Use of IEEE 1588 Best Master Clock Algorithm in IEEE 802.1AS

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Outline

- 802.1AS clock quality
- 802.1AS clock preference level
- Best Master Clock Algorithm (BMCA)
- General references for BMCA

Introduction

- IEEE 802.1AS will use a subset of IEEE 1588 version 2 Precision Time Protocol (PTP) to provide timing/synchronization for A/V Bridging (AVB) networks
  - Each AVB node can contain the following, depending on whether it is a bridge, a wireless access point, or a wired or wireless endpoint
    - Standalone peer-to-peer (P2P) Transparent Clock (TC) (A/V bridge)
    - P2P TC collocated with OC (A/V Bridge)
    - Standalone ordinary Clock (OC) (wired or wireless endpoint)
    - 802.1 AS Boundary Clock (BC) (wireless access point (AP) or A/V bridge)
    - Other combinations of functions in the same box are possible
  - One BC or OC will be Grandmaster (GM) and the other BCs and OCs will be slaves
    - An AVB network will consist of a single PTP sub-domain
  - P2P TCs will not be part of the synchronization hierarchy (i.e., they are neither master nor slave)
  - AVB networks will not contain End-to-End (E2E) TCs
  - AVB networks will have a single clock requirement with a single quality

802.1AS Clock Quality - 1

- There will be a single set of requirements for the 802.1AS node clock (i.e., free-running oscillator), and therefore a single clock quality
  - Clock class (formerly stratum) will be 4
    - Describes the traceability of a clock
    - Note that class 1 is used for a primary reference standard synchronized to TAI (e.g., a calibrated atomic clock or a GPS clock); class 2 is used for a primary reference standard in holdover and still within its holdover accuracy specification
    - See table (from 1588 V2) on next slide
  - Time source (formerly clockIdentifier)
    - Describes the accuracy of a clock
    - Values in IEEE 1588 are ATOM, GPS, NTP, HAND, INIT, DFLT
    - This attribute indicates where the clock is getting its time from
    - See table (from 1588 V2) on next slide

802.1AS Clock Quality - 2

PTP Class	Specification
0	May be used temporarily for special purposes by PTP implementations to force the best master clock algorithm to deem a clock better than other clocks in the system. It is also used by the protocol to manage version compatibility, see section xxx.
1	Designates a clock as a primary reference standard synchronized to a recognized standard source of TAI time. Aclock of this class shall not be synchronized to another clock in the PTP Domain. NOTE— GPS clocks and calibrated atomic clocks fall into this class.
2	Designates a clock as a secondary standard reference clock. A clock of this Class shall: — A be primary reference clock that is in holdover mode and still within its holdover accuracy specification. — Be synchronized to a PTP Class 1 clock or another source deemed to be a correct source of time for the PTP Domain, or — Have been previously synchronized to a PTP Class 1 clock or another source deemed to be a correct source of time for the PTP Domain and is within its holdover accuracy specification.
3	Reserved for P1588 Committee.
4-253	Reserved for Profiles.
254	Default (Editor's Note:Version 1 will be mapped here)
255	A slave-only clock, section xxx, shall have a PTP class number of 255.

802.1AS Clock Quality - 3

Clock Time Source	Applicable to clock Class	Specification of the clock's time output
ATOM	1	Time is derived from a calibrated atomic clock maintaining a TAI-TRACEABLE time base accurate to better than 25ns
GPS	1	Time is derived from a correctly operating GPS receiver maintaining a TAI-traceable time base accurate to better than 100 ns.
ATOM	2	The stability of the clock is such that it is accurate to within 100 ns of the TAI-traceable time base established the last time it was synchronized to a Class 1 clock with clock_Time Source ATOM.
GPS	2	The stability of the clock is such that it is accurate to within 100 ns of the TAI-traceable time base established the last time it was synchronized directly to a Class 1 clock with clock_Time Source GPS.
NTP	2	The clock meets one of the following specifications: • The clock is participating in a suite of clocks using the NTP or equivalent protocol to maintain a TAI-traceable time base accurate to better than 15 ms, or • The stability of the clock is such that it is consistent to within 50ms of the time base established the last time it was participating in a suite of clocks using the NTP or equivalent protocol to maintain time consistent with TAI. NOTE—Examples of protocols providing time bases and accuracies equivalent to NTP are SNTP and a link to NIST time server.
HAND	2 or greater	The clock has been set to the correct TAI-traceable time to accuracy better than 10 seconds by a management procedure and is consistent with that time except for normal phase change of this clock.
INIT	2 or greater	The clock has been set with unspecified accuracy to an application specific or user defined time by a management procedure and is consistent with that time except for normal phase change of this clock.
DFLT	3 or greater	Shall be used if none of the other clock_Time Sources apply. Clocks which lack a battery backed clock and record elapsed time since power up shall use the DFLT designation.

802.1AS Clock Quality - 4

- Two possibilities for setting time source
  - Allow a number of the values, but have clock set it automatically based on where it is getting its time from
  - To do this, the clock would have to detect if it is getting its time from
    - External network (e.g., service provider) traceable to TAI
    - GPS receiver
    - NTP
    - Whether user set the clock by hand
    - If none of the above, DFLT would be used
      - E.g., would use DFLT if there is no service provider network or GPS receiver, NTP is not being used, and user did not set the clock by hand
  - Another possibility would be to always use DFLT
    - In this case, the user would have to configure the preference for a clock at the gateway to the service provider if the user wanted that clock to be GM
      - See following slides

802.1AS Clock Quality - 5

- 802.1AS will not need the clock variance attribute
- However, for interoperability with non-802.1AS networks (through a BC), we must decide how to set this by default
  - logVariance is Integer16; the field is 2^8 multiplied by the log of the actual PTP Deviation (square root of PTP Variance) in seconds
  - If we set to smallest value, this could cause a clock in the 802.1AS network to be better than an otherwise equivalent clock outside the network
  - If we set to largest value, this could cause a clock outside the 802.1AS network to be better than an otherwise equivalent clock in the network

802.1AS Preference Level

- Users will optionally be able to configure a Grandmaster preference level for each clock
  - If the user does not configure a preference level, then all AVB node clocks will be equally preferred
- The preference level will be set using the PTP priority1 or priority2 field in IEEE 1588 V2
  - Priority1 is an absolute priority; the general 1588 algorithm considers this ahead of all other clock attributes
  - Priority2 is considered after all attributes except the tie-breaking clock/port identity (i.e., uuid and port number)
  - Both priority1 and priority2 are integers in the range 0 to 255 (inclusive)
- For purposes of IEEE 802.1AS, it does not matter whether we use priority1 or priority2
  - However, it makes a difference if the 802.1AS network interfaces to a non-802.1AS network to another IEEE 1588 network
  - If we use priority1, this could have the effect of forcing a clock in the 802.1AS network to be GM
  - If we use priority2, this could have the effect of preventing a clock in the 802.1AS network from being GM (e.g., if a clock outside the 802.1AS network had a greater priority1 value)

Best Master Clock Algorithm

- Best Master Clock (BMC) Algorithm (BMCA) compares the data describing 2 clocks to determine which data describes the better clock
  - Use algorithm to determine which of the clocks (described by Announce messages on a port) is best
  - Determine which of the best clocks on each port is best
  - Determine whether the best clock determined above is better than itself
  - Also determine whether a newly discovered master is better than itself
  - Data describing the local clock is contained in internal data sets
  - Data describing the remote clocks is contained in received Announce messages
- The BMC consists of two parts
  - Data Set Comparison (DSC) algorithm
    - Compares the properties of two clocks, as indicated by their respective data sets
    - The input to the algorithm may be taken directly from a data set or from equivalent information contained in an arriving Announce message
    - The output of the algorithm is the best of the two clocks (i.e., which of the two is the best candidate for GM
  - State Decision (SD) algorithm
    - Based on the results of the DSC algorithm, the SD algorithm computes the best clock and the recommended state

Best Master Clock Algorithm – 2

- The general IEEE 1588 Data set comparison algorithm is based on binary comparisons of attributes with the following precedence (note: use distance attribute is described in second slide that follows)
  - a) Priority1: user configurable absolute priority
    - 802.1AS will use this or Priority2
  - b) Class (formerly called stratum): Attribute defining a clock's TAI traceability
    - Fixed in 802.1AS to 4
  - c) Time Source (formerly called clockIdentifier): Attribute defining the accuracy of a clock
    - 802.1AS will either set this automatically or fix the value
  - d) Variance (PTP Variance): An attribute defining the precision of a clock
    - 802.1AS will fix this to some value (e.g., largest value, smallest value)
  - e) Whether the clock is a Boundary or an Ordinary clock
    - IEEE 1588 gives precedence to BC if items (a) – (d) above do not indicate that one clock is better; the basis for this is that a BC would generally be a better clock than an OC, all other things being equal
  - f) Priority2: This is a user configurable designation that provides finer grained ordering among otherwise equivalent clocks
    - 802.1AS will use this or Priority1
  - g) Port Identity (formerly called UUID): A tiebreaker consisting of the combination of clock uuid and port number

Best Master Clock Algorithm – 3

- Relevant attributes in 802.1AS

a)Priority1

b)Class (formerly called stratum): Attribute defining a clock's TAI traceability

c)Time Source (formerly called clockIdentifier): Attribute defining the accuracy of a clock

d)Variance (PTP Variance): An attribute defining the precision of a clock

e)Whether the clock is a Boundary or an Ordinary clock

f)Priority2: This is a user configurable designation that provides finer grained ordering among otherwise equivalent clocks

g)Port Identity (formerly called UUID): A tiebreaker consisting of the combination of clock uuid and port number

Best Master Clock Algorithm – 4

- In addition to the above precedence order, the “distance” measured by the number of BCs between the local clock and foreign (i.e., potential) master is used when
  a) Two Announce messages reflect the same foreign master. This can occur in PTP systems with cyclic paths not removed by a protocol outside of PTP, and
  b) When two primary reference clocks — clocks with Class number 1 or 2 — have identical Class and Time Source attributes
- The data set comparison algorithm will unambiguously select one of the two clocks as better (either absolutely better or better determined by tie breaking procedures)
- The state decision algorithm determines the recommended next state
- The recommended next state is then evaluated by the state machine

Best Master Clock Algorithm – 5

- IEEE 802.1 AS will also include the possibility of 802.11 Wireless network portions (connected to 802.3 network via 802.1AS BC)
  - Currently no explicit consideration of whether traceability to a foreign master is via a wireless link
  - Should we consider this?
    - A node with a wireless link would need to detect this (and maybe keep information in one of the data sets (port configuration data set))
    - Would need to carry this information in Announce message
    - This would require a change in IEEE 1588 Version 2 draft
  - Presumed reason to consider this would be if, for example, we wanted to favor potential GMs reachable only over wired links via those reachable via wireless (and wired) links
  - Could achieve this using priority1 or priority2, but would require user to configure it

General References for Background on BMCA

1. IEEE 1588™, *IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*, IEEE Instrumentation and Measurement Society, November 8, 2002.
2. John C. Eidson, *Measurement, Control and Communication Using IEEE 1588*, Springer, 2006.
3. IEEE P1588™, *Draft Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*, October 18, 2006 draft.