V2 carrier messages.

Complementing the basic building block described above may be an auto-discovery/advertising mechanism dedicated to inform a management or a control plane of the position of these ADD/DROP elements in order to ease the (dynamic) establishment of the most preferred paths between an NTP Server and an NTP Client.

In general, the denser the deployment of ADD/DROP elements across the network, the more the NTP to IEEE-1588 V2 inter-operation would allow optimal flexibility for the timing synchronization distribution to yield an expected homogenous performance within the network. Associated mapping functions between IEEE-1588 V2 and NTP would enable an interchange of clock sources while needed allow for additional functionality of protection and load balancing of synchronization sources.

As a further observation, the inter-operating method and system described above would enable networks to have a lighter prioritization treatment of the synchronization signaling at the Network Element level for a given performance level. This is because these network elements have only to consider one (IEEE-1588 V2) protocol signaling flow instead of two (NTP and IEEE-1588 V2).

A main advantage of the described embodiment is to guarantee a better NTP performance by taking advantage of the IEEE-1588 V2 "on-path-support" in an inter-operating way. With expectations of a similar performance level in terms of...
achievable time accuracy, both protocols would be able to address timing stringent applications such as the wireless networks.

[071] The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof. Numerous modifications, variations and adaptations may be made to the embodiment of the invention described above without departing from the scope of the invention, which is defined in the claims.
WHAT IS CLAIMED IS:

1. A system for providing protocol inter-operation between an IEEE-1588 protocol region having on-path-support for messaging and an NTP protocol region wherein NTP messages traverse the IEEE-1588 protocol region, said system comprising:
   a first NTP ADD/DROP element at a protocol boundary between said NTP protocol region and said IEEE-1588 protocol region where the NTP messages enter the IEEE-1588 region;
   a second NTP ADD/DROP element at a protocol boundary between said IEEE-1588 protocol region and the NTP protocol region where at NTP messages exit said IEEE-1588 region;
   wherein said first NTP ADD/DROP element encapsulates incoming NTP messaging time-stamps within IEEE-1588 messages entering said IEEE-1588 protocol region, and updates said messaging time-stamp with timing information according to IEEE-1588 timing information, and
   wherein said second NTP ADD/DROP element de-encapsulates said NTP messaging time-stamps for forwarding to an NTP Client and updates said messaging time-stamp with timing information according to IEEE-1588 timing information.

2. A system as claimed in claim 1 wherein
   said first NTP ADD/DROP element further comprises a local clock which times a buffering delay incurred by said NTP messaging time-stamp while awaiting an IEEE-1588 message.
3. A system as claimed in claim 2 wherein
   said buffering delay is used by said first NTP ADD/DROP element to adjust the
   NTP messaging time-stamp.

4. A system as claimed in claim 2 wherein
   said local clock has an inherent accuracy on the order of one microsecond and
   a precision on the order of 100 ppm.

5. A system as claimed in claim 1 wherein
   said encapsulation uses the Type_Length_Value field of said IEEE-1588
   messages.

6. A method for providing protocol inter-operation between an IEEE-1588 protocol
   region having on-path-support for messaging and an NTP protocol region wherein
   NTP messages traverse the IEEE-1588 protocol region, said method comprising
   the steps of:
      encapsulating an NTP timing message within an IEEE-1588 timing message upon
      entry of said NTP timing message into said IEEE-1588 protocol region;
      de-encapsulating said NTP timing message from said IEEE-1588 timing message
      upon exit from said IEEE-1588 protocol region; and
      adjusting a time-stamp of said NTP timing message according to timing
      information contained within said IEEE-1588 timing message.

7. A method as claimed in claim 6 comprising the further step of
   incrementing said time-stamp of said NTP timing message by an amount
   representative of a buffering delay incurred before said NTP timing message
   could be encapsulated within said IEEE-1588 timing message.
8. A method as claimed in claim 7 wherein
   said incrementing step is performed prior to encapsulation.

9. A method as claimed in claim 7 wherein
   said buffering delay is measured by a clock located at the network element which
   performs the encapsulating step.

10. A method as claimed in claim 9 wherein
    said clock has an accuracy on the order of one microsecond and a precision on
    the order of 100 ppm.

11. A method as claimed in claim 6 wherein
    said encapsulating step uses the Type_Length_Value field of said IEEE-1588
    messages.
IEEE-1588
Transparent Clock Domain

Fig. 3
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04J3/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Date of the actual completion of the international search

17 December 2009

Date of mailing of the international search report

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**INTERNATIONAL SEARCH REPORT**

International application No

PCT/IB2009/052799

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